1996

Final report - SRDC project BS100S
improving the ratooning ability of sugarcane

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This project was funded by Sugar Research and Development Corporation during the 1993/94, 1994/95 and 1995/96 financial years. This project is a continuation of project BS7S funded by the Sugar Research Council/Sugar Research and Development Corporation during the 1988/89, 1989/90 and 1990/91 financial years and by BSES/CSIRO during the 1991/92 and 1992/93 financial years.
1.0 SUMMARY

Good ratooning cultivars had attributes of rapid canopy development, associated with early development of adequate stalk numbers, for increased interception of light in early growth, and stability of harvested stalk weight to maintain yields over the ratoon cycle. These conclusions were drawn from Project BS7S conducted at Tully and Mackay for plant crops and two or three ratoons, respectively. This current project had the objective to determine if these attributes were applicable to older ratoon crops grown at Mackay.

A concern with the early project was that genotype x crop and genotype x year interactions were confounded. In order to overcome this concern, sixth and seventh ratoon crops of rainfed and irrigated cane were grown adjacent to irrigated crops of plant and first ratoons in this project. All three experiments had the same six cultivars known to have different ratooning potential. Comparing the sugar yields for plant and first ratoon with sixth and seventh ratoon crops, there were three groups of cultivars with regard to yield: no decline (Q124, Q138); slight decline (Q87, NCo310); and large decline (Q50, Q68).

The good ratooning cultivars achieved production through the attributes established in the early project. Early canopy development was also associated with cultivars which maintained stool·production, that is, they did not develop gaps following harvester damage when crops lodged. The gappiness of ratoons of the good ratooning cultivar Q124 was higher than that for Q138 and NCo310, two cultivars which suffered no harvester damage and developed few gaps. Gaps were the sum of distances greater than 0.5 m between stools. Although Q124 developed 20% gaps along the cane row, individual gaps were usually less than 0.75 m and early canopy development was only slightly retarded and the cultivar was able to compensate for this disability. When yield was adjusted for gappiness, sugar production per stool for all cultivars was shown to be relatively constant over the complete crop cycle. This result has significant industry implications for it indicates that yields in ratoon crops can be stabilised if the stool population can be maintained. Therefore, reducing harvester damage to stools appears to be a key to maintaining production during long ratooning cycles.

Returns were calculated for varying crop cycle lengths from plant/fallow to plant/seven ratoons/fallow, assuming the current price of sugar and current costs for fixed, operating and harvesting expenses. Return data followed the trends for yield, and there were three distinct groups of cultivars, namely: Q124, Q138 high; Q87, NCo310 medium; and Q50, Q68 low. The high and medium groups of cultivars had a plateauing of returns with crop cycles between four and seven ratoons, while the low group had plateauing between two and seven ratoons. There were large differences in maximum returns which averaged 1946, 1425 and 628 $/ha for the high, medium and low producing cultivars respectively, for irrigated cane. The newest varieties had the highest returns, indicating that plant breeders have been successful in releasing higher performing cultivars between 1946 and 1994, the period over which these cultivars were first released for commercial production. Irrigated cane gave higher returns than
rainfed cane and the new cultivars had larger increases in returns from irrigation than the old cultivars.

2.0 BACKGROUND

The economics of sugarcane growing improves with the number of ratoon crops which can be grown from a single planting. Ratoon crops are considered to have lower average yields than plant crops. An increase in the number of ratoons grown would contribute to a decline in yield per harvested hectare. Yield of sugar is a function of crop duration, the amount of light intercepted by leaves and the proportion of the dry matter which is sugar at harvest (harvest index). The accumulated amount of light intercepted is determined by the duration of the crop, its leaf area, the rapidity with which a closed canopy develops and the amount of solar radiation incident on the crop.

In Project BS7S, data could only be collected for a plant and two ratoon crops at Tully, and a plant and three ratoon crops at Mackay. As profitability is likely to be higher when four or more ratoons are grown, the performance of ratoons older than those studied in BS7S needed to be measured.

3.0 OBJECTIVES

Evaluate if relationship between plant attributes and ratooning ability identified in previous research (BS7S) is applicable to older ratoon crops.

4.0 INTRODUCTORY TECHNICAL INFORMATION

The conclusions from Project BS7S were that varieties with better ratooning ability possessed the following characteristics:

(i) rapid canopy development, for increased interception of light early in growth, which was associated with early development of adequate stalk numbers

(ii) stability for harvest 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 cultivars had better ratooning ability, even in adverse seasonal conditions.

This current project was designed to compare production in older ratoons with production in plant and early ratoons in the same season, thus eliminating the seasonal influences in the comparison. This comparison was not possible in Project BS7S.

5.0 RESEARCH METHODOLOGY

Three experiments were conducted at the Central Sugar Experiment Station, Mackay, with six commercial cane varieties (Q50, Q68, Q87, Q124, Q138 and NCo310) that were known to have poor and good ratooning ability.
Rainfed (Expt 1) and irrigated (Expt 2) experiments were planted in June, 1987 and another irrigated (Expt 3) experiment was planted in July 1993 (Chapman et al. 1992; Ferraris et al. 1992; Ferraris et al. 1993a; Chapman & Wilson 1996). Experiments were randomised blocks with three replicates, conducted with normal cultivation, and cane was burnt before harvest, except for 1995 which was harvested green. Harvesting dates were between 21 August and 6 October so that the average plant crop age was 59 weeks, range 54 to 64 weeks, and average ratoon crop age was 51 weeks, range 44 to 59 weeks. No yield adjustment for crop age was made. Features of the climate for Expt 1 and 2 was an adequate and well distributed rainfall for first ratoon crops, but all cane lodged extensively after cyclonic winds in late summer. Cyclonic conditions in mid-summer twice caused flooding of the third ratoons. The fourth, fifth and seventh ratoons had below average rainfall with dry conditions in spring. The sixth ratoon crop had below average, but well distributed and light rainfall. Fertiliser applications averaged 120N, 35P, 100K kg/ha for plant cane and 170N, 17P, 103K kg/ha for ratoon cane.

Cane yield, canopy development and stalk population were measured (Chapman et al. 1992; Ferraris et al. 1992; Ferraris et al. 1993a, 1993b). 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 yield (Jones et al. 1993).

6.0 RESULTS AND DISCUSSION

6.1 Yield

The highest producing cultivars were Q124 and Q138 for both cane and sugar yield. In measured yields, there were large seasonal effects for both the rainfed and irrigated experiments. Extremes were, low yields for third ratoon [Experiments 1 and 2] which was affected by cyclonic rain and prolonged water logging, and high yields for sixth ratoon [Experiments 1 and 2] and plant cane [Experiment 3], which resulted from well distributed but less than average rainfall (Fig. 1). Irrigation increased average cane yield by 18 ± 3 t/ha/yr. The yields of rainfed cane (Expt 1), adjusted for seasonal conditions (Fig. 2), showed an increase to first ratoon, a decline to second ratoon, followed by an increase to sixth ratoon and a decline in seventh ratoon for the four best cultivars Q124, Q138, Q87 and NCo310. The low yielding cultivars Q50 and Q68 declined in yield to third ratoon followed by slightly increased yields. The adjusted yields for the irrigated cane (Expt 2) followed a similar, but more variable pattern to the rainfed cane. The statistical adjustment of yields to reduce seasonal effects had the effect of moderating the high and low yields (Fig. 2) and followed a similar pattern to measured cane yields. Q124 and Q138 consistently were the highest yielding cultivars.

6.2 Crop growth

In project BS7S ratoon performance by cultivars was examined in terms of interception of light and efficiency of light use. Interception of light is a function of the
development and duration of leaf area index, which is an expression of leaf area per stem and the number of stems per unit area. These and other attributes were studied in this project.

6.2.1 Stem production

Data on tillering showed that the production was not affected by tillering. All cultivars produced an excess of tillers during early development, relative to the numbers harvested (Ferraris et al. 1993b; Hurney 1992). This continued into the older ratoons. The number of stalks at harvest generally increased as the ratoons became older particularly for the four best ratooners Q124, Q135, Q87 and NCo310 (Fig. 3). For example, for irrigated Q124 the number of stalks increased from 7 to 12 per m² from plant cane to seventh ratoon in Expt 2. The decline in numbers of stalks harvested in the poorer ratooners was associated with the development of gaps. The low number of stalks in Plant and IR crops in Expt 2 was not as evident in Expt 3, and this can in part be attributed to the good growing conditions in the 1994 and 1995 seasons. Weight of individual stalks declined from plant to third ratoon but then plateaued from fourth ratoon to seventh ratoon in rainfed Expt 1, but declined slightly in irrigated Expt 2 (Fig. 4). The stalk weights of early (IR) crops were similar in Expt 2 and Expt 3 but the slight difference in the P crop may have been a function of stalk number. Irrigation had the effect of increasing stalk weight and the tendency to reduce stalk populations compared to rainfed conditions.
Figure 1. Yields of cane and sugar for cultivars by crop classes for rainfed (Expt 1) and irrigated (Expt 2, 3) experiments. Bars equal least significant difference P=0.05.

Rainfed

Expt 1

Irrigated

Expt 2

Expt 3

--- NCo --- Q124 --- Q138 --- Q50 --- Q88 --- Q87
Figure 2. Cane yield and sugar yield (excluding year effects) for cultivars by crop classes for rainfed (Expt 1) and irrigated (Expt 2).

Expt 1 Expt 2

![Graphs showing cane yield and sugar yield for Expt 1 and Expt 2.](image)

Figure 3. Number of stalks at harvest for cultivars by crop classes for rainfed (Expt 1) and irrigated (Expt 2,3) experiments. Bars are least significant difference $P = 0.05$.

Expt 1 Expt 2 Expt 3

![Graphs showing number of stalks at harvest for Expt 1, 2, and 3.](image)
Figure 4. Weight of stalks at harvest for cultivars by crop classes for rainfed (Expt 1) and irrigated (Expt 2, 3) experiments. Bars are least significant difference $P = 0.05$. 

Expt 1

Expt 2

Expt 3
6.2.2 Stalk elongation

Stalk elongation is largely a function of temperature and incident radiation. There was a consistent bell-shaped pattern of stalk elongation between crops (Fig. 5) with the peak elongation occurring around January. The largest stalk elongation occurred over the November to March period. Under irrigation, growth of Q124 and Q138 peaked at approximately 25 mm/day in the plant and first ratoon crops while the sixth and seventh ratoons peaked at approximately 20 mm/day. The lower stalk elongation of the second and third ratoon crops are associated with a missed irrigation and heavy and prolonged rainfall and low incident radiation, respectively.
6.2.3 Loss of stool

Loss of stool was largely caused by harvester damage which caused gaps in the succeeding crop. There was some stool tipping associated with the crop lodging. There were cultivar differences, with three distinct groups, NCo310 and Q138, Q124 and Q87, Q50 and Q68, which had, respectively, few, moderate and many gaps (Fig. 6a). Development of gappiness was associated with a decline in production of ratoon crops, as the production of sugar per stool of cane remained relatively consistent over crop class from plant cane to seventh ratoon (Fig. 6b). The loss of production in old ratoons of Q50 and Q68 was mainly associated with the development of gaps. By fifth ratoon the production per stool of Q50 and Q68 began to increase relative to earlier crops and this was likely to be associated with the lack of competition between stools as gaps developed.

6.2.4 Canopy development

In irrigated Expt 3, time for canopy development to 70% of light interception was 156 days for plant cane and 119 for first ratoon, with no differences between cultivars (Table 1). Expired time for canopy development was similar for first and seventh ratoon crops of the cultivars Q138 and NCo310 which had few gaps develop in ratoons, but as gaps developed in the older ratoons of Q50 and Q68, canopy closure was slower. Even though gaps up to 25% developed in Q87 and Q124, canopy development was only slightly retarded. A study of the distribution of gaps indicated that gaps were usually less than 0.75 m in Q124, but often up to 2 m in Q50 and Q68. Irrigation decreased the time for canopy development compared to the rainfed cane by approximately 30 days in the seventh ratoon crops for the four best ratooners, but by
only 11 days for the two poor ratooners. The association between rapid canopy development and higher yield of ratoon cane established for Mackay (Ferraris et al. 1993a and 1993b) may be due to the effects of gaps on canopy development rather than genetic effects.

Table 1. Days after planting or ratooning for canopy to intercept 70% of light.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Crop class</th>
<th>Irrigated Plant (3)</th>
<th>IR (3)</th>
<th>7R (2)</th>
<th>Rainfed 7R (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q138, NCo310</td>
<td></td>
<td>156</td>
<td>119</td>
<td>120</td>
<td>153</td>
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<tr>
<td>Q124, Q87</td>
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<td>157</td>
<td>118</td>
<td>123</td>
<td>153</td>
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<td>Q50, Q68</td>
<td></td>
<td>155</td>
<td>121</td>
<td>166</td>
<td>177</td>
</tr>
</tbody>
</table>

( ) = Expt number.

6.3 Environmental effects

This study had plant and first ratoon cane growing in the same years as the sixth and seventh ratoons. Thus the disability of not being able to separate crop class (genotype x crop) from the environmental (genotype x year) effects was partly overcome. The procedure of using neighbouring farm yields as environmental indicators to remove year effects, assuming the adjusted yields were due to crop class effects (Jones et al. 1993), was continued with the sixth and seventh ratoon results (Fig. 2).

6.4 Economic considerations

Annual returns to canegrowers were calculated for crop cycles of plant/fallow, plant/one ratoon/fallow, up to plant/seven ratoons/fallow. Assumptions for these calculations were a price of sugar of $350/tonne and costs of production for fixed, operating and harvesting as estimated by Chapman and Wilson (1996). The impact of crop cycle length on returns was marked, with the longest cycles being the most profitable. There was a plateauing of returns for crop cycles with four to seven ratoons for both rainfed and irrigated cane (Fig. 7). Variety by irrigation interactions were not significant. The profitability of cultivars fell into three groups with Q124 and Q138 having highest, Q87 and NCo310 medium, and Q50 and Q68 lowest returns, irrespective of crop cycle length. Q124 and Q138 had approximately a threefold increase in returns compared to Q50 and Q68, when grown for crop cycle lengths of from four to seven ratoons, under irrigation (Expt 2). Also, increasing the crop cycle length from three ratoons to seven ratoons increased returns by more than 30% for the two highest producing cultivars Q124 and Q138, when grown under irrigation.
Figure 7. Economic return for crop cycle by cultivars for rainfed (Expt 1) and irrigated (Expt 2) experiments. (PF = plant then fallow; P1F = plant, first ratoon then fallow.)

2000
(a) Expt 1 (b) Expt 2
1500
1000
500
0
-500
-1000
-1500
-2000
PF P1F PF P1F PF P1F PF P1F PF P1F

Crop cycles

6.5 Yield increases from plant breeding

The cultivars grown in this project were released for commercial use over the period 1946 to 1994. The cultivars all had the same management and were all important cultivars at Mackay. Yield data were used to evaluate the effect of plant breeding on sugar production. Sugar yield was increased by 0.12 and 0.15 t/ha/yr for rainfed and irrigated sugarcane culture, respectively (Chapman 1996). This increase in yield, if projected across the Australian Sugar Industry would return 135% on investment for plant breeding expenses in 1994.

6.6 Pachymetra

Cane yield is adversely affected by Pachymetra root rot (Margarey 1996). Spore counts in soil samples indicated that Q68 was probably retarded in growth by Pachymetra, which may have also contributed to harvester damage and the development of gaps in this cultivar.

7.0 IMPLICATIONS AND RECOMMENDATIONS

7.1 Difficulties

A major difficulty was that it takes years for crops to reach the 'old ratoon' category. This project had the advantage of taking over experiments established in Project BS7S which were then maintained by BSES/CSIRO funding. A disadvantage is that data are not available on a range of cultivars which are currently of interest to the industry. In 1995, unfortunately the experiments had to be harvested green to avoid a fire risk as all
other cane on the Sugar Experiment Station was green harvested. The BSES harvester was not designed for green harvest and there was an estimated 15% reduction in yields due to cane loss from the extractors. Although 1995 yields were depressed by cane loss, results are conservative and in no way alter the conclusions from this project.

### 7.2 Future research

This project has clearly demonstrated the increased profitability of growing long crop cycles with cultivars which do not become gappy because of probable harvester damage following lodging. Future research should address the cause of gappiness in old ratoons and evaluate management strategies to maintain stool populations. This research should particularly address the issue of stool tipping and its interactions with harvest operations. The decline of stalk weight in ratoons appears to be associated with an increase in stalk population, so that production per stool remains relatively constant. The previous concerns about the decline in stalk weight in ratoons may be a natural phenomenon associated with ratooning and not a research topic.

### 8.0 INTELLECTUAL PROPERTY

No intellectual property of commercial significance arose from this project.

### 9.0 TECHNOLOGY TRANSFER

The outcomes of this project were to understand the plants' regrowth processes in order to improve the ratooning ability of sugarcane. Growing longer ratooning cycles have important implications on the profitability of canegrowing. The success of maintaining stool populations and production in old ratoons is to a large degree dependent on the cultivars grown, but there are also implications for farm management and harvester operations.

Interim results were presented to canegrowers in poster displays at annual Field Days at Mackay. Groups of canegrowers in organised tours have visited the experimental sites on a number of occasions to inspect cane growth and discuss results.

### 10.0 ACKNOWLEDGEMENTS

Thanks are extended to Rita Kupke, Kayleen Harris, John Jackson and James Currie for technical assistance in this project.

### 11.0 REFERENCES


12.0 LIST OF PUBLICATIONS ARISING FROM PROJECT


13.0 APPENDIX

Attached are the papers arising from Project BS100S.
INCREASE IN SUGAR YIELD FROM PLANT BREEDING FROM 1946 TO 1994

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ABSTRACT

Sugar yield was increased by 0.12 and 0.15 t/ha/yr for rainfed and irrigated sugarcane culture respectively, by the release of new varieties over the period 1946 to 1994. This increase in yield gave a 135% return on investment to the Australian Sugar Industry from plant breeding expenditure, in 1994.

These estimates were calculated from the results of two variety trials grown at the Sugar Experiment Station, Mackay over 8 seasons, 1987-95.

The six varieties used in the experiments were the dominant commercial varieties for the period in central Queensland, thus enhancing the reliability of the predicted gain in yield.

INTRODUCTION

The Bureau of Sugar Experiment Stations is the main provider of new sugarcane varieties for the Australian Sugar Industry. The majority of these varieties are bred at Sugar Experiment Stations located at Meringa, Ayr, Mackay and Bundaberg along the Queensland east coast. There is an exchange of varieties with other sugarcane breeding countries and some foreign varieties are grown. Currently, 90% of sugar production in Australia is from locally bred varieties. When new varieties are introduced they have superior attributes which may be associated with specific disease and insect resistance, improved sugar quality, and favourable agronomic attributes. Usually, they are also selected to have a higher yield than the varieties they replace.

The trend in sugar yield over time associated with the introduction of new varieties is confounded with changes in cultural and management practices. Consequently, it is usually impossible to isolate the magnitude of the individual effects. Examples of change in cultural and management practices over the last 48 years include increased irrigation and fertiliser use, the adoption of mechanical harvesting, the use of herbicides and reduced cultivation, to name but a few.

This paper used data from recent experiments in the Mackay district to assess the gain in yield and industry benefit from important commercial varieties released over the last 48 years. The experiments were a series of ratoon trials on a range of varieties, released between 1946 and 1994, which were grown under common cultural and environmental conditions. The six varieties were grown in rainfed and irrigated experiments for eight crops on the Sugar Experiment Station, Mackay. The benefit to the Australian Sugar Industry on expenditure on plant breeding was estimated by extending these results to the whole industry.

METHODS

Full details of the field experiments were published by Chapman et al. (1992). Briefly, the varieties Q50, Q68, Q87, Q124, Q138 and NCo310 were grown in two experiments on the Sugar
Experiment Station, Mackay between 1987-95. One experiment was rainfed and the other furrow irrigated. Scheduling of irrigation was based on estimating soil water deficit from 'Class A' pan evaporation. Plots were irrigated at a soil water deficit of 64 mm, calculated by using pan evaporation, canopy development and a pan factor of 0.8 (McGuire 1991). Experiments had three replicates, and a plant crop and seven ratoons were grown.

Notable features of the seasonal conditions were good moisture for plant, first, fifth, sixth and seventh ratoons, dry conditions for early growth of second, third and fourth ratoons and late growth of third ratoons. Plant and third ratoon growth was adversely affected by high cyclonic rainfall. Cane yield was measured in whole plots by weighing harvested-cut-billets with a truck-mounted scale. CCS content was measured by the standard method (Anon 1984) in juice crushed from 10-stalk samples from each plot at harvest.

The yield level of varieties was calculated as the mean production over 8 crops for cane yield, CCS and sugar yield. These were then regressed over the year that the varieties were first grown commercially in central Queensland: Q50, 1946; NCo310, 1958; Q68, 1957; Q87, 1968; Q124, 1984; Q138, 1994.

RESULTS

The newer varieties Q124 and Q138 consistently had higher cane yield than the older varieties (Table 1). Cane yield generally declined from first to third ratoon, increased again from fourth to sixth ratoon and declined in seventh ratoon. Irrigation increased cane yield, but there was a seasonal variation, even in the irrigated yields, not entirely related to water stress effects on crop growth. Season variation also occurred in CCS with NCo310 and Q124 having high levels in most seasons, and Q87 having high levels under irrigation (data not presented).

Regressions of cane and sugar yield on time of first commercial planting were significant for both the rainfed and irrigated crops (Figure 1). These regressions indicated that introducing new varieties increased cane yield by 0.75 and 1.00 t/ha/yr, or 0.12 and 0.15 t sugar/ha/yr for rainfed and irrigated situations respectively. There were no significant trends for CCS. This contrasts with the results of Cox and Hansen (1995) who attributed recent high CCS to new varieties in the central and southern Queensland regions.

DISCUSSION

In assessing the reliability of these estimates of the yield benefit from plant breeding there are a number of positive features of this study. The positive attributes are the cultivars selected for the experiments have been or will in the near future be significant for the central Queensland area. Q50 and NCo310 have both, in their time, produced over 90% of the crop in one year. Q68 and Q87 were also widely popular and successful varieties. Q124 contributed over 60% of the crop in 1994 and is increasing in popularity. Q138 is not yet widely grown, because it was released in 1994. The experimental data were not confounded with management or cultural effects, as the varieties were all grown together at the same site in a properly randomised experiment and all received the same treatments under rainfed and irrigated conditions. Current commercial
practice is to use a crop cycle of plant and four ratoons. However, older ratoons are regularly grown. Provided yields can be maintained, profitability of cane growing is favoured by having a longer ratooning cycle, as the high cost of planting can be amortised over a longer crop cycle. Mean yield of sugar for varieties was therefore calculated over plant and seven ratoons rather than plant and four ratoons.

However, in contradiction to these various positive features, the data are somewhat limited in scope because they are only from two experiments at one site over one eight year period. Notwithstanding this above limitation, a cost/benefit analysis was conducted to compare the return to the Australian Sugar Industry from improved varieties against the cost of plant breeding, using data for the 1994 season. Several assumptions were made: (1) a crop cycle of plant and seven ratoons; (2) the increase in sugar yield of 0.12 and 0.15 t/ha/yr was applied across all rainfed and irrigated canegrowing areas respectively; (3) the irrigated area was 0.4 of the total area and (4) the sugar price was $350/t.

The returns to the Australian Sugar Industry from the use of new varieties, both imported and locally bred, was calculated as: 365 000 ha x 0.4 irrigated x 0.15 t/ha of sugar x $350/t = $7.7M; plus 365 000 ha x 0.6 rainfed x 0.12 t/ha of sugar x $350/t = $9.2M; giving a total of $16.9M. The cost of plant breeding activities in 1994 was estimated at $7.2M. These costs include $5.3M by BSES (BSES 1994), $0.5M by CSR (A Wood, personal communication), $1.4M from SRDC (SRDC, 1994/95).

CONCLUSIONS

Plant breeding in 1994, delivered a return of 135% on the year's investment using this simple cost/benefit analysis. This return was reduced to 100% if a crop cycle of plant and 4 ratoons was assumed. There is a 10-12 year delay from the time of original crossing until new varieties are delivered. As investment on plant breeding is ongoing, this analysis is adequate to indicate yield increases are occurring and that the high costs are justified. The cost input included not just the funds used for direct crossing, selection and production of new varieties, but also those used for research into plant breeding technologies such as disease resistance, molecular markers, flowering control and so on. Not included in the returns from new varieties are benefits to the industry of disease and insect control, and of sugar quality, which are often associated with new varieties.

Investing in plant breeding is profitable for the Australian Sugar Industry as plant breeders are producing higher yielding varieties. The investment in research into new technologies are likely to enhance returns from plant breeding in the future.

ACKNOWLEDGMENTS

The author wishes to thank the BSES staff for assisting with experiments, in particular Rita Kupke, Kay Harris and James Currie and staff from CSIRO Tropical Crops and Pastures. Funding for the project was provided by Sugar Research and Development Corporation and BSES Board.
REFERENCES

Bureau of Sugar Experiment Station 14th Annual Report (1994)
Sugar Research and Development Corporation Annual Research and Development Program (1994/5)
TABLE 1 - Yield of cane (t/ha) for six varieties grown to seventh ratoons in rainfed and irrigated experiments.

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<tr>
<th>Crop Class</th>
<th>Variety</th>
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<td>119</td>
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</table>
Fig. 1 Regressions of mean (a) cane yield, (b) CCS and (C) sugar yield on year (-1946) variety was first planted commercially in central Queensland, for rainfed (●) and irrigated (■) sugarcane.

(a) $y = 0.97x + 81.16$
$R^2 = 0.79$

(b) $y = 0.75x + 68.22$
$R^2 = 0.68$

(c) $y = 0.15x + 11.83$
$R^2 = 0.78$
ECONOMICS OF RATOON CYCLE LENGTH IN SUGARCANE

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ABSTRACT

Profitability of growing sugarcane is enhanced if long ratooning cycles are used, for high costs for the plant crop can be amortised over a number of lower cost ratoon crops. A crop cycle of plant and six ratoons was the most profitable management procedure for cultivars which maintained stool populations. However, cultivars which became gappy, due to mechanical harvester damage, were less profitable. Gappy cultivars were three times less profitable, when grown under either rainfed or irrigated conditions.

No decline in sugar yield per stool occurred in any cultivar as a result of long ratooning crop cycles.

Yield data were analysed by a technique which minimised the confounding effects of cultivar by year interactions with the cultivar by ratoon number interactions. Mean cane yield from neighbouring farms was used as an indication of year effects. Year effects were also eliminated by comparing plant and first ratoon crops to sixth and seventh ratoon crops grown in the same year. Good ratooning cultivars yielded as high in late ratoons as in plant and early ratoon crops.

INTRODUCTION

Management practices which can achieve longer, more profitable ratoons are a high priority for the Australian sugar industry. The growing of good ratooning cultivars is a necessary component of these practices in order to contain costs, since operating costs are three times higher for plant than ratoon cane. Also, the proportion of farm in production is usually increased with longer ratooning cycles.

Ratoon yields in Australia are usually believed to decline later in the cropping cycle, but in other countries this is not always the case. For example, in Swaziland there was no yield decline for crop cycles up to 24 ratoons (Todd G M, personal communication).

The decision to discontinue ratooning and replant is ideally taken when the cumulative lost production, and therefore returns from the past ratoons, plus the forward estimate of the next ratoon crop, exceeds the cost of replanting (Simms 1982).

Six cultivars of sugarcane, grown commercially in central Queensland ranging from 50 years ago to the present, were compared in rainfed and irrigated experiments. Yield was compared over a succession of 7 ratoons, and also with new plant and first ratoon crops coinciding with sixth and seventh ratoons. The profitability of longer ratooning cycles was analysed by comparing the estimated lost value of production in later ratoons with the higher costs of replanting after a plant crop or after a varying numbers of ratoons.

METHOD

Six cultivars of sugar cane, Q50, Q68, Q87, Q124, Q138 and NCo310, were planted into three
experiments on the Sugar Experiment Station, Mackay (149.21°E, 21.46°S). Experiment 1 and Experiment 2 were grown under rainfed and irrigated conditions respectively for a plant crop and 7 ratoons. Experiment 3, also irrigated, was planted so that plant and first ratoon crops could be compared with sixth and seventh ratoon crops in Experiment 2. Plots were 4 rows wide and had three replicates. Harvesting dates were between 21 August and 6 October so that the average age of plant crops was 59 weeks (range 54 to 64 weeks) and ratoon crops was 51 weeks (range 44 to 59 weeks). No yield adjustment for crop age was made.

Cane yield was measured in whole plots by weighing billets cut by a harvester into a truck-mounted weighing bin. Sugar concentration was measured, in juice extracted from 10-stalk samples of cane, by the CCS method (Anon 1984).

**Adjusted yield**

Measured yields include the effects of true yields over ratoons and variations due to year, principally climatic, effects. These latter effects were excluded from the measured yields of cane to give an adjusted yield which was used for the economic analysis in this paper. Adjusted yields for seventh ratoon are not yet available. This was done by a statistical procedure which used yields from neighbouring farms, five irrigated and five rainfed, which provided an index of seasonal variation (Jones et al. 1993). Adjusted sugar yield was calculated as the product of measured CCS and adjusted cane yield.

**Gaps and production per stool**

Single stools of sugarcane cannot be readily identified in machine planted fields as a continuous row of setts is planted and stools intergrow. Stools were assumed to occupy 0.5m of cane row in this paper. When stubble pieces failed to ratoon, gaps occurred along the cane row. Gaps, greater than 0.5m, were measured when each crop was established and total gaps were calculated as a percentage of the row length. Sugar production per stool was calculated as the adjusted sugar yield divided by the total stools, adjusted for gaps.

**Economic considerations**

Adjusted sugar yields for each cultivar and year were used to calculate mean production for seven crop cycles of plant/fallow, plant/one ratoon/fallow, up to plant/six ratoons/fallow. There is one year lost production in a fallow as the stubble is ploughed out in summer and cane replanted in autumn.

Annual returns to canegrowers for crop cycles were calculated as adjusted sugar yield multiplied by the value of sugar ($350/tonne) multiplied by 0.66, minus fixed, operating and harvesting costs. The remainder of returns goes to millers.

Costs of production included: fixed (administration, electricity, mill deductions, rates and repairs), operating (cultivation, planting, fertiliser, crop protection and irrigation) and harvesting (fuel, harvester and transport). Wages were not included.

Annual costs per hectare were: fixed ($600), operating ($1100, $400 and $100 for plant, ratoon and fallow respectively) and irrigation ($250). Harvesting costs were $40/tonne of sugar. These estimates are based on financial records from 83 canegrowers in central Queensland (Graham 1995).
RESULTS AND DISCUSSION

Yield

The highest producing cultivars were Q124 and Q138 for both cane and sugar yield. In measured yields, there were large seasonal effects for both the rainfed and irrigated experiments. Extremes were, low yields for ratoon three which was affected by cyclonic rain and prolonged waterlogging, and high yields for sixth ratoon and plant crop of Experiment 3, which resulted from a well distributed but less than average rainfall. Irrigation increased average cane yield by $18 \pm 3 \, \text{t/ha/yr}$.

The adjusted cane yields (Fig. 1a) showed an increase to first ratoon, a decline to second ratoon followed by a plateauing from third ratoon to sixth ratoon for the four best cultivars Q124, Q138, Q87 and NCo310. The low yielding cultivars Q68 and Q50 had a drop in yield to third ratoon followed by slightly increased yields. The patterns for adjusted cane yield were similar but more variable for the irrigated crops. A feature of these data is that the high and low yields caused by seasonal variation have been moderated by the statistical manipulation. Adjusted sugar yields (Fig. 1b) followed a similar pattern to the adjusted cane yields, with Q124 and Q138 consistently being the highest yielding cultivars.

Fig. 1 Adjusted yields of cane (a) and sugar (b) for cultivars by crop class for rainfed Experiment 1 and irrigated Experiment 2.
Gaps and production per stool

When crops lodged, some stools levered the stubble out of or higher in the soil in a process called tipping. Stool tipping led to harvester damage as the base cutter sliced under the stubble including stool pieces with the harvested crop. If stubble was damaged or removed, gaps within the cane rows occurred in the next crop. For Experiment 2, gaps generally increased in older ratoons and were highest in Q50 and Q68, with Q124 and Q87 having fewer gaps and NCo310 and Q138 virtually no gaps (Fig. 2a).

![Graph](a)

![Graph](b)

**Fig. 2** Effect on (a) loss of stools (gaps as % of row length) and (b) sugar yield (kg) per stool for cultivars by crop class, under irrigation.
Q124 developed a full canopy even though it had 25% gaps by sixth ratoon in the irrigated experiment. It could sustain yield because 80% of gaps were only 0.50 - 0.75m long. By comparison, Q50 had Q68 had 50 - 60% gaps by sixth ratoon with most gaps 1 - 1.5m, and 12% >2m. Q50 and Q68 could not compensate for this gappiness and therefore lost yield. Gaps in the irrigated and rainfed experiments were similar, with most gaps developing after the plant and fourth ratoon harvests.

The perceived decline in production in older ratoons has generally been attributed to lower productivity per stool due to disease, insect attack, soil physical and chemical properties or unknown factors. The analysis of adjusted sugar yield when calculated on an individual stool basis (i.e. taking account of gaps) showed no decline in production for most cultivars with successive ratoons as shown for Experiment 2, the irrigated experiment (Fig. 2b). Q50 and Q68 showed some yield decline per stool for second and third ratoon but recovered stool productivity for fourth to sixth ratoons. These latter increases are probably due to the larger gaps reducing competition for light and water between stools. The same pattern of maintenance of productivity per stool in older ratoons was also evident in the rainfed experiment.

Economic considerations

Adjusted sugar yield for the plant/fallow cycles ranged from 6.8 to 9.1 t/ha/y and increased to 14.0 to 16.8 t/ha/y for plant/sixth ratoon/fallow for cultivars Q124, Q138, Q87 and NCo310 in Experiment 2 (data not shown). The lower producing cultivars Q50 and Q68 had maximum yields of 9.5 t/ha/y for plant/fourth ratoon/fallow rotation and 11.1 t/ha/y for plant/second ratoon/fallow cycle respectively. The effect of cycle on adjusted sugar yield was similar in general trend, but with lower yields, for the rainfed experiment. The operating costs per tonne of sugar decreased with increasing number of ratoons for all cultivars in both the rainfed and irrigated experiments, as the high planting costs were amortised over a larger number of crops, for example, 48,41,38,35,33,32 $/tonne sugar for cycles of 1 to 6 ratoons respectively for Q124 in the rainfed experiment.

The combined effect of increased production and reduced operating costs per tonne of sugar had a dramatic effect on returns per hectare for various length of crop cycle (Fig. 3). Returns increased from a loss of $128/ha for growing Q50 for a plant crop only to $1603/ha for growing Q124 for a 6 ratoon rotation under rainfed conditions. Extremes for the irrigated experiment were a loss of $270/ha for a plant crop only for Q50 to a return of $1946/ha for a 6 ratoon crop cycle for Q138. A 6 ratoon crop cycle is unquestionably the most profitable for cultivars Q124, Q138, Q87 and NCo310 for both rainfed and irrigated cane. There was a general plateauing of returns after first ratoon for cultivars Q50 and Q68. There was no cultivar by irrigation interaction in these experiments, but this result may not extend to all districts in central Queensland. Many ratoons, including Q124, failed under rainfed conditions from the disastrous drought which existed for some periods of these experiments.
Fig. 3  Economic return for crop cycle by cultivars for rainfed (Experiment 1) and irrigated (Experiment 2) [PF=plant crop then fallow; P1F=plant crop, first ratoon then fallow].

Yields for early vs late crop

Further evidence of the comparable yields from older ratoons was obtained by comparing sixth and seventh ratoon in Experiment 2, with plant and first ratoon in Experiment 3 grown in the same years. Both experiments were fully irrigated. There was no decline in actual sugar yield in older ratoons compared to plant and first ratoon crops for cultivars Q124, Q138 and NCo310 (Table 1). All three of these cultivars have a record of successful commercial production in older ratoons compared to cultivars Q87, Q50 and Q68 which were generally grown for shorter crop cycles. These results confirm that the estimates of sugar production, excluding year effects, by the use of neighbouring farm yields, gave realistic predictions.

Table 1. Sugar yields (t/ha) of early (Experiment 3, plant and first ratoon) and late (Experiment 2, sixth and seventh ratoons) crop classes for irrigated sugarcane cultivars grown in the same years. (mean yields and standard errors).

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Early Plant/first ratoon</th>
<th>Late Sixth/seventh ratoon</th>
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<tbody>
<tr>
<td>Q124</td>
<td>18.5 ± 1.9</td>
<td>19.0 ± 1.7</td>
</tr>
<tr>
<td>Q138</td>
<td>18.5 ± 2.0</td>
<td>19.3 ± 1.7</td>
</tr>
<tr>
<td>Q87</td>
<td>18.6 ± 0.8</td>
<td>15.3 ± 1.6</td>
</tr>
<tr>
<td>NCo310</td>
<td>15.8 ± 2.4</td>
<td>15.3 ± 2.0</td>
</tr>
<tr>
<td>Q68</td>
<td>17.1 ± 2.3</td>
<td>10.9 ± 0.3</td>
</tr>
<tr>
<td>Q50</td>
<td>16.6 ± 2.2</td>
<td>10.1 ± 0.8</td>
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</tbody>
</table>
CONCLUSIONS

The most profitable crop cycle was a plant crop/six ratoons/fallow for cultivars which maintained stool populations. An earlier plough-out would be the most profitable for cultivars which became gappy due to harvester damage. Gappy cultivars were three times less profitable when grown under either rainfed or irrigated conditions. Sugar yield per individual stool did not decline in any cultivar, due to long ratooning effects. Good ratooning cultivars yielded as high in sixth and seventh ratoons as in the plant and first ratoon crops.

ACKNOWLEDGMENTS

The authors wish to thank BSES staff for assisting with experiments, in particular Rita Kupke, Kay Harris, James Currie and Bob Ferraris and Peter Ruckett from CSIRO Tropical Crops and Pastures. Funding for the project was provided by the Sugar Research and Development Corporation, BSES Board and CSIRO.

REFERENCES
