

**AN ANALYSIS OF SUGAR PRODUCTION ISSUES
IN THE ORD RIVER IRRIGATION AREA**

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SRDC TECHNICAL REPORT No 01/2000

This report was prepared as an extension of an initial commission to the authors by the Sugar Research and Development Corporation and the Ord Sugar Industry Board which was the subject of a Preliminary Report on 31 October, 1998.

May 2000

Sugar Research and Development Corporation 2000

ISSN 1327-9475

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CONTENTS

	<u>pp.</u>
Acknowledgements	(ii)
List of Figures	(iii)
List of Appendices	(v)
Executive Summary	(vi)
Recommendations	(ix)
1. INTRODUCTION	1
2. INVESTIGATIONAL STRATEGY AND METHODOLOGY ...	3
2.1 General Strategy for the Study	3
2.2 Adjustment of Pol Determinations by the Mill... ..	3
2.3 Mean Yields and Mean Pol Levels for Year x Variety x Class	4
2.4 Analysis of TCH and Pol for Farm x Year x Variety Patterns	4
2.5 Comparison of Ord and Pioneer Cane and Environments ...	5
2.6 Cane Growth and Sucrose Accumulation in Ord Cane ...	6
2.7 Project Report - Factors Affecting Yields of Sugar on the Ord River - H.G. and M.A. Gardiner, April 1999 ...	6
3. RESULTS AND DISCUSSION	7
3.1 Cane Performance at District Level	7
3.2 Cane Performance at Paddock Level	20
3.3 Cane Agronomy	28
3.4 Paddock Records and Mill Analyses	37
4. CONCLUSIONS AND RECOMMENDATIONS	39
4.1 General	39
4.2 Variability in Cane Yields	39
4.3 Variability in Cane Quality	41
4.4 Paddock Records	46
4.5 Agencies for Research and Advice	46
5. FIGURES	
6. APPENDICES	

ACKNOWLEDGEMENTS

In addition to those whose material assistance was acknowledged in the Preliminary Report, our enquiries have been aided further by the following:

- C. Ryan, Director and E. Cain, Librarian, Bureau of Sugar Experiment Stations for extensive use of BSES Library;
- J. Engelke, Agriculture WA in particular regard to correct identification of cane varieties, the need for which was first identified by J. Foreman, CSIRO Tropical Agriculture;
- R. Muchow, CSIRO Tropical Agriculture whose counsel and generosity in providing access to raw data from 1998 dry-down experiments, extended to his assessment of Appendix II;
- B. Keating and C. Grof, CSIRO Tropical Agriculture on matters pertaining to the photoperiodic and temperature responses of sugar cane;
- J. Wilson, formerly CSIRO Tropical Agriculture, whose knowledge of carbohydrate and fibre formation in tropical C4 grasses may prove to be invaluable;
- H.G. Gardiner, in his capacity as Executive Officer, Ord Cane Growers' Association for further provision of data and advice; and who with J. Buchanan as farmers engaged in consideration of cane variability on their paddocks; and
- Our collaboration with K. Basford and I. Phillips, University of Queensland which proved to be more fruitful than any of us had imagined.

Finally, we pay tribute to E. Wallis, Executive Director, Sugar Research and Development Corporation whose enlightened administration of our contract enabled us to complete our task fully in a very constructive environment.

LIST OF FIGURES

Main Report

- Figure 1 Unadjusted Pol in Fresh Cane vs Time of Harvest - Weekly Mill Analyses 1996-1998
- Figure 2 Impurity Imbalance Relative to Time of Harvest - Ord Weekly Mill Analyses 1996-1998
- Figure 3 Dry Matter in Fresh Cane vs Time of Harvest - Weekly Mill Analyses 1996-1998
- Figure 4 Pol in Fresh Cane vs Time of Harvest - Weekly Mill Analyses 1996-1998
- Figure 5 Pol % Dry Matter vs Time of Harvest - Weekly Mill Analyses 1996-1998
- Figure 6 Fibre % Dry Matter vs Time of Harvest - Weekly Mill Analyses 1996-1998
- Figure 7 Pol/Fibre Ratio vs Time of Harvest - Weekly Mill Analyses 1996-1998
- Figure 8 Comparison of Ord Pol and Pioneer CCS - Weekly Averages for All Classes
- Figure 9 Crop Growth Rates for Ayr and Kununurra
- Figure 10 Maximum and Minimum Screen Temperatures - Ayr and Kununurra (monthly means)
- Figure 11 Pol for Plant Cane vs Time of Harvest - Ord 1996-1998. Regressions for All Paddocks in Each Year and for All Years
- Figure 12 Pol for Ratoon Cane vs Time of Harvest - Ord 1996-1998. Regressions for All Paddocks in Each Year and for All Years
- Figure 13 Pol for Plant and Ratoon Cane vs Time of Harvest - Ord 1996-1998. Regressions for All Paddocks in All Years as in Figure 11 and 12
- Figure 14 Plant and Ratoon Cane CCS for Pioneer Mill Area, 1993-1997 Weekly Averages
- Figure 15 Pol in Plant Cane for Three Varieties - Ord 1996-1998
- Figure 16 Pol in Ratoon Cane for Three Varieties - Ord 1996-1998
- Figure 17 Pol vs Time of Harvest - All Groups, All Classes (except Standover Cane) and all Varieties at Paddock Level - Individual Group and All Group Regressions
(iii)
- Figure 18 Group 13 - Pol vs Time of Harvest (All Classes except Standover Cane and All Varieties) - Regressions for Individual Farms and for Group

Appendix II:

- Figure 1 Distribution of Brix and Fibre along the Primary Stalk of Sugar Cane (from Fernandes and Benda, 1985)
- Figure 2 Photosynthetic Utilization of Solar Energy and its conversion to Fibre and Sucrose for Sugar Cane in Formosa (from van Dillewijn, 1952 attributed to Ozawa)
- Figure 3 Seasonal Changes in Sucrose and Non-Sugar Dry Matter Formation Rates (from Bull, 1980)
- Figure 4 Sucrose Changes with Time and with Biomass (from Bull, 1980)
- Figure 5a Pol % DM vs Cumulative Temperature Deficit - All Years ORIA 1996-1998
- Figure 5b Monthly Pol % Dry Matter ORIA All Years vs Cumulative Deficit Below 29 degrees preceding 2 months
- Figure 5c Actual Pol % Dry Matter 1996-1998 ORIA vs Cumulative Week Degrees below 29 after 1 April
- Figure 6 % ERS Cane vs Date of Harvest for Eight Times of Ratooning (from Rostron 1972)
- Figure 7 Percent Dry Matter of Cane vs Date of Harvest for Eight Times of Ratooning (from Rostron 1972)
- Figure 8 Relationship between Stalk Dry Matter and Stalk Biomass
- Figure 9 % ERS Dry Matter Basis vs Date of Harvest for Eight Times of Ratooning (from Rostron 1972)
- Figure 10 TERSH vs Stalk Biomass (after Rostron 1972) for all Ages and Times of Harvest
- Figure 11 Stalk Sucrose Concentrations for Q96 Crops Initiated at Four Planting and Ratooning Times, Ayr (from Kingston et al 1984)
- Figure 12 Stalk Sucrose Concentrations for Q111 Crops Initiated at Four Planting and Ratooning Times, Bundaberg (from Kingston et al, 1984)
- Figure 13 Relationship between Stalk Sucrose Concentrations (Dry weight basis) assuming No Juice Retention or Full Juice Retention in Pressed Biscuit

Appendix I Ord Paddock Production Data Analysis -
 I. Phillips, K. Basford

Appendix II A Review of Sucrose Concentration in Cane Stalks -
 J.K. Leslie

Appendix III References

AN ANALYSIS OF SUGAR PRODUCTION ISSUES IN THE ORD RIVER IRRIGATION AREA

TERMS OF REFERENCE

1. To analyse existing data, meet with Ord industry personnel and with scientists already engaged in sugar activities in the Ord to make an assessment of the current situation and the seriousness of it.
2. To suggest strategies directed at improving sugar content in cane worthy of immediate implementation even if the basis of the recommendation is hypothesis and not firm evidence.
3. To recommend:
 - procedures for data collection,
 - direction and priority of future researchwith the aim of improving sugar content levels in the longer term bearing in mind that the Ord industry is a small industry with severely limited resources.
4. To recommend agencies or sources of advice which could be of immediate benefit and benefit/cost effective.

EXECUTIVE SUMMARY

1. The analysis considered both cane yield and sugar content. A Preliminary Report in October 1998 utilised 1996 and 1997 production data, and concentrated on whether that data evidenced any changes from the pilot phase of 1977-1983. It concluded that there has been no apparent change in yield or quality of millable stalk. The pilot projections of commercial expectations did not discount sufficiently for the effects of mechanical harvesting. Cane losses, extraneous matter and soil contamination have reduced pol in commercial deliveries on average 2.33% pol below the level in millable stalk.
2. This report updates those conclusions and extends to several other issues. Its analyses have focused on identifying differences between Ord paddocks, and between the Ord and Pioneer (Q) districts. They utilised three full seasons of Ord production data 1996-1998 inclusive. The intent was to understand the characteristics of Ord cane as a pathway to strategies for productivity improvement.
3. The analyses encountered three particular issues where Ord experience could not be reconciled with contemporary knowledge of the factors and processes controlling cane growth and sucrose accumulation viz.:
 - Cane stalk elongation slows and almost ceases in autumn-winter when radiation and temperature levels indicate that high growth and elongation rates should maintain.
 - Cane yields in 1997 were depressed but low levels of radiation and temperature during an abnormally wet 1996/97 summer were not a satisfactory explanation.

- Pol % cane is highly variable at the paddock level both between and within times of harvest. Expectations from the high air temperatures that prevail, are that Ord cane should be consistently low pol and high fibre. There was no ready explanation for the paddock variability from high to low quality.
4. This necessitated an extensive review of sugar cane research literature for knowledge that could explain these realities. The review is the subject of Appendix II. It also necessitated pattern analysis - a statistical procedure to interpret paddock variability. This was contracted to the University of Queensland and is reported in Appendix I. The main report is concerned with analysis of Ord and Pioneer data, and its interpretation using the knowledge accruing from the review and the pattern analysis. Section 4 - Conclusions and Recommendations - has been written as a stand alone section for less technically minded readers.
 5. Ord cane slows or stops stalk elongation in autumn in response to climatic stimuli which are probably falling air temperatures and shortening day lengths. It does not stop increasing in cane yield. The increase in yield is almost entirely sugar. This sucrose enrichment of stalks is an important phenomenon in generating variable pol levels and economic value in Ord cane. Water stress during this period limits sucrose enrichment and increases soluble impurities. Harvesting from April-June foregoes substantial sugar yield and aggravates purity problems.
 6. Enrichment is superimposed on the stalk conditions existing at the end of summer. There is reason to suspect that at that time sucrose:fibre ratios are lower than for Burdekin cane because of the much higher September-November maximum air temperatures of the Ord. Fibre established then will persist and may preclude the attainment of high pol concentrations at harvest in spite of autumn enrichment. It is postulated that even, heavy crops may experience lower leaf and stalk temperatures, and be less affected in this way than thin gappy stands. If confirmed, this phenomenon may be relevant to genetic improvement of cane for the tropics generally.
 7. Immediate inferences are that Ord husbandry should aim at high, even stool densities, and that fertiliser, irrigation and weed control practices should maximise cane yield for age at the end of summer. Adequate but not excess water and nutrients are required in autumn-winter, and dry-down periods for harvest should be the shortest necessary to achieve trafficability and minimal soil contamination. This is at variance with some views, but appears consistent with the husbandry of high-achieving Ord farmers, and with pilot farm experience.
 8. The yield depression of 1997 has been attributed to waterlogging associated with abnormally high rainfall from December 1996 to February 1997, shallow water tables and restricted surface drainage. The combined effects of the three factors on waterlogging varied greatly between paddocks. The implications for the future management of water tables and salinity in the ORIA are very important.
 9. There is inadequate Ord data to confirm the foregoing conclusions (paras 5-8).
(vii)
The report emphasises this and makes recommendations for research to characterise and understand stalk yield, sucrose and drymatter changes. It also recommends evaluation of the waterlogging hypothesis and that farmers be involved in that evaluation.

10. There were errors and deficiencies in paddock records which, if overcome, would enable routine use of those records in lieu of much applied R&D which is necessary but unlikely to be undertaken in the Ord in the foreseeable future. The most serious errors are those where deliveries are incorrectly related to paddock numbers and harvested areas, and those arising from the analytical systems of the mill which do not correctly define the pol, brix and fibre properties of each paddock. Recommendations are made in respect of these matters.
11. The contamination of millable stalk with extraneous matter and soil in mill deliveries, and the unknown levels of cane and juice losses in the field are an inevitable consequence of mechanical harvesting of lodged, heterogeneous crops. Levels of contamination and between-paddock variability of those levels are likely to be high in the Ord, and thorough measurement of this on mill deliveries is recommended as a basis for designing remedial strategies.
12. A few relatively minor issues were identified. There is a tendency not to plant cane April-May and harvest August-September which would optimise sugar yield and establish a sound base for ratoon harvest schedules. NCO 310 should not be held over for harvest after calendar week 40 because of its disposition to fall off badly in quality. Good establishment of plant cane is essential to productivity throughout the life of a cane stand but is not achieved as frequently as it should be.
13. With sound husbandry and attention to drainage issues, it appears that average plant cane yields of 160+ TCH and ratoon yields of 130+ TCH are achievable. The pol future is less certain. It will probably vary from 13-15% from hot to cold years. It is premature to estimate the extent to which this can be manipulated by husbandry based on sound knowledge of sucrose accumulation. At some time, consideration will have to be given to a later start for the harvest season, and to a pol payment system that does not discount the price of sugar in cane for increased water content of cane. The cost of early harvesting, and the disincentive of the latter to practices which increase productivity are serious limitations of the present scenario.
14. After further analysis we have had to conclude that the assertion of the Preliminary Report that the quality of millable stalk has not changed from 1977-83 to 1995-8 cannot be made from the data available. The reason is that the juice extraction and analysis systems that have been used preclude absolute comparisons of sucrose % dry matter. The problem is a continuing one with errors inherent in both first-expressed-juice and press methods. These problems must be redressed wherever precise measures of sucrose in cane are required, whether expressed on a fresh or a dry matter basis.
15. Recommendations "in principle" have been made in respect of agencies for research or advice pertinent to the findings.

(viii)

RECOMMENDATIONS

- R1. That the speculative proposals related to waterlogging be cross-examined and that Ord farmers be involved in their evaluation to the extent of rating paddocks for their relative wetness.
- R2. Strategies for minimising waterlogging in future, be developed as adjuncts to the

broader strategies being directed at managing water table levels and salinity in ORIA. Such strategies may involve the provision of effective surface drainage, and the formation and maintenance of appropriate bed contours.

- R3. Cane should be planted as per pilot farm recommendations i.e. April/May, and the objectives should be high, even stool densities and maximum early growth rates.
 - R4. That farmers manage crop husbandry to maximise crop growth rates throughout, and in particular to enter autumn with the maximum yield and crop homogeneity consistent with crop age.
 - R5. That crop management from autumn to harvest be directed at securing maximum sucrose enrichment and sucrose % DM at the scheduled harvest time.
 - R6. That farmers practise a moderate level of soil and crop logging coupled with paddock records of operations, chemical applications and observations to facilitate future problem analysis.
 - R7. That soil analyses be undertaken by Agriculture WA to check the existence of NO_3 bulges in cane paddocks.
 - R8. That farmers undertake their own response experimentation with N and S fertilisation.
 - R9. That the Ord mill modify its testing system so that the pol, brix and fibre analyses calculated for paddock deliveries correctly define the quality of those deliveries.
 - R10. That a rigorously designed program be instituted at the Ord mill to sample selected deliveries for a full season in a representative way, to fractionate those samples into components for weighing and full quality analyses (pol, brix, fibre and water) and to compute the level and quality impact for comparison with parallel analyses of shredded cane (prior to crush return) from the same deliveries. Shredded cane should also be analysed for silica content to estimate soil contamination. The selection of deliveries should be unknown to farmers and harvesting contractors prior to delivery. Immediately after delivery there should be a visual appraisal of the structure of the source crop in the field.
 - R11. That no assertions or inferences relating to EM and soil contamination be made until this data is available and interpreted.
 - R12. That no attempt be made in the Ord to measure field losses of cane and juice due to mechanical harvesting, but the Ord industry should maintain close contact with Queensland based R&D in this area.
- (ix)
- R13. That research be initiated to sample sound stalks from say 20 ratoon crops representing the full range of times of ratooning, at not more than monthly intervals from initiation to late November the following year. Data recorded should be stalk weight, length and node number, monthly stalk elongation rates and a full range of rigorously determined quality data including pol, sucrose, reducing sugars, brix, fibre, moisture content and juice ash. Interpretations should seek to characterise and explain the patterns of quality change, and to identify options for increased profitability for the growers and the mill.

- R14. Further efforts should be made to locate pilot/farm data from serial stalk sampling and analyses undertaken monthly from March-September on Commercial Variety Trial CVT1, Block 63, Bay 2 1982 and 1983 and to interpret that data for evidence of autumn sucrose enrichment as an Ord phenomenon.
- R15. That fertiliser and irrigation be managed throughout crop growth to avoid plant nutrient and water stresses or excesses, and to maximise crop growth rates; with dry-down for harvesting prior to the end of July being limited to the shortest period necessary to provide trafficability and minimise soil contamination.
- R16. That further research on dry-down and ripeners be deferred until R13 documentation provides justification for such research. (Continuation of dry-down research in 1999 led by R. Muchow may influence this recommendation.)
- R17. That for the remainder of its use as an Ord variety, NCO 310 be harvested by the end of September.
- R18. That Ord negotiations for Year 2000 allocations of blocks into harvest round sequences consider class scheduling in relation to the sugar yield potential of plant and ratoon crops.
- R19. That if documentation of Ord cane identifies increases in fibre deposition due to extremely high temperatures, further physiological and genetic research be sponsored to confirm and explore the phenomenon.
- R20. That the Ord industry design a single paddock record system, that it negotiate with all stakeholders to secure complete entry of correct data and that it make budgetary provision for its periodic analysis and interpretation.
- R21. That SRDC work with relevant institutions to design an economically feasible total program and then to determine the most appropriate ways to structure it for execution.

AN ANALYSIS OF SUGAR PRODUCTION ISSUES IN THE ORD RIVER IRRIGATION AREA

1. Introduction

- 1.1 The emphases of our initial investigations and the preliminary report were on establishing whether commercial cane production since 1995 has differed from expectations that were based on the experimental work and pilot production phase of 1977-1983; and on determining the causes of differences detected.

We compared cane yields (TCH), and the fibre and sucrose contents of cane (CCS or pol) from the 1977-83 period with those determined by the Ord Mill on 1996, 1997 and part-1998 paddock deliveries.

Commercial production has approximated pilot phase cane in respect of cane yields. There was however, an average difference of 2.33% pol between pol measured on clean millable stalk during the pilot phase and the adjusted pol of 1996 and 1997 deliveries. This was 0.83% pol greater than the empirical adjustment of 1.5% that had been applied to projections.

There was no evidence that average pol levels in millable stalk of current Ord cane are lower than those of millable stalk during the pilot phase. The difference of 2.33% was attributed to admixture of millable stalk with soil, extraneous matter (tops, trash, stools), dead and diseased stalks and immature suckers in mechanically harvested cane. It was recommended that measurements be made to examine this assertion, which was largely speculative and based on similar assertions for the wet tropics in Queensland (Leslie and Wilson, 1996) which now appear to be confirmed.

- 1.2 During 1998 season, research in Queensland (Crook et al, 1999; Norris, C.P., pers.comm.) examined quantitatively, harvester performance and cane deliveries at the mill, in separate but related projects. The results indicate:-

- that substantial sucrose losses and sucrose enrichment of extraneous matter can occur during the passage of millable stalk through the harvester - particularly at high pour rates;
- that admixtures of millable stalk with nil or low sucrose fractions dilute pol (and hence CCS) measured on cane deliveries by an average 4.2 CCS units below that of sound stalk in the fields providing those deliveries.

The two effects are not additive but are likely to be jointly greater than the 2.33% pol we sought to explain on the Ord.

The magnitude of such effects in the Ord can be established only by similar measurements. We see no point in pursuing pilot phase - commercial comparisons further by repeating our 1996 - 97 analyses on 1998 season data given the probable magnitude of harvesting losses and dilutions.

Rather we propose that losses and dilutions associated with mechanical harvesting of

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Ord cane be accepted as the probable cause of the 2.33% pol difference. It should be recognised that individual deliveries can display greater or lesser differences. The questions of whether the measurement and remediation of these losses and dilutions should be priorities for specific action in the Ord are reconsidered later in this report.

1.3 Our new emphasis has been to examine 1996-1998 Ord production in regard to farm-paddock-year variability in TCH and pol, and to compare the characteristics of Ord cane with those of cane from the Pioneer Mill Area, Queensland. This area, while different environmentally from the ORIA, provides the closest Australian cane environment for comparison.

The objectives of this focus were:

- (a) to identify differences between paddocks in the Ord that may lead to defining beneficial changes in management practices;
- (b) to understand better the characteristics of Ord cane and the extent to which those characteristics reflect unique features of the Ord soils and climate - again as a possible path to defining useful manipulation(s).

By this means we now endeavour to address the full terms of reference of our commission as documented on p. (vi).

2. Investigational Strategy and Methodology

2.1 General Strategy for the Study

The overall strategy was to assign between paddock variability in TCH and pol to responses to factors such as variety, class, crop age, time of harvest, time of ratooning and water table depth, and then to:

- (a) Use Pioneer comparisons to identify Ord responses to these factors that are "different" and to seek underlying causes for those differences. Crop class, time of harvest and time of ratooning were examined in some detail.
- (b) Utilise the residual variability left after the direct effects of such factors had been removed, to examine effects of farms, years and farm x year interactions which, in turn, might be attributable to soil properties, husbandry practices, weather and their interactions.

The strategy was restricted by incomplete data (e.g. planting dates), highly variable numbers of paddocks between farms, and some confounding (e.g. classes x years). Nevertheless, there was sufficient data from the three years to support useful enquiry.

The strategy involved applying statistical models to response relationships, either by regression or covariance analysis. Such models are empirical and rarely express causality or the physical and biological processes by which even strong statistical relationships arise. For this reason there can be no guarantee that relationships established on 1996-98 data will predict the nature of relationships in future years.

2.2 Adjustment of Pol Determinations by the Mill

In 1996 and 1997 the Mill utilised pol balance to adjust pol-in-cane (calculated from pol in first crush juice) upwards by 0.5 and 0.44% respectively. In 1998 undetermined gains and losses were more dynamic week to week and the Mill made upward adjustments of 0.5% for calendar weeks 15-27, 0.9% weeks 27-31, 1.4% weeks 32-35, 0.9% weeks 36-37 and 1.2% weeks 38-48. This led us to recalculate pol adjustments weekly according to the formula:

$$\text{Adjusted Pol} = \text{Unadjusted Pol} \left[\frac{(1 - \frac{\text{Undetermined Gain/Loss \%}}{100})}{1.005} \right]$$

(Gain is negative; Loss is positive)

Initially we examined the effect of doing this on the 1996-1998 weekly 'Cane Analyses' of the Mill, checking that the total pol for each season remained unchanged. Polynomial regressions were calculated for these weekly adjusted pols vs calendar weeks to smooth the time trends of pol with time of harvest through each season. In all cases third order coefficients were non-significant at $P = 0.05$. Occasionally intercepts and second order coefficients were also non-significant.

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The decision was then made that Impurities (as listed in the Cane Analysis) could not be adjusted and that (Adjusted Pol + Impurities + Fibre) would be used as a measure of average Dry Matter % (DM) in cane each week.

The analyses were then extended to examining the seasonal patterns of Adjusted Pol % DM and Fibre % DM - again using polynomial regression to smooth time trends. From this experience it was decided that individual paddock pol data should be adjusted weekly also using the same formula. All paddock data for the three years 1996 - 1998 were adjusted prior to further analyses and in some cases for reanalysis of results presented in the Preliminary Report. Weekly pol adjustment seeks to eliminate pol variability attributable to this feature of the Ord mill, from the pursuit of other causes of pol variability. Factually, it merely alters the variability imposed by the mill because the level of undetermined gains/losses using first expressed juice probably varies between individual deliveries.

Further justification for weekly pol adjustment is provided in 'Results and Discussion'. Unfortunately, the resultant pol data differ from either the 'actual' or 'adjusted' pol data in other data bases and presentations. The differences are mostly small but are occasionally quite large. **Unless otherwise specified, the remainder of this report uses the word pol for weekly adjusted pol.**

Towards the end of our study we were made aware that we could have recompiled the entire paddock database using paddock specific brix and fibre analyses. This would have eliminated some uncertainty related to fibre and impurities, and may have reduced the residual variability unexplained by our analyses. We regret that Mill officials did not inform us of this option at the outset.

2.3 Mean Yields and Mean Pol Levels for Year x Variety x Class

These summaries which exclude standover cane have been recompiled for 1996 and 1997 to incorporate weekly pol adjustments and the summary for 1998 is similarly derived. The summaries have been extended also to include pol yield (tonnes pol per hectare - TPH) along with TCH and Pol %. Means are weighted by total area or tonnes cane (Table 1). The major corrections to varieties for individual paddocks which were advised by J. Engelke in July 1999 have been included. TCH records greater than 250 and less than 30 were deleted. Such extreme values occur, it is assumed, due to incorrect paddock areas, to deliveries from partial- or across-paddock harvests, or to husbandry disasters. Less extreme errors remain undetected in the database.

2.4 Analysis of TCH and Pol for Farm x Year x Variety Patterns

The paddock spreadsheet data were subjected to analysis of variance and pattern analysis by subcontract to K. Basford and I. Phillips, University of Queensland.

Full details are reported by them in Appendix I.

TCH and Pol were analysed separately for effects of Farm (F), Year (Y), Variety (V), Farm x Variety (FxV), Farm x Year (FxY), Water Table Depth (WTD), and Time of Harvest (TH). A value for WTD (metres) was determined for each paddock by overlaying detailed paddock maps on the depth to groundwater as mapped in August 1996 (Plate 8, Yesertener, 1997).

The analyses concluded with comparisons of the productivity of varieties within farms and of farms within varieties for NCO 310, Q95, Q96, Q99, Q101 and Q117 which are presented in box diagrams.

Cane classes were not differentiated in these analyses but standover cane was excluded.

2.5 Comparison of Ord and Pioneer Cane and Environments

Pioneer Mill (R. Gellweiler, P. Statham and J. Comollatti) provided data for season average TCH and CCS for Plant and 1R-8R cane, and for average weekly CCS for Plant and 1R-3R cane for each year 1992-1998. They had earlier provided season average Pol, CCS and Fibre data for the years 1955-1960 and 1992-1997.

These data were used for various comparative purposes with similar Ord data viz:

- to provide an example of the effect of moving from manual to mechanical harvesting;
- to evaluate the relative performance of plant and ratoon cane in respect of TCH and CCS/Pol;
- to examine within season trends of CCS/Pol relative to time of harvest (TH);
- to identify cane quality differences in terms of Pol, Fibre, Impurities and Water in cane;
- to dimension the relative performance of the two areas in respect of TCH, CCS/Pol and TPH.

It then became relevant to compare climatic environments in an attempt to rationalise the differences in cane productivity.

B.A. Keating, CSIRO Tropical Agriculture, converted daily weather data for Ayr and Kununurra into weekly average "potential crop growth rates" with the radiation use efficiency and temperature index algorithms of the APSIM-SUGAR model (Figure 9). J.R. Wilson, (formerly CSIRO Tropical Agriculture) guided one of us (JKL) through the forage quality literature relating to the effects of high temperatures on soluble carbohydrate and fibre levels in tropical grasses. By assuming sugar cane to be an analogous tropical grass, by reviewing the sugar cane literature on growth, sucrose accumulation, maturation and ripening, (Appendix II) and by utilising temperature data for Kununurra and Ayr (Climatic Averages - Australia, Bureau of Meteorology, Department of Administrative Services, 1988), an hypothesis was developed to explain

6.

differences in pol and fibre levels between the Ord and Pioneer and between years within the Ord, in terms of air temperatures.

2.6 Cane Growth and Sucrose Accumulation in Ord Cane

Our collaboration with R. Muchow, CSIRO Tropical Agriculture continued on matters related to laboratory cane analysis, the findings of four 1998 Dry-Down experiments in the Ord, and to the crop physiology of cane growth and sucrose accumulation. He collaborated further to check the silica content of fibre in millable stalk of Ord cane.

Relevant findings from these collaborations are detailed with acknowledgement in Results and Discussion and in Appendix II.

2.7 Project Report - Factors Affecting Yields of Sugar on the Ord River - H.G. and M.A. Gardiner. April 1999.

Independently of our study, a concurrent project was commissioned by the Ord Sugar Industry Board.

That project involved pre-harvest measurements of clean stalk quality, disease, suckers and lodging, and post-harvest measurements of gaps in plant stands, soil analysis (0-30cm soil), and cane yields and cane quality at the mill. The draft and final reports, raw data and some statistical analyses were made available to us by G. Gardiner with Board approval. One particular finding of the Gardiner's - a possible linkage between extractable sulphur in soil and fibre content in clean stalk - was the subject of a literature review and some personal enquiries which are reported here and were transmitted direct to G. Gardiner.

We had proposed to Agriculture WA that post-harvest measurements of soil mineral - N to 2m depth be made in 1998 for selected paddocks to check for NO₃-N bulges in the subsoil. If these exist, they might be causally related to "growing-on" of cane crops and low pol. It was not possible to make those measurements but they should still be made in the interests of sound management of N fertilisers.

3. Results and Discussion

3.1 Cane Performance at District Level

3.1.1 Mill Analyses

3.1.1.1 Unadjusted weekly pol levels are plotted against time of harvest (TH) in Fig.1. There is week-to-week variability about the polynomial trend lines with $\pm 0.4 - 0.7$ pol standard errors. From the commencement of crushing to about week 38, there was no effective rainfall in any of the three years. Significant rain ($> 10\text{mm}$) commenced in October 1996 ($> \text{week } 39$), November 1997 ($> \text{week } 43$) and September 1998 ($> \text{week } 34$) and this may have impacted to reduce pol - particularly in November 1998. Unless extreme, rainfall should not induce responses in irrigated crops unless irrigation is suboptimal or unless it interferes with drying down for harvest.

Rainfall occurrence was not responsible for the time trends nor week-to-week variability prior to week 40 in any of the three years. It may have been a factor in pol declines after weeks 44-45 in 1996 and 1998.

3.1.1.2 Nevertheless, a primary question exists as to whether these time trends in pol % cane are due, at least in part, to seasonal time trends in the moisture content of cane. Moisture content can be estimated if one assumes that:

$$\text{Dry Matter (DM) \% Cane} = \text{Brix \% Cane} + \text{Fibre \% Cane, or}$$

$$\text{Pol \% Cane} + \text{Impurities \% Cane} + \text{Fibre \% Cane}$$

and $\text{Moisture Content \% Cane} = 100 - \text{DM \% Cane}$.

It is known that unadjusted pol % cane values for the Ord are erroneous and that they are susceptible to adjustment from the pol balance determinations of undetermined sucrose gains/losses. It is not known whether Impurities % Cane, and hence Brix % Cane, should be adjusted separately and/or additionally to pol. Impurity levels in Ord cane (2.38%) are similar to those in Pioneer cane (2.32%). Impurities show no consistent seasonal patterns across years although there are significant relationships with time of harvest within years (not shown). Weekly values lie in the range 2-3% cane for the Ord with a tendency for higher values at the beginning or end of the crushing season. All mills undertake "Impurity Balances". These annually account for 20-30% less soluble impurities in mill outputs (R. Kirk, unpublished CSR data) than are estimated for cane at delivery as the difference between brix % cane and pol % cane. Imbalances are lowest for the Ord mill. Weekly variations in these imbalances, or "undetermined impurities", are wide with some extreme values early in the Ord crushing season. There is no significant correlation between weekly undetermined impurities and the undetermined sucrose gains/losses in the same weeks ($R^2 = 0.024$, $n = 96$), but (extreme values aside) the undetermined impurities displayed mid-season maxima in 1996 and 1997. There was no

8.

evidence for a seasonal trend in 1998 (Fig.2). It needs to be understood that unlike pol balances, impurity balances actually involve changes in the chemical identity of "impurities" which preclude proper mass balance accounting.

One has to recognise also, that calculations of cane components for the Ord based on first expressed juice analyses are susceptible to several independent sources of error viz. mill settings, crush recycle, non-calibration of the F+3 and F+5 formulae, the fibre determinations themselves and probably other sources.

We concluded that there is no basis to justify adjustments of Impurities % cane as reported by the Ord mill, and certainly no valid method for such adjustment. Accordingly, we have utilised the sum of Impurities, Adjusted Pol and Fibre (all % cane) to calculate DM and moisture contents for weekly deliveries. The inherent errors associated with this methodology, and their consequences, are inestimable but seem unlikely to be seriously misleading. Our major concerns are that the estimate involves standover cane and unknown extraneous matter levels.

In all years, moisture content estimated in this way decreased approximately 5% from start of crushing to a minimum about week 40. Conversely, dry matter content increased 5% from week 15 to week 40 each year (Fig.3). Such changes would account for a significant increase in pol for this period even if there were no parallel changes in pol:fibre ratios. Cane throughout 1996 had considerably lower DM than 1998 and particularly 1997. This means that pol % cane levels for 1996 would be 0.8 - 1.0 units lower than 1997 due to simple dilution.

3.1.1.3 Weekly adjustment of pol preserved the seasonal trends and brought the annual trends for the three years closer together throughout the crushing season to within the standard errors of individual estimates which were increased to a range of $\pm 0.7 - 0.9$ (Fig.4). Adjusted pol peaked around weeks 35-37 at 14.4 - 15.1%. The seasonal pattern was maintained when adjusted pol was expressed on a dry matter basis (Fig.5) and 1996 was clearly the superior year overall. These features were mirrored by opposite trends in fibre % dry matter (Fig.6). The latter trend was not apparent in fibre % cane (not presented), due it is thought, to independent and opposing variations in the moisture content of cane.

3.1.1.4 Low pol:fibre ratios are characteristic of Ord cane as delivered to the mill with that ratio increasing from 0.6 to 0.95 mid-season and then declining to 0.7 at the end of the season (Fig.7). This can be compared with the characteristics of cane for Pioneer, where the season average pol:fibre ratio was 1.13 for the period 1992-97. Prior to mechanical harvesting (and of course to other changes over forty years in varieties and husbandry) the Pioneer average for 1955-60 was 1.42. This change is presumably due to the joint effects of crop structure changes and mechanical harvesting (Leslie and Wilson, 1996) but there must have been offsetting genetic improvements in pol:fibre ratios to account for the minor fall in pol % cane from 16.23 to 16.08.

Pioneer cane under a similar harvesting regime has higher pol and lower fibre (16.08 and 14.19% respectively 1992-97) than Ord cane (13.59 and 15.90, 1996-

98). These differences could have little to do with the slightly lower moisture contents in Pioneer cane - 67.4 vs 68.7% - which can account for only 0.4% pol difference and should be responsible for slight underestimation of the real fibre difference.

Both districts display seasonal trends in sucrose content of cane as illustrated by plotting Ord adjusted pol and Pioneer CCS on the same graph (Fig.8). Pioneer district starts its crushing season around week 23 at approximately 1.2% pol higher than the Ord for the same week ($\text{Pioneer Pol \%} = \text{Pioneer CCS} + 1.16$). It peaks about 2.0% pol higher than the Ord and, in normal seasons (1998 excluded as abnormally wet), finishes the season about 3% pol higher than the Ord. Expressed another way, average pol % DM of Ord cane deliveries has been 42.0% cf. Pioneer cane at 49.3%.

This comparison became the basis for one line of our enquiries which sought to understand why Ord cane displays both low levels and extreme seasonal trends in pol:fibre ratios relative to the Pioneer district. We have scrutinised both pol and fibre because (genetic influences aside) physiological influences on plants tend to affect the partitioning of assimilates to soluble and insoluble carbohydrates in opposite directions.

Some idea of the Ord dynamics can be obtained by extracting data from Figures 3, 5 and 6. For example, for weeks 15 and 40 in 1998:

	Week 15	Week 40
DM % cane	26.8	33.0
Pol % DM	32.1	43.3
Fibre % DM	58.2	49.4
Pol:Fibre	0.55	0.88
Pol % Cane	8.60	14.29

Table 2: Two-way Relationship for Pol % Cane (ORIA, 1998)

	Dry Matter (%)		Mean
	26.8	33.0	
0.55	8.60	11.71	10.16
Pol:Fibre			
0.88	12.54	14.29	13.42
Mean	10.57	13.00	-

In this case the increase in pol% cane from week 15 to week 40 is associated with both lower water content and, to a slightly greater extent, with increasing pol:fibre ratio. It is a reasonable general statement that within and between season changes in pol % cane embody these two components and that their separate effects are additive. No attempt has been made to examine Pioneer cane for equivalent trends within seasons. It was noted earlier that Pioneer cane averages 1.3% H₂O lower than Ord cane. It is suspected that this is simply due to earlier harvesting of higher moisture cane in the Ord. It is probable that the main difference between Ord and Pioneer cane is in pol:fibre ratio. This is examined further in Section 3.1.3.

3.1.2 Effects of Year x Variety x Class

3.1.2.1 Scrutiny of these effects was pursued after first excluding Mixed varieties and all Standover cane.

The relevant data are shown in Table 1. Class averages for the three years have not been calculated because of the wide differences in paddock frequencies between years e.g. Plant cane in 1996, 3R cane in 1998.

For similar reasons Table 1 is extremely difficult to interpret. Low frequencies in individual Variety x Class cells coupled with some extreme individual values for Pol or TCH, create apparent differences between means which have little or no credibility.

Pol means are often an expression of individual times of harvest rather than of real differences between varieties or classes. Pol values are re-examined later after accounting for time of harvest effects. There is however a range across years from 13.3 in 1998 to 14.4 in 1997.

Table 1 here

12.

TCH means also reflect extreme values. Some involve effects of crop age - particularly the greater ages of 1996 plant cane crops - and others must result either from husbandry variations such as poor establishment, inadequate irrigation etc. or from undetectable errors in yield recording.

There are no consistent differences in TCH or Pol between Q96, Q99 and NCO 310.

3.1.2.2 Pioneer means (Table 3), which are based on much higher paddock frequencies, indicate that plant cane in that district consistently averages more than 20% higher TCH than does 1R cane. This is due presumably to the greater average age of Pioneer plant cane crops, as well as to such beneficial features as higher, more even plant density, lack of stool injury, less pest and disease pressure, superior weed control, etc. All these benefits diminish to negative attributes as ratoons age up to 7R (4R - 7R not shown in Table 3). Their negative impact is probably underestimated since inferior ratoons are selectively removed for replanting.

Ord experience is too restricted to expect such patterns. A very superficial appraisal is that Ord ratoon production has been about normal; but only in 1996 was the TCH potential of plant cane realised. Since there is no planting date data for 1998 and little for 1997 crops we were unable to assess whether low crop age was a cause of these lower plant cane yields.

Further interpretation is resumed in Section 3.2.

3.1.3 Factors responsible for Location and Seasonal Differences in Cane Quality

3.1.3.1 There is a substantial literature on this subject but it has not yet led to the creation of process based relationships to account for quality differences in the field. A review of this literature is presented in Appendix II and the conclusions of that review are utilised in this discussion.

3.1.3.2 One has to believe that the important differences between the Pioneer and Ord production areas are climatic, although varietal and soil differences need to be appraised. The climatic differences are quite large - in radiation, temperature and evaporative demand.

Potential crop growth rates calculated for Ayr and Kununurra by B.A. Keating are shown in Fig.9. They are similar during summer from Week 40 (October) to Week 10 (March) and show the effect of cloud cover. They differ widely between the two districts from April to September. The minimum Kununurra values for June/July, which are still about 80% of maximum values, are analogous to those for Ayr in weeks 13 (late March) and 34 (late August). In these calculations, low temperature was rarely the cause of any reduction in growth rates and then only of very slight

Table 3 here

14.

reductions for a few days in some years at Ayr.¹ Radiation was virtually the sole factor driving growth. There is, in that influence, no apparent explanation for the observed increases in the sucrose content of cane from April to September.

3.1.3.3 Air temperatures differ substantially between Ayr and Kununurra (Fig.10 and Table 4). The greatest differences occur from June-December in both minima and particularly maxima. There is some overlap of the 86- to 14- percentile ranges in minima from April-September.

Whether temperatures exert effects on cane growth that are not fully accounted by APSIM and in Figure 9 is problematic. Figure 9 implies mid-winter growth rates for Ayr slightly more than half peak summer growth rates. Kingston et al (1984) provided data in their Annexes III and X which allow comparison of stalk and sucrose yield increments at Ayr for the 3 month periods December-March, March-June and June-September for plant and first ratoon cane which was 6, 9 and 12 months old commencing each period. The average TCH and TSH increments for Q96 (3 ages x 2 classes with no apparent effect of age or class) were:-

Growth Period	Δ TCH	Δ TSH
December - March	67.1	5.5
March - June	21.2	8.6
June - September	13.9	4.1

Unfortunately there is no published data for the DM content of cane. It is however obvious that the DM components of the increments in cane yields from March to September are almost entirely sucrose, in marked contrast to the December-March increments. This means that elongation growth at Ayr must have virtually ceased about March/April. We could locate no similar data for Ord cane. If however, temperature responses are comparable across locations and can be simply related to daily heat units, one would not expect cessation of elongation growth in Ord cane outside June-July. It is difficult to reconcile this with the summary statement on 1978-82 experimental program (Anon 1982, p.3) - "varieties currently available in the Ord do not appear to increase their cane yield during the crushing period." This remains the common view, and 1998 cane was regarded as atypical for "growing on" during winter.

It is not possible to examine growth during the crushing season using district level yield data. The question is considered again in Section 3.2 where analyses of paddock data show that relationships between TCH and

¹ The temperature algorithm in APSIM-SUGAR reduced growth rate linearly from 15° to 5°C mean daily temperature.

Table 4 here

16.

time of harvest are confounded by age and useful estimates of winter growth rates are precluded.

3.1.3.4 The issue is the conventional view (e.g. Bull, 1980) that high sucrose concentrations require a growth stress which arrests or greatly reduces stalk elongation but not photosynthesis, and that such stresses are mediated by low temperatures, water deficits or nitrogen deficiencies. In popular interpretations there is an erroneous tendency to consider the modus operandi of these three stresses to be physiologically synonymous, and the effects substitutional. Thus, confronted with the facts that Ord temperatures appear too high to stress stalk elongation, that stalk growth can be slow in autumn-winter, that there is considerable variation between crops in the sucrose %DM of millable stalk and that some Ord crops attain ceiling levels of 48-52% sucrose, popular diagnoses focus on the manipulation of irrigation and nutrient supply as both the causes of variation and the sources of improved pol levels.

3.1.3.5 Appendix II questions the conventional view in several respects. The difficulties are that the physiological issues raised in that review can be resolved only by further research, and that there is a paucity of data for the Ord on which to base alternative explanations. With these qualifications the following interpretations are offered.

3.1.3.6 The underlying seasonal pattern of pol accumulation and stalk growth at both locations is probably jointly driven by the normal partitioning of 0.5 - 0.6 of stalk DM increases to sucrose, and by progressive reductions in stalk moisture contents that occur as the proportion of mature internodes increases in continually elongating stalks.

It seems probable that autumn ripening, i.e. sucrose enrichment of internodes by a shift of partitioning almost entirely to sucrose storage, may also be a major feature of both Ord and Pioneer environments. The shift is probably triggered by shortening day lengths and temperature drops after the autumn equinox (21 March). It is possible that enrichment is greater for Pioneer because the temperature drop is greater or more rapid.

More speculative, there is the possibility that very high air temperatures (>40°C) may exert a separate physiological influence towards low pol:fibre ratios and high fibre - particularly on clear days during summer. This influence could cause lower pol% DM in Ord cane entering autumn compared with Pioneer cane and this lower base level may persist in relative terms throughout the subsequent months. One can imagine that microclimatic niches in cane crops, e.g. due to lodging or gappiness in stands, could be even more temperature extreme (particularly in regard to plant tissue temperatures) than meteorological screen data may indicate. We are informed that symptoms akin to sunburn are often noted on lodged cane.

Superimposed on these major dynamics affecting cane quality from April to September, will be the effects of water and nitrogen supply which are mostly concerned with cane hydration and sucrose dilution rather than with altering

sucrose %DM. There may however be extreme effects on cane crops being harvested during ripening in the April-June period. Such effects may include serious reductions in sucrose %DM and parallel increases in soluble impurities associated with "drying down" for harvest (Appendix II, 6.3.4).

These postulates may cover the Ord harvest period from April to September. Beyond that time there is a decline in pol % cane for the Ord relative to Pioneer cane. We have made virtually no rigorous analyses that can account for this difference. It will be noted that Ord temperatures (maxima, minima and means) increase rapidly September-November by comparison with Ayr. It is also noted that the post-ripening phase can be subject to diverse influences (Appendix II, 2.3, 6.7.5). This is further discussed in 3.1.3.12.

3.1.3.7 These are, at best, credible theories. None of the phenomena have been adequately researched to predict, let alone integrate, their differential influences on field cane. Superficially, the dual temperature theory is consistent with 1998 (a hot year January to June) being a low pol year in the Ord (13.26%), and 1997 (daily average temperature almost 2°C cooler for the same period) being the highest pol year (14.42%) so far. 1996, which had the coldest May of the three years and which featured the highest pol % DM and pol:fibre ratios appears to have been offset by generally low cane DM contents (Fig.3) to display intermediate pol % cane. We have no credible explanation for the apparent differences in DM across years.

If these interpretations are valid, there can be some optimism in that approximately 50% of Ord years will have equal or lower March-June temperatures than did 1996 and 1997, and relatively few will be hotter in this period than 1998.

3.1.3.8 We considered making a probabilistic analysis of Pioneer vs Ord pol levels, and the year frequencies of their seasonal patterns in each district relative to temperature deficit integrals (see 4.3.7, App.II). This would introduce the real risks of basing strategies and other interpretations on a falsity which attributes the entire increase in pol % cane below base temperature to the temperature drop stimulation of ripening. In fact, about half of the increase is probably due to progressive dehydration of the stalk of maturing cane. As yet no process based model which incorporates both of these phenomena has been developed.

There can be no progress towards such a model without further research.

3.1.3.9 We are far from advancing an holistic model for sucrose concentrations, and are very aware that our hypotheses lack proof of causal processes. We are nevertheless confident that such climatic interactions with the phenotypic growth and development characteristics of sugar cane are the primary causes of the seasonal pol patterns of the Ord and Pioneer districts and for their differences in pol levels. They are also the probable causes of other quality differences in fibre and cane purity.

3.1.3.10 On these patterns will be superimposed differences due to variety, class and age

18.

schedules, mechanical harvesting, irrigation practices, unseasonal rainfall occurrences, soil fertility - including N (and perhaps sulphur) status - and probably other factors which will be a feature of between-paddock variability. To the extent that such factors reflect systematic differences in the husbandry practices of different farmers and the soil properties of different farms, they may also cause between-farm variability. This is discussed further in Section 3.2.2.

3.1.3.11 It may be that there will be a range from the hottest years to the coolest years of about two pol units - say 13-15% pol annual average - on the present length of crushing season. The pol, fibre and cane impurity characteristics of Ord cane are unquestionably disadvantaged by the extended crushing season. For example, if the Ord had crushed mid-June to mid-November 1996-1998 the annual average pol (assuming equal week weightings, that no factors other than time of harvest are reflected in the full season regressions, and that there was no stand-over cane) may have been as follows:-

	Calendar Weeks	Average Pol (1996-98)
Mid-April - End November (Normal Season)	16 - 47	13.16
Mid-June to Mid-November (Short Season)	24 - 45	13.97

i.e. Average pol % could be increased by 0.8 units by shortening the crushing season by 10 weeks. Most of this would be a real increase in total sugar production. Purity would also be enhanced.

It is unlikely that any strategy other than reducing the crushing season, could alleviate the quality problem to the same extent. It would seem that the negative consequences of the current 32 week season were not fully and properly accounted prior to establishment of the Ord Mill.

3.1.3.12 Less attention has been directed at the decline in pol % cane which occurs late in the harvesting season after calendar weeks 35-40 (Fig.4). This decline is more pronounced for the Ord than for Pioneer (Fig.8). The factors of influence were not reviewed in Appendix II.

The Ord decline is almost totally due to a fall in pol % DM (Fig.5) and strong upturn in fibre % DM (Figs. 6, 7) - particularly in 1997. It is not normally associated with a reduction in DM% (Fig.3). (The low value of 29.3% DM for week 48, 1998 is an exception due to 78mm of rain during November. This caused sucrose dilution in cane without changing pol % DM.) It is therefore unlikely that the late season decline phenomenon is due to a resumption of growth of mature stalks and/or to increasing proportions of low pol suckers.

It is most likely related to decrease in sucrose in flowered, lodged or dead stalks of mature cane which would be consistent with the changes noted above. In the

absence of extreme rainfall in spring and early summer which was a feature of the Burdekin in 1998, it is likely to occur normally in both the Ord and Pioneer areas. It may well be exacerbated by high extraneous matter levels in mechanically harvested cane late in the season. This could explain a more rapid decline in pol measured on mill deliveries than is normal for 12-15 month old millable stalk alone (Rostron 1972, Kingston et al 1984).

3.1.3.13 Individual paddock analyses reported later (3.2.2.2/3) indicate that the Ord decline was similar across classes and ages of cane but was most pronounced for both plant cane and ratoons of NCO 310 with Q96 least affected.

This is summarised (Table 5) by presenting the arithmetic mean pol % cane for NCO 310 paddocks in time of harvest intervals of 35-39, 40-44 and 45-50 calendar weeks compared with Q95, Q96 and Q99 paddocks. The data are derived from all 1996-1998 paddocks for which crop age was available i.e. most ratoons and approximately one-third of the plant cane paddocks.

Table 5: Mean Pol % by Varietal Group and Time of Harvest Interval

Varietal Group	Time of Harvest (calendar weeks)		
	35 - 39	40 - 44	45 - 50
NCO 310	15.01(12)	14.03(24)	12.88(22)
Q95, Q96, Q99	14.74(41)	14.72(30)	13.91(23)
"t" test probability	Non-significant	P = 0.029	P = 0.008

Figures bracketed () are numbers of paddocks in each mean.

Collectively, Q95, Q96 and Q99 have occurred in 2.4 times as many paddock-years as NCO 310 in the Ord. In the data above they have occurred in only 1.2 times as many of those paddocks harvested after 40 weeks. Thus NCO 310, which also showed a disposition to flowering, lodging and rapid decline in pol % after 40 weeks during the pilot phase, has been emphasised fortuitously in later harvesting. Since NCO 310 is not produced in the Burdekin, and has been harvested contrary to its characteristics in the Ord, it is proposed that this is one cause for the Ord decline being greater than the much smaller Pioneer decline.

It is suggested that earlier harvesting should be preferred for NCO 310 in its remaining life as an Ord variety. We conclude later that apart from this NCO 310 influence, the pol differences between the Ord and Pioneer are not likely to be due to variety differences.

3.1.3.14 There is a research need to provide a knowledge base from which the field quality phenomena can be predicted and against which the preceding theories could be tested. This would enable sound diagnosis and strategy to replace our speculations.

It is surprising and disappointing that Australian research over several decades has not generated this knowledge base. The need is clear and we would of course, like to see such research. However, we believe that this research would be too basic and costly to be justified for the Ord industry alone, and unlikely to provide even mid-term benefits for the Ord industry. The proposed research would have priority in the context of an industry-wide need to rationalise cane quality differences from Grafton to the Ord.

A less costly approach for the Ord, would be to routinely sample stalks of say 20-30 ratoon crops at monthly intervals from initiation through to late November. Data recorded would be stalkweight, length and node number, and a full range of rigorously determined quality data. The Hatch and Glasziou (1962) technique for measuring stalk elongation rates by making needle marks in immature internodes through the leaf sheath should also be adopted and applied. We recommend this as a means of characterising the main dynamics controlling cane quality without the effort required to sample sequentially for accurate per hectare yields.

3.2 Cane Performance at Paddock Level

3.2.1 Analyses of Paddock Data - TCH

3.2.1.1 It was not possible to extend the previous analyses of 1996 and 1997 plant cane TCH to the 23 plant cane crops of 1998 because planting dates were not recorded.

There were 166 ratoon paddocks analysed for 1998. For these, ratoon age (RA) was weakly correlated with time of ratooning (TR) - $R^2 = 0.205$. There was no significant effect of TR on TCH, and the TCH relationship with RA was weaker than that obtained for 1997 ratoons (Equation 3, p.25, PR) viz.

$$1997 \text{ TCH} = -10.9 + 0.3504 * \text{RA} \quad \dots 1) \\ R^2 = 0.295; \text{SE} = \pm 28.8$$

$$1998 \text{ TCH} = 58.11 + 0.2103 * \text{RA} \dots \dots \dots 2) \\ R^2 = 0.109; \text{SE} = \pm 32.4 \quad (\text{RA in days})$$

The 1997 and 1998 regressions estimate similar yields for ratoons aged 70 weeks. At RA = 40 weeks, estimated TCH is 26% lower in 1997 than 1998. This range is consistent with the calculation in 3.2.1.2 that crop growth rates were 11% lower on average in 1997, and with the notion that the yield depression attributed to the very wet 1996/97 summer was reflected most in younger ratoons irrespective of TR.

There is, with only two years experience, reason to doubt that Ord ratoons of a given RA will yield less the later they are ratooned - a relationship which has been established in Queensland (Chapman and Leverington 1976, Leverington et al 1978); given more general form at 27°S latitude in South Africa (Rostron 1972, Thompson 1978); and allegedly confirmed by the crop cycle experiment

(WA 78/1) on the Ord. The reporting of this BSES/WADA experiment by Gallagher (1986) deleted data for one season that was contrary to these expectations.

This conclusion does not mean that ratoons will not be affected more severely by waterlogging occurring soon after ratooning, i.e. on early regrowth. However, the very wet 1996/97 summer did not appear to impose its yield depression any more on the later ratoons than it did on earlier ratoons and on plant cane.

3.2.1.2 Diagonal scanning of TCH for sequential P → 1R → 2R → 3R across years in Table 1 indicates that 1997 was a lower yielding year than 1996 or 1998. This was examined further by dividing TCH by crop age for each paddock each year to obtain a "Crop Growth Rate" (CGR) (tonnes cane per hectare per week of age) to reduce the effects of crop age inherent in TCH. These paddock CGR's were then correlated 1997 with 1996 and 1998 with 1997. There were 42 and 109 paired paddocks respectively. Unfortunately, planting dates were available for only 54 of 130 plant crops.

The relationships between paddock CGR's in consecutive years are statistically very weak ($R^2 = 0.038$ for 1997 vs 1996; 0.112 for 1998 vs 1997). The reason for this is not immediately obvious. One would expect that CGR would reflect stand density, homogeneity and soil fertility and that these qualities would rank paddocks similarly across years.

Average between season effects computed by regressing through the origin gave CGR values for 1997 which were 19% lower than those for 1996 and 11% lower than those for 1998. This range of 11-19% is a measure of between year differences which may relate to the yield depression effected by the abnormally wet December 1996 - February 1997 period on all classes and varieties. In our Preliminary Report (4.1.2/3) we concluded that this depression was less likely to be an effect of low radiation per se (which should affect all paddocks), than an effect of variable waterlogging interacting with variable agronomy at the individual paddock level. We were unable to identify any aggravation of this TCH depression due to later ratooning i.e. to late harvesting in 1996. We maintain our previous interpretations and consider the issue further in 3.2.3.

3.2.1.3 Six of 24 plant cane crops in 1998 and 12 of 29 in 1997 yielded less than 100 TCH. The latter 12 averaged 66 TCH, and only 96 TCH as 1R crops in 1998. This is indicative of sub-optimal husbandry, and shows that poor plant cane does not augur well for the production of subsequent ratoons.

There seems no reason why good husbandry and early planting (April) should not average 160+TCH for plant cane, and resultant 1R - 4R ratoons should average 130 TCH. Overall commercial average yields of 135 TCH+ should be achievable, and this is very high for an annual harvesting system.

It is noted that Albertsen (1982) stressed "plant(ing) as soon as practicable after the commencement of the dry season", and the parallel strategy of harvesting the plant crop in August-September to optimise plant crop and subsequent 1R

22.

performance. That is, we are told, not general practice in the Ord at present.

3.2.1.4 Given the wide variation between paddock yields for cane of the same age, it is not possible to determine from these data whether cane growth rates differ through the year due to radiation and temperature seasonality. It is obvious from the internode lengths of mature stalks that stalk elongation rates vary widely across seasons and are minimal in winter.

The slope coefficients in 1) and 2) of 3.2.1.1 (0.3504 and 0.2103), imply ratoon growth rates from 23-38 tonnes stalk biomass (dry) per hectare per year. These, and the previous TCH/Age relationship for plant cane (ref. 3.5.1.2, PR) might suggest that cane displays no marked seasonality in its growth rates on the Ord, and that yields plateau at a biomass of 180 ± 25 TCH, probably when stalk elongation is balanced by stalk deaths as proposed by Muchow.

They also reveal that wide variations occur in paddock yields of cane at equal ages. The causes of these variations are presumably agronomic - stand density, irrigation practice, fertiliser treatment etc.

This variability conceals reduced stalk elongation rates coupled with sucrose enrichment during autumn and winter. The 1998 Dry Down Experiments of R. Muchow and colleagues provided concrete evidence that stalk biomass increased almost linearly into the winter months at an average rate of 0.07 tonnes stalk biomass per hectare per day. The continuance of these high growth rates after March was not associated with stalk nitrogen (0.10 - 0.24% N) at harvest, but was attributed largely to sucrose storage (see Table 4, Appendix II). This means that nil or low stalk elongation rates and sucrose enrichment were features of these four crops during autumn and winter 1998.

We have previously (3.1.3.14) recommended a sequential stalk sampling program to characterise these changes for the Ord environment.

3.2.2 Analyses of Paddock Data - Pol in Cane

3.2.2.1 Second order polynomial regressions of pol % cane on time of harvest were descriptive of the seasonal patterns for plant and ratoon cane in each of the three years (Figs.11, 12). These figures are plotted with all data points to emphasise the large between-paddock variability.

There were some differences between the patterns generated from individual paddocks separately for plant and ratoon cane, and the patterns generated from weekly mill data for the same years.

In the first instance the cane crushed weeks 17-19 in 1996 and 16-22 in 1997 was almost entirely standover cane that has been omitted from Figures 11 and 12.

The lower pol of 1998 cf. 1997 is maintained in both classes which tends to confirm the year difference as real. The behaviour of 1996 plant cane is less

consistent - particularly for early harvests. This may simply reflect an influence of younger cane. Unfortunately, these analyses can't be extended to pol % DM, and to pol:fibre ratios at paddock level, but it seems reasonable now to assume that the interpretations of 3.1.3 should stand.

3.2.2.2 The tendency noted previously for plant cane to have lower pol than ratoon cane (3.6.7.3, PR) is now seen as a reflection of the early plant cane behaviour in 1996 and the dominance of this class in a year when cane had a high moisture content. It is not possible to resolve whether this is the cause or effect of the apparent class difference. There were no real differences in 1997 with substantial numbers in both classes. The tendency for 1998 plant cane pol to be lower than ratoon pols late in the season is thought to be due to frequency weightings in a plant cane regression involving only 23 paddocks. When all years are pooled the difference persists mid-season but lies well within the standard errors for both classes. (Fig.13). We conclude that there is little overall difference in pol levels between plant and ratoon cane in the Ord, if time of harvest and moisture content effects are properly accounted. This is also true for CCS levels in the Pioneer district (Fig.14) and represents broad agreement with the class mean pol % comparisons of Table 1.

This became the basis of our decision not to differentiate plant and ratoon cane in the subsequent pattern analyses. It does however, beg the question as to what does cause between-paddock variation in pol % cane at a given time of harvest, which variation is of similar magnitude to the cross-season effect of time of harvest.

3.2.2.3 Availability of three seasons' data permitted regression analyses of pol % cane for Q96, Q99 and NCO 310 separately for plant and ratoon cane (Figs. 15, 16). More detailed analyses of ratoon pols indicated that significant year x class effects do not distort the varietal comparison of Fig.16. There were insufficient numbers to check this for plant cane. NCO 310 has displayed the disposition to rapid pol decline after week 40 which was a feature of its behaviour during the pilot phase (Gallagher 1984, 1986). This is consistent for plant and ratoon cane. Q96 displays least decline and Q99 is intermediate. The early behaviour of Q99 seems consistent with the research and pilot farm experience (Anon 1982). Its ratoon behaviour during the pilot years was variable showing a disposition to low pol both early and late in one report (Albertsen 1981), but a very stable high pol pattern in later reporting by Gallagher (1984). We suspect that such differences reflect low observation frequencies rather than inherent varietal differences.

Our conclusions are that Q96 is a slightly superior pol variety in the Ord across the harvesting season, that Q99 is probably slightly lower pol than Q96, but similar TPH due to higher TCH and that NCO 310 is comparable to both until about week 40, but its pol tends to fall rapidly thereafter. It has already been suggested (3.1.3.12) that avoidance of late harvesting of NCO 310 would be a worthwhile strategy for the remainder of its commercial life on the Ord.

Since there appears to be no consistent differences in TPH between Q96, Q99

24.

and NCO 310, it may be that continued use of Q96 and Q99 and the phase out of NCO 310 will have negligible effect on Ord sugar production in the next few years.

3.2.3 Variance and Pattern Analyses of Farms x Years x Varieties

We are indebted to K. Basford and I. Phillips for these analyses which are fully reported in Appendix I.

3.2.3.1 To summarise their findings:

- There were no significant differences between varieties in respect of pol and the significant varietal effect on TCH seems to reflect a Q101 vs Q117 difference and low paddock frequencies of those two varieties.
- There was no relationship between Pol and TCH for any variety, farm or year (Fig. 1.1, Appendix I). This confirms the previous conclusion to that effect, and sustains the view that high pol is not foregone by producing crops for high TCH. Some farms do achieve both e.g. Bothkamp, who has achieved TPH levels ≥ 20 in each of the three years. From our limited interviews we see no evidence that the high achievers have consistent attitudes towards irrigation or N fertiliser management.
- The effect of TH on Pol was strong but removal of that effect by fitting a spline (Fig. 2.2, Appendix I) left substantial variation of 2-4% pol for any particular TH.
- There is a considerable range in water table depths across ORIA cane paddocks, - from 0.8 to 10.2 metres as surveyed by the Water and Rivers Commission in August 1996. There is no apparent effect on TCH or Pol over this range.
- There are identifiable groups of farms which have differed markedly from above average to below average TCH and Pol with substantial year interactions. Farms divided into 7 relatively homogeneous groups for pol and 6 for TCH with retention of 83 and 88% of the total information respectively.
- For Pol, there were strong differences among the farms. The majority, including most of the larger farms, were in groups with relatively constant performance across years at average to above average Pol. This may reflect, in part, an averaging effect of the larger numbers of paddocks within the larger farms. Many of the other farms had an erratic performance across years.
- For TCH, there were quite large and often contradictory changes in farm mean performance across years. However, the majority of the farms, including most of the larger farms and some relatively small producers, were in groups with relatively stable and above average productivity across years. This suggests that significant improvements in productivity may be achievable by modifications to crop management on other farms regardless of the scale of the farm operation.

Only one farm (Causley) grouped High Pol/High TCH, and none grouped Low Pol/Low TCH. Some (Buchanan, Oasis Bananas) grouped High Pol/Low TCH, and others (Bardena, Farmyard Holdings) grouped Low Pol/High TCH. The majority, which included most of the larger farms, grouped around average to above average Pol and TCH.

3.2.3.2 Inspection of the least square means for farm TCH levels (Table 3.2, Appendix I) suggested that with the exceptions of Buchanan and R.B. Dessert which yielded low in 1998, the major differences between farms occurred in 1997. Eight farms averaged below 100 TCH in 1997 (Buchanan, Macevilly, Oasis Bananas, R.B. Dessert, Rogers, Scott, Smith RO and Smith NB).

This led to re-examination of individual paddock TCH in 1996, 1997 and 1998 in the particular context of water table depth. There were a number of relevant findings viz.:

1998 1R² yields were quite strongly and positively related to 1997 plant cane yields:

$$1997 \text{ TCH P} = 0.905 * 1998 \text{ TCH 1R} + 2.8$$

$$r^2 = 0.599; n = 22.$$

Whatever factors controlled the yield of 1997 plant cane also set the capacity of those crops to yield as 1R cane in 1998. The data set is too restricted to identify the controlling factors. However, it is unlikely that crop age was a significant factor, and possible that shallow water tables were involved in the low plant cane yields of Smith R.O. and R.B. Dessert.

1997 and 1998 Ratoon yields were weakly correlated ($r^2 = 0.182$; $n = 99$). This compares with the earlier analyses of Crop Growth Rates (CGR, see 3.2.1.2) which found no useful relationships.

When 1997 ratoon yields were grouped into yield intervals all but one of the correlations between 1997 and 1998 TCH within groups were non-significant. The slope coefficients were either very low or negative for yields below 100 TCH in 1997 and positive and close to 1.0 for paddocks that yielded above 100 TCH (Table 6). Grouped into two ranges viz. 30-100 TCH and >100 TCH in 1997, the distinction is more obvious. i.e.: paddocks yielding <100 TCH in 1997 expressed much less of their capacity to yield (as measured in 1998) than did paddocks yielding >100 TCH.

The regressions may seem to reverse x/y. They have been calculated to relate the abnormal (1997 TCH) to the normal (1998 TCH).

²

Smith, R.O. 2.40, 244 TCH 1R deleted - 11 ha. harvested in 1998 cf. 18.39 ha in 1997.

- There are 42 of 44 ratoon paddocks in the 126 TCH and greater ranges that had very similar high yields in 1997 and 1998, i.e. these showed no evidence of suffering from a general effect of cloudiness and low radiation in 1996/97 summer.
- While the frequencies of low yielding paddocks in 1997 were slightly higher with shallower water tables (<4m) than deeper (>4m) there were occurrences of low yield over deep water tables and high yields over shallow ones.
- Some of the low yielding paddocks continued with low yields in 1998. This was mostly true for 1R following 1997 plant cane, and for some low yielding 1R crops in 1997 over deep water tables e.g. Macevilly, Cummings, Scott. Other low yielding paddocks in 1997 continued on to give high to very high yields in 1998. This was mostly restricted to ratoon cane and occurred on both shallow (e.g. Cummings 69.11, 2.5m 88 TCH 1997, 186 TCH 1998) and deep water tables (e.g. Causley 2.30, 10.2m, 83 TCH 1997, 151 TCH 1998).

Table 6: Regression Analyses of 1997 TCH (y) on 1998 TCH (x) for Ratoon Cane

1997 TCH	Regressions for 1997 TCH relative to 1998 TCH			
	n	a	b	r ²
30 ³ - 85	15	53.3; P=6.9E - 05	-0.193; P=0.032	0.308
86 - 100	21	357.5; P=0.085	-2.380; P=0.270	0.064
101 - 125	19	37.5; P=0.491	0.810; P=0.110	0.143
126 - 150	29	21.9; P=0.805	0.848; P=0.201	0.060
≥ 151	15	-11.7; P=0.934	1.008; P=0.242	0.104
30 - 100	36	70.5; P=1.83E -11	0.124; P=0.032	0.128
> 100	63	79.1; P=1.37E -07	0.407; P=5.5E -05	0.236
All paddocks	99	58.6; P=1.84E -05	0.441; P=1.07E -05	0.182

3.2.3.3 A possible explanation is that waterlogging was severe on plant and ratoon cane over shallow water tables (<3m) where it was not alleviated e.g. by surface drainage and bed heights, on some farms with shallow water tables (R.B. Dessert, Smith R.O, Buchanan, Bardena). High 1997 yields on other shallow water table

paddocks (Cummings, Rocky Lerch) suggest that waterlogging had been controlled. It also seems feasible that localised waterlogging may have occurred on isolated paddocks with deep water tables (Rogers, Smith N.B, Kimberley, Causley) and that low 1997 TCH occurred as a paddock specific result of other husbandry outcomes on some other deep water table paddocks (Macevilly, Scott, Kimberley). The situation of Oasis Farms with several paddock water tables at 4.0 - 4.5m and quite variable 1997 yields is unclear.

We did not undertake the enquiries necessary to test this explanation, but would encourage the local industry to consider its feasibility.

Nor do we know the actual water table depths during 1996/97 summer, nor the more recent water table situation. If however the explanation has validity, its future implications are obvious - particularly in wet summers if water tables continue to rise and the salinity/sodicity of that water continues to increase in the ORIA. There may be some encouragement in the possibility that management of surface drainage can be manipulated on water tables as shallow as 0.8m (Rocky Lerch). There seems little point in pursuing other causes of variable TCH unless these questions relating to waterlogging and salinity can be resolved.

3.2.3.4 Further attempts were made to understand variation in Pol independent of TH. Pol vs TH regressions were derived for each of the seven pol groups (Figs. 17, 18). Either by interview or inspection of the database, we sought to rationalise paddock performance in Group 5 (High Pol) and Group 12 (Low Pol). The outcome has been somewhat equivocal but the following observations are thought to be valid:

- High Pol and low TCH can result from non-irrigation after the wet season ends (Buchanan);
- Low Pol at farm level can be due simply to a preponderance of late harvested NCO 310 paddocks (Farmyard Holdings, Bardena);
- High Pol at farm level may associate with no NCO 310 (Oasis Bananas), no late harvested NCO 310 ratoons as well as no plant cane since 1996 (Causley), and with a majority of mid-season harvests (Oasis Bananas 1998 - all between 25-37 weeks);
- While the influences of NCO 310 characteristics are fairly consistent - note particularly the Pol vs TH plot for Berg who had 5 of 6 paddock years in NCO 310 (Fig.18) - there are exceptions such as Bothkamp where four NCO 310 paddocks (average TH = 45 weeks) averaged 14.05% Pol, which is an outstanding result.

3.2.3.5 The experience gained in attempting this rationalisation indicates that individual farmers might usefully seek to interpret their own paddock performances in similar ways. Individual farm plots of Pol vs TH can be generated to facilitate this. We could not devote the time required to rationalise each

28.

farm and concluded that the chance of identifying new explanations for high or low Pol levels was too low to justify such effort. This is particularly so, since some of the variability is unquestionably due to differential harvesting efficiency, extraneous matter, non-matching of fibre determinations to paddock deliveries, and the unknown influence of the undetermined gain/loss problem at the mill. All of these have inestimable effects but are readily associated with $\pm 1\%$ Pol errors which is almost half the variability we sought to explain.

3.3 Cane Agronomy

Previous sections 3.1 and 3.2 have concentrated on analysing and interpreting district and paddock data. In this section a number of crop husbandry issues are considered - mostly without quantitative linkages to Ord crop performance and with a deal of speculation.

3.3.1 Crop Homogeneity

3.3.1.1 This is a useful concept discussed by Yates (1996b). He describes homogeneous cane at harvest as a beneficial feature comprising only "primary and early secondary shoots which may have up to a 4-month range of ages in primary stalks." By contrast, heterogeneous cane may comprise "immature, mature and senescent stalks ... bull-shoots (suckers) and damaged stalks". The issues are:

- how can husbandry throughout crop life be manipulated to maximise homogeneity at harvest; and
- which of these manipulations are relevant to Ord TCH and Pol?

It will be realised that homogeneity interacts strongly with mechanical harvesting to influence field losses of sucrose and extraneous matter dilution of sucrose with fibre in mill deliveries. It is also influenced greatly by cane variety. It is at the core of a current preoccupation of the wet tropics industry in Queensland with "crop structure" (Anon, 1998).

3.3.1.2 Yates states simply that "homogeneity is promoted by cultural methods which encourage early tillering and discourage lodging, by the selection of appropriate varieties and by harvesting at the correct age." To these might be added even plant cane establishment, minimising stool injury at harvest and avoidance of water, nutrient and weed induced stresses throughout crop life. One cause of heterogeneity in Ord crops is uneven and gappy plant stands (Gardiner and Gardiner, 1999).

3.3.1.3 There is a linkage between homogeneity and other factors which have been shown to influence Ord TCH and Pol. This translates into a husbandry objective of maximising stand evenness and growth rate from planting or ratooning through to the end of March. The objective is to enter autumn with the maximum stalk maturity and homogeneity which is possible for a particular time of crop initiation, and to minimise the opportunities created by gaps, late canopy closure

and reduced stalk growth rates for late tillers and immature stalks to be significant fractions of crops. In this regard, we suspect that lodging of thin or gappy crops may create greater heterogeneity - at least through to September - than the inevitable lodging of even, heavy crops.

It is thought that heavy crops (including lodged ones) may minimise stalk and leaf temperatures and hence the effect of high October-December air temperatures and radiation on $\cdot S/F$ if that proves to be a real phenomenon (ref. 3.1.3.6 and Appendix II 4.2.7/8 and 6.7.1). It is suggested that early (April-May) planting is more likely to achieve the above husbandry objective than late planting, which should be avoided (ref. 3.2.1.3). Obviously, there is little choice in ratooning times. Overall, it is clearly too late to seek to offset sub-optimal crop conditions at the end of March, by autumn-winter husbandry manipulations when elongation growth has virtually ceased.

3.3.1.4 On the evidence that stalk sucrose enrichment and cessation of stalk elongation coincide in autumn-winter in the Ord and are climatically controlled, the main objective of management in this phase should be to maintain homogeneity and ensure that photosynthesis is maintained at a level which secures ceiling sucrose enrichment of unsaturated storage capacity. Little is known about the agronomy of this, but it is unlikely to be optimised by imposing water or nitrogen stresses, or using ripeners if they reduce the desired photosynthetic rate. It seems probable that such strategies presently exacerbate the low pol and purity characteristics of cane harvested in this period, thus compounding an approximate 6% loss of commercial sugar yield associated with the decision to crush ripening cane in the late-April to mid-June period. An analogy would be to harvest grain crops at the milky grain or soft dough stage of maturation, and to impose water and nutrient stresses in this period to offset the effects of immaturity on grain quality.

3.3.1.5 The post-ripening phase from August-September onwards is one of increasing and somewhat uncontrollable heterogeneity. There is no descriptive data for Ord crop structures, and little or no quantitative knowledge of the effects of stalk age, lodging, flowering, stalk deaths, resumption of stalk growth and suckering on sucrose concentrations. Those farmers who appear to pursue homogeneity as proposed above, appear also to sustain TCH and Pol best in the post-ripening phase. Indeed, their achievement overall is partly the origin of our proposals.

3.3.1.6 In Section 4 recommendations are made for research to monitor Ord crops. This will overcome much ignorance of these matters. It is unlikely that varietal replacement of Q96 and Q99 could achieve anything short term. Long term varietal selection would be aided by better knowledge of cane homogeneity/heterogeneity in the Ord environment, and of genotypic variation related to this.

3.3.2 Nutrition

3.3.2.1 Confirmed mineral deficiencies in cane on Kununurra clays involve nitrogen and phosphorus (Gallagher 1986). Zinc and sulphur have been regarded as marginal for cane production but there is no field response confirmation. All four

30.

elements are included in the current plant cane recommendations of BSES for the Ord. No data is available on fertiliser use at farm or paddock level. There is therefore no basis to examine paddock records for TCH or Pol effects due to deficiencies or excesses of any of these four elements.

The mostly high yields of 1996 and 1998 do not indicate any widespread nutrient deficiency in Ord cane. On the other hand, there are some low yields without explanation and the yield depressions of 1997 which have been attributed to a primary effect of waterlogging (3.2.3.2/3) may well have been associated with induced nitrogen deficiency due to denitrification and/or with sulphur deficiency.

Gardiner and Gardiner (1999) examined relationships of TCH, Pol and fibre with soil analyses at sixteen sites in 1998, and identified zinc, sulphur and boron as worthy of further scrutiny.

3.3.2.2 Nitrogen

The Gardiner's soil analyses to 30cm depth found no site with significant $\text{NO}_3\text{-N}$ at harvest. It is possible for high levels still to occur at greater depths (say 1-2m) and this should be surveyed. At this time, there is no evidence that the alleged "growing on" of 1998 or the low pol occurrences in all years are due to excessive nitrogen fertiliser use and/or subsoil nitrate accumulation.

It was earlier noted (3.2.1.4) that nil or low stalk elongation rates in autumn-winter 1998 were recorded in conjunction with sucrose enrichment for the four dry-down trials of Muchow et al across a low-high range of nitrogen conditions.

Further the review of sucrose accumulation (Appendix II) leads us to question whether high nitrogen supply at this time does any more than maintain higher cane hydration, and hence pol dilution. It would be of more concern if nitrogen deficiency in autumn-winter reduced photosynthesis rate and hence sucrose enrichment. We therefore adhere to our conclusion in the Preliminary Report (3.1.1, p.10; 3.1.2.6, pp.13-15; and 3.6.3, pp.34-35) that "provided there are no NO_3 bulges at depth, producers in the Ord are more likely to underfertilise than overfertilise with nitrogen."

At the same time it is emphasised that this view is dependent on there being photoperiod/low temperature control of stalk elongation and sucrose enrichment in Ord cane during autumn-winter. Crop monitoring to characterise seasonal sucrose accumulation patterns and to test this particular assumption is essential.

It is now feasible to use soil, plant and juice analyses to log the nitrogen status of cane crops and soils at all stages of growth and post-harvest. Conservative use of these tools by farmers is both a cost effective guide to optimum economic use of nitrogen fertiliser, and a safeguard against the environmental consequences of excessive use. It is recommended that farmers and their advisers use these tools.

3.3.2.3 Silica

We have sought to understand the high fibre content of Ord cane deliveries, and needed to check whether this related to high silicate uptake from soil and its concentration in millable stalk.

R. Muchow arranged for ash and silicate analyses on nine stalk samples of cane from the Frank Wise Institute on 20 April 1999. The analyses were on biscuits ex Carver press.

Fibre levels averaged 12.4% cane, and the ash and silicate (SiO₂) contents in the dry fibre were 1.68 and 0.78% respectively. The last equates to 0.19% Si in stalk DM which is slightly higher than figures quoted by Berthelsen et al (1999) for the wet tropics. These results lead to two conclusions, viz.:

- high fibre in millable stalk is primarily organic compounds, and is not due to luxury silicate absorption;
- high ash levels in bagasse ex mill are probably due to soil contamination from mechanical harvesting.

3.3.2.4 Sulphur

Our attention was directed to this nutrient by the recent finding of Gardiner and Gardiner (1999) that for ten crops sampled in 1998 there was a significant correlation between extractable-S in 0-30cm soil and fibre % cane in clean stalks. The potential significance of this given the low pol:fibre ratios of Ord cane is obvious. We sought to support the Gardiner's enquiry by reviewing the sulphur status of Ord soils, irrigation water and crops, the sugar cane literature for effects of S deficiency on pol and fibre, and the forage literature for effects of S on soluble carbohydrates and fibre.

There was no correlation between extractable-S and pol ($r^2 = 0.0597$) and there were too few samples to remove effects of time of harvest. One has to face the possibility that the S-fibre relationship is a fortuitous outcome of a limited data set. Notwithstanding, the validity of the Gardiners' screening for possible leads is unquestioned and the credible possibility of widespread S-deficiency in Ord cane warranted serious evaluation.

In the soil surveys of the Ord Plain (Stewart 1967, 1970; Gunn 1969; Isbell et al 1986) and related soils of the Weaber and Keep Plains (Aldrick and Moody 1977; Aldrick et al 1990), there are no descriptions of gypsum occurrences in Cununurra clays. Isbell (personal communication) says that as a group they quite frequently have gypsum (a S source) at depth but he is not aware of such occurrences on the Ivanhoe Plain. The only profile data accessed was a type profile in Stace et al (1968) for which total S was low (0.01%) to a depth of 97cm.

Analyses of surface soil for "available" S - mostly using 0.01 - 0.05M calcium phosphate extraction - indicate sulphur status is low (less than 5ppm) (Chapman 1979, Isbell 1985). The extractant used by Agritech for the recent Gardiner

analyses was potassium chloride, and we do not know its correlation with plant response to S. Probert and Jones (1977) found that many soils have higher phosphate extractable S at depth and this needed to be accounted in separating S responsive from non-responsive soils. There have been several glasshouse studies that have given large S responses on surface soil of Cununurra clays (Chapman 1979, Russell and Chapman, 1988) but with the exception of an oft-cited response in dry land Phaseybean by Parbery (unpublished 1963), there is no recorded case of a sulphur response in an irrigated field crop. The reasons are believed to be that earlier fertilisers contained S and the irrigation water itself contains $\text{SO}_4\text{-S}$ at a sufficient level to meet crop requirements. The most recent water analysis accessed (SGS Australia Pty Ltd 23.11.98) was $2\text{mgL}^{-1}\text{S}$ as SO_4 , and there appears to have been little real change across the last thirty years. In 25 ML per hectare annual irrigation this would apply 50kgSha^{-1} . This is normally considered sufficient to meet crop S requirements but is probably at or below the annual S removal by cane which ranges from 0.3 - 0.5kg per tonne of cane harvested (Chapman, L.S. 1985).

Hence, there is a possibility that S supply to Ord cane could be marginal where high analysis fertilisers are used, and particularly during the wet season when irrigation inputs are low. It is also possible that waterlogging effects of 1996/97 summer had a S-deficiency component. There is only unpublished information to indicate that past S inputs have not accumulated in the 0-60cm soil depth and that accumulation at greater depths has been observed (see Chapman 1994).

Experience with sulphur deficiency in sugar cane is limited internationally. Sedl (1971) and Chapman, L.S. (1985) are important references to Queensland work, but for the one harvest that gave a significant yield increase from 33 harvests made in trials "there does not appear to be any relationship between CCS levels and sulphur treatment".

Gosnell and Long (1969) in Rhodesia reported a substantial yield response to S from 18.5 to 41.2 tons cane per acre associated with an increase in sucrose % cane from 11.4 to 13.8. Bonnet (1967) in Puerto Rico reported a very difficult experiment to interpret which seems to evidence an approximately 10% increase in sucrose % cane resulting from S treatment. We have not located more recent papers on the subject of S in cane. This limited evidence indicates that cane yield is more sensitive to S deficiency than sucrose %, i.e. maximum sucrose % was achieved at lower S application rates than was maximum yield.

The forage literature (Rendig, 1986) leads one to expect a general effect of S-deficiency towards lower reducing sugars and sucrose, and higher insoluble carbohydrates in grasses and legumes (e.g. Jones et al 1970); but there are examples to the contrary (e.g. Rees and Minson (1978) for pangola grass). We have encountered no publications reporting increases in fibre with S deficiency without a concomitant reduction in soluble carbohydrates. This tends to make us think that the S-fibre correlation of Gardiner and Gardiner is fortuitous.

At the same time the evidence is that Ord surface soils are naturally disposed to S deficiency, S inputs in irrigation water alone may be insufficient to meet cane

needs particularly during the peak growth summer rainfall period, and S deficiency would be expected to reduce yields substantially and pol/CCS to some extent with a matching increase in fibre content.

Our conclusion is that these possibilities are too important to reject on current knowledge. The most direct way to check the possibility is to measure response to applied S on Ord paddocks with no recent histories of fertiliser S inputs.

3.3.2.5 We are unable to make definite statements about mineral nutrition of Ord cane and effects on yield or Pol levels. It would be unusual if some crops were not affected in some way, but also unusual if there was a widespread, acute suboptimality of one or more elements. It is suggested that there be periodic response screening for zinc and sulphur deficiencies, and for all other essential elements combined. Further research on nitrogen should be deferred until the pattern of sucrose accumulation in Ord cane is clearly defined. Routine monitoring of soil and plant nitrogen and phosphorus levels should be commenced. Good records on fertiliser treatments should be maintained for all paddocks.

3.3.3 Irrigation and Drainage

3.3.3.1 There are many important practical aspects of this topic which are beyond useful observation by this study. Discussion is warranted on the question of whether TCH and Pol levels can be manipulated by irrigation and harvest dry-down practices, and whether variations between farmer's practices are a source of 1996-98 farm and paddock differences. The subject of waterlogging, surface drainage and management of the ground water has been associated with low yields of 1997 crops in 3.2.3.2/3 and deserves further attention.

3.3.3.2 The key issues relevant to manipulating pol levels with irrigation are whether water stress at any level increases $\cdot S/\cdot C$, and if it does, whether the quantum of the increases in S and S/C can be controlled by the duration of sustained stress (see Appendix II, p.4). Put more simply, it is the question of whether water stress increases sucrose % DM in cane, or increases % DM, or both.

Our difficulty is that the information required to resolve this question is not available. There seems to be virtually no data on the effects of water stress on sucrose dynamics during maturation to examine for differential effects on the normal $\cdot S/\cdot C$ of 0.5 - 0.6 for this phase. Experiments involving

preharvest dry down treatments have often imposed water stress during the autumn sucrose enrichment phase when stalk elongation is probably arrested by temperature drops anyway. It is not surprising that "of the 137 drying off regimes studied in the southern African trials, a total of 83 (61%) resulted in a statistically significant change in CCS, cane yield or sugar yield" (Robertson et al 1999). It is important to know how many of these 83 actually achieved increase in $\cdot S/\cdot C$ and S but that was not reported.

Robertson and Donaldson (1998) state that 19 of the 83 involved increases in S which averaged 8% relative to "well watered controls". The overall frequency of

S increase (within 137 regimes) is low and it is not clear whether the reference controls involved normal dry down for trafficability etc. or whether they were impractically wet for mechanical harvesting. The frequency of gaining an increase in sucrose % cane was three times that of gaining an increase in S. They provided no interpretations involving ·S/·C.

The dry-down experiments being conducted by R. Muchow in the Ord are continuing in 1999 and we have accessed only 1998 results. Those experiments will be interpreted and reported by Muchow et al in due course. We have been privileged to access the interim data and that has provided the only evidence at this stage that a sucrose enrichment phase occurs in the Ord in autumn-winter (see Appendix II, 6.3). A summary of other interpretations is:

- increasing dry-down duration did not increase Pol % cane, sucrose % DM, % DM or sucrose yield per hectare, at harvest;
- drying down during autumn enrichment reduced sucrose concentrations and increased impurity levels.

There is therefore good reason until further research indicates otherwise, to minimise dry-down periods - particularly April to June, and to withhold irrigation for the shortest period prior to harvest required to achieve trafficability and minimise soil contamination. The pilot farm advice was 2-3 weeks. There is also good reason to maintain optimum water relations throughout crop life to maximise TCH.

The priority for research is to resolve how water stress affects stalk DM %, sucrose concentration and yield during the separate stalk maturation, ripening and post-ripening phases. Such research should be deferred until there is sound documentation of these phases for Ord cane as recommended elsewhere.

3.3.3.3 The physiological effects of ripeners such as etephon and fusillade seem to be more analogous to those of water stress than of photoperiod/low temperature (Donaldson 1999). We have not reviewed the extensive ripening literature but suspect that it too has tended to confound the imposition of ripeners and the separate phases of sucrose accumulation.

Consequently, it is recommended that Ord research on ripeners also be deferred until the phases of sucrose dynamics are better documented for the Ord.

3.3.3.4 It is realised that these findings are contrary to conventional thinking, and that they imply that much effort to manipulate pol via dry-down, ripeners and nitrogen depletion has been misdirected. For this reason alone, it is important to evaluate our assertions thoroughly. If however, they are substantially correct there will be need to reconsider the cane analysis and sugar payment systems and the extent to which their non-differentiation of discounts for high water content (low % DM) in cane from discounts for low sucrose % DM create incorrect incentives for growers. For example, the present price schedule delivers a discount of 9.4% (\$143 per hectare) for a 140 TCH 15% Pol 30% DM crop if it changes from 32

to 28% DM without change in TPH. Discounts for water content should do no more than balance the water-increased yield against the reduced Pol/CCS i.e. payment per tonne of sucrose should be the same. Obviously this can't be done unless correct estimates of % DM for individual deliveries become a routine component of cane analyses.

3.3.3.5 Our interviews with growers were very superficial with regard to irrigation and fertiliser practices. Reference to our notes from farmer interviews and to farm productivity analyses supports the proposal that practices should aim at high growth rates and maximum TCH (without excess) and use minimum dry-down periods. There seems to be nothing contrary to this in the pilot phase results with irrigation and nitrogen fertiliser.

3.3.3.6 If it had been suspected earlier that surface drainage was an important variant in 1997 paddock yields, it would have been relevant to try to quantify this. For example, slopes, slope lengths, bed heights, bed maintenance and water table profiles could have been utilised in hydrological calculations to estimate "surface wetness duration". Also, farmers could have been asked to rate their paddocks for "relative wetness". Such information may have replaced the conjectural treatment of waterlogging/yield in 3.2.3.2/3 with something more diagnostically convincing. The farmer rating approach would be an economical way for the industry to evaluate our conclusions.

3.3.4 Harvesting

3.3.4.1 In 1.2 it was stated that priorities for action related to harvesting would be considered later. We have made no further analyses of cane and/or sucrose losses or of extraneous matter dilutions. Any change in priorities now relative to those of the Preliminary Report are due to our more complete understanding of Ord production.

3.3.4.2 Is the ash content of Ord bagasse abnormally high? The issue is raised because of a statement by R. Kirk that the capacity of the mill's ash pits needed to be three times that for (unstated) other mills. Silica and ash analyses on clean stalk from one 1999 crop (3.3.2.3) indicate that abnormally high ash in Ord bagasse is most likely due to soil contamination of cane. We previously estimated % soil in deliveries from mud solids % cane (P.R. 3.2.5.1) to range from 1.0 to 2.7% cane. These may be underestimated if there is abnormal soil retention in bagasse by the Ord mill. There is also reason to query whether fibre determinations may be underestimates because of variable loss of soil colloids in the analytical methods used.

It therefore seems important to have better information on levels of soil contamination and the between-paddock variability in same.

3.3.4.3 The discussion on crop homogeneity (3.3.1.3/6) stressed the importance of better descriptive data for crop structure throughout the harvest season, and earlier discussion (3.1.3.14) recommended stalk quality monitoring from February to November. The interaction of crop structure and stalk quality with mechanical

36.

harvesting to generate variable extraneous matter dilutions of sucrose and sucrose losses is obviously quantitatively important on the Ord. There seems little doubt that there is much higher fibre in cane deliveries than in millable stalk and this can result only from extraneous matter (including soil).

3.3.4.4 The most economical way to quantify this is via a systematic sampling program at the mill involving -

- (a) fractionation of samples from cane deliveries into sound billets, damaged billets, dead/diseased billets, trash, stools and disintegrator/press analyses of those fractions for brix, pol, fibre and drymatter content;
- (b) related sampling of shredded cane (prior to point of crush return) for disintegrator/press analyses plus silica (to measure soil contamination).

It is not recommended that Ord research concern itself with harvester losses in the field, or that measurements try to account for changes in yield and quality from standing crops to cane deliveries. The program of field stalk quality monitoring recommended elsewhere, should be sufficient if this mill sampling is matched with it. Yield matching requires very intensive and arduous physical effort.

3.4 Paddock Records and Mill Analyses

3.4.1 In spite of several problems that have been mentioned elsewhere and are not reiterated here, we are impressed by the potential value of Ord paddock records for the diagnosis and resolution of many problems past and future. It may be years before the Ord cane industry can obtain comprehensive R&D support, and that alone is reason to extract as much guidance as possible from paddock records. We are however of the opinion that good records will in fact give better insights on some issues than normal field plot research can.

It may be that the relatively uniform topography, soil and climatic conditions of Ord cane farms result in less variability than larger cane districts elsewhere. That would be another reason favouring deliberate use of paddock records. Other reasons are the relative simplicity of tracking paddock cane through the mill with the two-harvester operation, and the relatively few people involved.

3.4.2 There is no reason that mill analyses cannot be made specific for paddock deliveries and utilised for computations of yield and quality and ultimately for grower payments. Unless the mill can utilise first expressed juice and F+3/F+5 computations of pol-in-cane and brix-in-cane with precision, it should maintain a more intensive parallel system of disintegrator/press analyses until it can. If the analytical systems do not allow brix + fibre to provide good estimates of drymatter content, then % DM should be measured directly on the samples taken for fibre analyses. Concurrent measurement of silica on these samples should be assessed as a possible way of monitoring soil in cane deliveries and applying price discounts for extreme contamination.

3.4.3 The system of recording paddock identity and harvested area, identifying deliveries,

measuring delivery weights, recording quality data against deliveries, and computing paddock yields and cane quality should operate virtually error free, and create one electronically transferable spreadsheet/database annually for use by both mill and grower organisation.

3.4.4 Farmers should be asked to agree with the compilation of some "minimum paddock data set" and then be supervised by their organisation to provide such data. We suggest:

- date of planting
- date of application, fertiliser description, rate of application
- plant cane stand density (to be measured by professional adviser(s) for calculation of paddock mean and standard deviation at some time before canopy closure).

This data should be compiled and stored centrally also, along with any other paddock specific data that may be collected for all farms, or for representative farms e.g. stalk quality, delivery fractionation of extraneous matter.

3.4.5 Obviously, there should be intent to analyse these databases annually for some matters, and periodically for others. This report provides some examples, but the power of good data, routinely and fully compiled, will expose other valuable analyses.

38.

4. Conclusions and Recommendations

4.1 There are several features of 1996-1998 sugarcane production in the ORIA which warrant attention in terms of increasing productivity. Broadly stated they are:

- variability in cane yields (TCH) between years, paddocks and classes;
- variability in the quality of cane (pol, fibre and purity) delivered to the mill between years, paddocks, times of harvest and possibly varieties;
- generally high fibre levels in cane deliveries;
- probable errors in yield and quality data for individual paddocks due to recording and analytical systems;
- inadequate farm records of paddock histories and management treatments.

Data errors constitute an unknown proportion of the variability in TCH and cane quality since only extreme errors can be identified. Errors do not seem to preclude useful analyses of variability, but probably create apparent inconsistencies with interpretations. This, coupled with inadequate farm records, limits diagnostic focus and, more importantly, the identification of optimal practices.

4.2 Variability in Cane Yields

4.2.1 Yields of plant and ratoon cane were very depressed on some but not all paddocks in 1997. This is attributed to waterlogging, possibly interacting with induced nitrogen and sulphur deficiencies.

Waterlogging was severe on paddocks with shallow water tables, but may have occurred randomly over deep water tables where surface drainage was restricted. It may also have been prevented by some farmers through provision of draining slopes and by bedding-up to achieve stool elevation, including on some paddocks with very shallow water tables.

Plant cane yields in 1997 matched 1R yields in 1998 indicating that stand potential was set in the plant crop by waterlogging and/or by other husbandry variables such as establishment.

Ratoon cane yields in 1997 reflected prior stand potentials with waterlogging superimposed. Subsequent ratoons in 1998 achieved yields which were little affected by 1997 waterlogging, but continued to reflect stand potentials set in 1996 or earlier.

This indicates that stand potential is directly related to stool density, that stool density may decrease but not increase materially through consecutive ratoons, and that stool density of plant cane but not ratoon cane was reduced by 1997 waterlogging. The effect of stool density on cane yield through ratoon sequences has been quantified by Chapman and Wilson (1996) and the general effects of stool and stalk density and geometry on yield were reviewed by Leslie (1999a, b).

It is recommended that:

R1. The speculative proposals related to waterlogging be cross-examined and that Ord farmers be involved in their evaluation to the extent of rating paddocks for their relative wetness.

If the proposals are substantiated:

R2. Strategies for minimising waterlogging in future, be developed as adjuncts to the broader strategies being directed at managing water table levels and salinity in ORIA. Such strategies may involve the provision of effective surface drainage, and the formation and maintenance of appropriate bed contours.

4.2.2 Cane yields increase with age i.e. time from planting or ratooning to harvest. There has been little opportunity to manipulate harvest schedules, but early planting (April-May) followed by mid-season (August-September) harvest of plant cane captures the age benefit for plant cane. It also facilitates optimal establishment husbandry and provides a basis for ratoon harvesting sequences.

R3. Cane should be planted as per pilot farm recommendations i.e. April/May, and the objectives should be high, even stool densities and maximum early growth rates.

4.2.3 There is no commercial evidence so far that late ratooning (November) materially affects subsequent ratoon yields. This may not always be so, particularly if early, high rainfall wet seasons occur. That possibility does not constitute a reason for early termination of the harvest season, but it would be prudent to schedule ratoon classes intended for plough-out for late harvesting. No specific recommendation is made.

4.2.4 Yields appear to be holding or declining normally through successive ratoons, indicating that harvesting damage to stools is normal. This probably means that some instances of severe damage do occur. Obviously this should be avoided. No specific recommendations can be made.

4.2.5 The magnitude of yield variability once the preceding factors are accounted is inestimable. There are a few farms where poor performance relates probably to poor husbandry; but most farms are operating at a level where plant cane yields of 160+ TCH and 1R - 4R yields of 130+ TCH should be achievable. There does appear to be a real difference between paddocks and possibly farms amongst these better farms which is probably husbandry related but we have no evidence to identify cause and effect. We suspect that as in all farming systems it has to do with variability - some controllable, some not - in the extent to which several husbandry variables are optimised. In this regard one must include control of stool density and evenness, nutrition, crop water relations, weed control and the objectives of achieving maximum economic growth rates and avoidance of excess watering and fertilisation. There are differences between farmers' strategies that are held by them with conviction. We cannot comment in specific terms on such things as minimum vs conventional tillage, fertiliser types, rates and timing, watering schedules and frequencies. The evidence is that maximum TCH can be pursued without compromising quality.

40.

R4. That farmers manage crop husbandry to maximise crop growth rates throughout, and in particular to enter autumn with the maximum yield and crop homogeneity consistent with crop age.

R5. That crop management from autumn to harvest be directed at securing maximum sucrose enrichment and sucrose % DM at the scheduled harvest time.

4.2.6 There is no evidence for widespread nutrient deficiencies or excesses in Ord cane but the possibility always exists that they can occur unrecognised at low frequency. Queries exist concerning:

- Whether some prehistories and current N fertiliser use have created N excess situations. This can be checked with deep soil and plant analyses in conjunction with fertiliser use records;
- Whether some farmers are underfertilising with N and their crops are N deficient late in the wet season onwards. This can also be checked as above, and tested with N applications;
- Whether sulphur deficiency may occur - particularly during the wet season when irrigation is withheld. This is susceptible to soil and plant analysis, but the simplest approach would be to test for responses to applications of sulphate fertilisers e.g. gypsum at a rate of 100kg S per-hectare.

R6. That farmers practise a moderate level of soil and crop logging coupled with paddock records of operations, chemical applications and observations to facilitate future problem analysis.

R7. That soil analyses be undertaken by Agriculture WA to check the existence of NO₃ bulges in cane paddocks.

R8. That farmers undertake their own response experimentation with N and S fertilisation.

4.3 Variability in Cane Quality

4.3.1 The seasonal pattern of rise and fall in sugar concentrations with time of harvest from April to November which is exhibited by weekly mill averages is an aggregate of individual paddock deliveries. The pattern therefore combines a similar seasonal rise and fall which occurs in the millable stalk of each individual crop with the different patterns of individual crops and the sugar concentrations at which they are harvested.

4.3.2 The pattern also conceals a between-paddock variable effect of mechanical harvesting which combines cane and juice losses in the field, with diluent effects of soil and extraneous matter. These contaminating fractions have quite different sucrose, fibre, moisture and impurity properties from those of undamaged millable stalk.

4.3.3 The quality of individual deliveries involves errors of determination due to errors in pol

(and probably brix) measured from first-crush-juice, coupled with the application of a non-paddock specific fibre analysis and a formula for the calculation of pol and brix in cane which has not been evaluated for the Ord mill. These errors impose a variability that is a serious impediment to diagnosis of production problems.

R9. That the Ord mill modify its testing system so that the pol, brix and fibre analyses calculated for paddock deliveries correctly define the quality of those deliveries.

- 4.3.4 There is virtually no data on the levels of extraneous matter and soil in cane deliveries. Until there is, there can be no guided influence on cane harvesting, and no precise knowledge of the quality effects, or of the degree of overestimation of millable stalk yields. Recent comparisons (R. Muchow, unpublished data) of mechanically harvested yields with field sampled millable stalk yields indicate high levels of contamination and hence yield overestimation. For three harvested areas on each of four farms the range of overestimation was 8.4 - 25.2%, average 17.1%. Such contamination is more than that required to explain the high fibre characteristic of Ord cane. If this is truly representative, the yield performance of Ord farms requires reconsideration.

It is circumstantially the major cause of failure to achieve the cane quality objective of 13.5 CCS which was based on millable stalk analyses from the pilot phase.

There is also no basis for differentiating the extraneous matter (tops, trash, dead and diseased stalks, suckers) and soil contributions. Anecdotal evidence for high ash levels in bagasse remains unconfirmed by us, but they are unlikely to be due to abnormally high plant uptake of silica, and are most likely due to soil contamination.

We do not want to guess at the levels of extraneous matter and soil contamination but obviously the Ord industry has to know what it is dealing with.

R10. That a rigorously designed program be instituted at the Ord mill to sample selected deliveries for a full season in a representative way, to fractionate those samples into components for weighing and full quality analyses (pol, brix, fibre and water) and to compute the level and quality impact for comparison with parallel analyses of shredded cane (prior to crush return) from the same deliveries. Shredded cane should also be analysed for silica content to estimate soil contamination.

R11. That no assertions or inferences relating to extraneous matter and soil contamination be made until this data is available and interpreted.

R12. That no attempt be made in the Ord to measure field losses of cane and juice due to mechanical harvesting, but the Ord industry should maintain close contact with Queensland based R&D in this area.

- 4.3.5 The seasonal pattern of quality changes in the millable stalk of a crop is the cumulative result of three consecutive phases each of which has its own unique physiology.

Phase 1 From stalk initiation through to the beginning of autumn (1 April), stalk

elongation and biomass growth respond primarily to solar radiation in the Ord (assuming water and nutrients are non-limiting). Temperatures probably do not restrict growth, but high maximum daily temperatures (>40°C) in October-December period particularly may cause some increase in the proportion of biomass increments deposited as fibre. If so, this is probably not reversible, and could be a cause of high fibre persisting in Ord cane two to eight months later at harvest.

It is not proven that this high temperature phenomenon occurs in Ord cane nor is there Ord data which allows computation of stalk sucrose:stalk biomass partitioning coefficients for this phase. For other cane areas they lie in the range of 0.5-0.6.

Phase 2 In this phase, stalk elongation slows and virtually ceases, but stalk biomass continues to accrue at a substantial rate. It appears that Phase 2 is triggered by an autumn temperature drop, possibly coupled with shortening day length. The accruing biomass is initially all sucrose storage i.e. the partitioning coefficient approximates 1.0. This continues until the cellular structure of the stalk is saturated with sucrose at a ceiling concentration (whole stalk) of 48-52% DM i.e. the cane is "ripe". The ripe level may be slightly lower for Ord cane because of irreversibly high fibre in cellular structures of the stalk laid down in Phase 1. Sucrose storage in this phase appears to be reduced by water stress from drying-down for harvest.

The seasonal patterns of Pol % DM for Ord cane April-July, 1996-1998 were empirically related to the cumulative deficit degrees below 29°C mean day temperature, after 1 April. Similar empiricisms accounted for the differences between Ord and Pioneer (Burdekin) Pol % cane. It is inappropriate to use such relationships to predict and analyse Ord patterns from long term weather data, because they do not constitute models of the processes controlling Pol % cane. At the same time there is reason to propose that Pol % cane in the Ord will vary from hot to cold years - possibly over a range from 13-15%, and that 1998 was a low Pol year because temperatures were well above average in autumn-winter.

No hypothesis is advanced for control of stalk growth and sucrose storage from July onwards. At some time after mid-winter stalks either resume elongation growth, flower or die. Either way sucrose % DM starts to fall and stalk enters Phase 3.

Phase 3 Knowledge of this phase is everywhere limited. Cane in this phase is a heterogeneous mixture of mature stalks flowering or resuming elongation growth; dead, diseased and rotting stalks, and immature suckers entering the harvest for the first time. It is not known how lodging and its different forms quantitatively influences sucrose concentrations. Pol % of NCO 310 appears to fall faster in this phase than that of Q96 with Q99 intermediate.

4.3.6 Across all these phases there is a seasonal pattern of declining moisture content in Ord cane about which virtually nothing is known. It may relate to stalk age or weight but is

also influenced by crop water relations, and by the moisture content of extraneous matter. Moisture content interacts with sucrose % DM to determine sucrose or Pol % cane. Approximately half of the overall change in Pol % cane from May to September 1998 was due to increase in sucrose as a proportion of biomass i.e. an increase in per hectare sucrose yield, and half was due to decrease in water content, i.e. increased concentration of sucrose in cane without change in sucrose yield. The estimates of moisture content from mill analyses display important differences in the seasonal patterns and levels for the three years and no explanation can be offered for those differences.

- 4.3.7 The uniquely low pol/high fibre feature of Ord cane cannot be addressed rationally until there is documentation of the full seasonal pattern of stalk growth and stalk quality. The assertions of 4.3.5/6 should be regarded as interim hypotheses only.

R13. That research be initiated to sample sound stalks from say 20 ratoon crops representing the full range of times of ratooning, at not more than monthly intervals from initiation to late November the following year. Data recorded should be stalk weight, length and node number, monthly stalk elongation rates and a full range of rigorously determined quality data including pol, sucrose, reducing sugars, brix, fibre, moisture content and juice ash. Interpretations should seek to characterise and explain the patterns of quality change, and to identify options for increased profitability for the growers and the mill.

R14. Further efforts should be made to locate pilot farm data from serial stalk sampling and analyses undertaken monthly from March-September on Commercial Variety Trial CVT1, Block 63, Bay 2, 1982 and 1983; and to interpret that data for evidence of autumn sucrose enrichment as an Ord phenomenon.

- 4.3.8 Since interpretations resulting from R13 will not accrue until at least 2001, the interim hypotheses have been considered for earlier action strategies. The most important, and probably contentious, relate to management of nitrogen and water to promote high growth rates.

R15. That fertiliser and irrigation be managed throughout crop growth to avoid plant nutrient and water stresses or excesses, and to maximise crop growth rates; with dry-down for harvesting prior to the end of July being limited to the shortest period necessary to provide trafficability and minimise soil contamination.

R16. That further research on dry-down and ripeners be deferred until R13 documentation provides justification for such research. (Continuation of dry-down research in 1999 led by R. Muchow may influence this recommendation.)

R17. That for the remainder of its use as an Ord variety, NCO 310 be harvested by the end of September.

- 4.3.9 There are no manipulable class differences in cane quality. Hence the scheduling of harvesting for plant and ratoon classes for each farm should seek to optimise the sugar

44.

yield of the plant crop by September harvest and to harvest the lowest yield potential ratoons earliest, and the next lowest latest in the harvest schedule. This is not explicitly recommended because the proposal has to be linked with the harvest round sequence and replanting strategies.

R18. That Ord negotiations for Year 2000 allocations of blocks into harvest round sequences consider class scheduling in relation to the sugar yield potential of plant and ratoon crops.

4.3.10 There may be important benefits from crop homogeneity. Heavy, even crops although lodged may minimise the occurrence of high temperature microclimates conducive to high fibre deposition if that is an Ord phenomenon.

Characterisation of crop structure is qualitatively simple but quantitatively very difficult - arduous and time consuming - particularly late in the harvest season when the issue is most relevant.

To some extent R10 if properly executed will provide a quantitative characterisation. No recommendations are made on this. R10 will encounter difficulties in discriminating some fractions and there needs to be a linkage to the field such that one can relate crop structure to the composition of deliveries. This is essential to a causative understanding of the extraneous matter problem. The most economical way to achieve this linkage would be to utilise the visual appraisal techniques used by pasture scientists.

R10 (extensions): The selection of deliveries should be unknown to farmers and harvesting contractors prior to delivery. Immediately after delivery there should be a visual appraisal of the structure of the source crop in the field.

4.3.11 The possible significance of the extent and cellular nature of fibre deposited in cane stalks under the influence of high temperatures during summer to the quality of cane at harvest, deserves wider consideration.

It may be a phenomenon susceptible to a degree of genetic control. It is unlikely to have been considered by sugar cane breeders in their search for useful parental germplasm for tropical environments generally.

R19 That if documentation of Ord cane identifies increases in fibre deposition due to extremely high temperatures, further physiological and genetic research be sponsored to confirm and explore the phenomenon.

4.4 Paddock Records

The fragmentary nature of paddock records, the lack of a central database and data errors have combined to make this task more difficult than it should have been. On the other hand, the diagnostic and interpretative value of these limited records indicates that more comprehensive and accurate records in a central database routinely interpreted could replace the need for much applied research to the benefit of all sectors of the industry.

R20. That the Ord industry design a single paddock record system, that it negotiate

with all stakeholders to secure complete entry of correct data and that it make budgetary provision for its periodic analysis and interpretation.

4.5 Agencies for Research and Advice

4.5.1 It is now appropriate to consider our fourth Term of Reference i.e. "to recommend agencies or sources of advice".

4.5.2 This enquiry has, of necessity, ranged across many scientific disciplines and many levels of the basic research - applied research - technology development - practical management continuum. In our reductionist systems these levels and disciplines are compartmentalised and institutionalised. Our recommendations also involve wide disciplinary coverage and several levels of involvement. Hence the issues of cross-discipline/cross-institution collaboration and coordination and above all program leadership are fundamental. There is, regrettably, no single source known to us that could evaluate this report. Unquestionably there will be areas of specific disagreement with it - some valid, some invalid - which in turn will prove difficult to evaluate.

4.5.3 No single Australian R, D and E agency has the resources, capability and orientation to undertake the necessary investigations and guide implementation of changes on farm or at mill. SRDC has the competence, experience and financial leverage to broker the necessary collaborations and coordination. We favour the appointment of a residential agronomist at Kununurra to lead a program involving Agriculture WA, BSES, CSIRO Tropical Agriculture, CRC for Sustainable Sugar Production, Ord Canegrowers and CSR. Unless a suitable person exists and can be funded it would probably be best if SRDC retained overall coordinating responsibility and contracted more specific, well defined projects, each within the capacities of contracting institutions to lead and conduct.

R21. That SRDC work with relevant institutions to design an economically feasible total program and then to determine the most appropriate ways to structure it for execution.