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RATOONING AND RATOON MANAGEMENT IN OVERSEAS CANE-SUGAR INDUSTRIES

by

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SD03007

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SUMMARY

Travel was undertaken to Florida, Louisiana, Brazil and Argentina in March-April 1994 and to southern Africa in October 1994. I assessed the environments and management of production systems in relation to productivity and length of the crop cycle. This followed the perception that crop cycles in Australia were much shorter than in some foreign sugar industries.

Many of the areas visited have been growing cane for as long as, or longer than, some districts in the Australian industry. In most cases, cane was grown as a monoculture, where succession rather than rotation or fallow-planting systems were the norm. Large areas of the Brazilian industry in São Paulo state were an exception in that soybeans or other legumes were used in a rotation; a rotation with rice and vegetables was also applied to large sections of the industry in Florida. However, I gained the impression that the monoculture system was not seen as a major impediment (in 1994) to continued productivity and length of the crop cycle, particularly in Africa.

Longest ratoon cycles (> 12 years) were achieved in southern African production systems still employing manual harvest systems on clay to clay-loam textured soils and in some cases still relying heavily on the cultivar NCo376. Similarly, long crop cycles have also been achieved in Florida in the warmer areas of very high fertility soil close to Lake Okeechobee. This result has also been achieved with manual harvests.

In most industries, the crop cycle varies from 4 to 8 years, with increasing tendency to shorter cycles with increased mechanisation of harvest and increased weight of in-field transport vehicles that cause damage to stools and compact soil.

I conclude that the Australian industry has maximum exposure to the adverse effects of mechanised harvest (stool damage from the harvester) and damage to stool and soil from transport traffic. Our soils tend to be of lower clay content than most other sugar industries. This influences cation exchange capacity and, therefore, nutrient requirement. This factor also influences available water capacity of soils. Fertility and moisture characteristics combine to place greater pressure on farm managers for timeliness and effectiveness of operations. Our industry also has the greatest exposure to impact from yield-reducing soil-insect populations.

I recommend that the Australian sugar industry moves towards a harvest/transport system that minimises physical damage to the cane stool, while minimising soil compaction. These goals might be achieved by adopting a production system that keeps wheels in the centre of the interspace and as far as possible from the cane stool. Such a system would require expanding row spacing from about 1.5 m to at least 1.8 m in combination with a strategy to avoid the inevitable loss of cane yield that occurs if single rows of cane are wider than 1.65 m. The harvest strategy should also include optimisation of base-cutter height and speed for forward speed of the machine to minimise shattering and removal of stool.

Our production strategies should also continue to focus on improvements to weed control, removal of constraints from nutrition, water management, and pest and disease management.

1.0 BACKGROUND

Travel was undertaken to Florida, Louisiana, Brazil and Argentina in March-April 1994 and to southern Africa in October 1994. I assessed the environments and management of production systems in relation to productivity and length of the crop cycle. This followed the perception that crop cycles in Australia were much shorter than in some foreign sugar industries.

This study tour was planned to occur in March and April 1994 with travel to the Americas and then to southern Africa. However, with events surrounding the South African elections in early April 1994, travel advice from the Department of Foreign Affairs did not recommend travel to that country. Therefore, the itinerary was interrupted in the UK with a return to Australia. The South African component of the trip was undertaken in October 1994 with supplementary funding from BSES. The complete itinerary is given in Appendix 1.

2.0 OBJECTIVE

- Obtain an international perspective of the effects of varieties, pests and diseases, the production system and climate on ratoon performance, in order to assist definition of research, development and extension requirements for achieving longer ratoon cycles.

The tour was of considerable benefit in gaining a greater understanding of the subject. I suggest that the greatest gains in ratoon performance in Australia will be achieved by research and management that address the fertility and moisture status of canegrowing soils, and control of pests and diseases.

3.0 LENGTH OF RATOON CYCLE AND PRODUCTIVITY

3.1 Florida

The average length of the crop cycle in the Florida sugar industry is a plant crop and 2.5 ratoon crops. These industry statistics hide the considerable variation between and within the various sugar companies. Only a plant crop and one ratoon are produced by the Talisman Sugar Corporation, which suffers coldest winters due to the distance from Lake Okeechobee and where peat muck soils are now shallow and crops have been harvested by choppers for over 5 years. The Okelanta Sugar Corporation restricts production to a plant and two ratoon crops to guarantee cane supply for the milling operation, whereas the US Sugar Corporation has no prescribed cycle length. At US Sugar, where plant cane yields range between 115 and 150 t/ha, the decision to plough-out is made on a field by field basis and is initiated at 63 t/ha; this criterion usually results in 5-7 ratoons, but up to 20 ratoons have been grown on the deeper peat soils in the warmer conditions adjacent to Lake Okeechobee, where manual harvest has been practiced until this year (1994).

The Florida sugar industry recognised the impact of several factors on length and productivity of the ratoon cycle. In 1994, 90% of the crop was mechanically harvested, compared with the long-term 25%, mainly at Talisman. Mechanical harvesting was thought to have significant impact on ratoon performance through varietal suitability to mechanical harvest (interactions included brittleness and large gaps caused by removal of tipped stools and impact of in-field traffic on wet muck soils with low soil strength). The impact of cold winters and water-logged soils was also significant in some areas. Yield responses of 15-20% and prolonged cycle life of one to two ratoons are claimed from use of calcium silicate slag. Responses to calcium silicate are reported for muck and sandy soils; the latter soils do not respond to dolomite.

3.2 Louisiana

The Louisiana sugar industry, on average, produces a plant crop and two ratoons; progression to the third ratoon is dependent on control of Johnson and itch grass populations and mild winters. Adverse conditions for ratooning are imposed by very cold winters, during which fields have high watertables and may be waterlogged for several months. The *Louisiana bank* or mound planting system was developed to manage these conditions. Subsurface drainage has produced yield responses out to the third and fourth ratoons in experiments, but has not been adopted commercially, because of high cost and the large proportion of caneland subjected to annual lease agreements. Johnson and itch grass are major competitors with sugarcane, especially in fields where there are large gaps in cane caused by harvest damage in wet conditions. Wider adoption of herbicides for weed control during the fallow is assisting with control of these weeds. Long-term responses have been obtained from liming products, but lime is not used to ensure long-term soil fertility because of the above mentioned lease arrangements.

Of the Louisiana crop, 70% comes from two old varieties (CP65-356 at 30% and CP70-321 at 40%). New varieties are performing well in selection trials, but appear more susceptible to RSD; they do not do well on farms where RSD is a major problem. Long-hot-water-treatment (LHWT) is not subsidised by absentee landowners and only 50% of lessee canegrowers may heat treat some cane. Only 200 ha of LHWT cane is planted each year; the Kleen-Tek® system of producing tissue-cultured clean-seed supplies enough seed for 1,620 ha per year, most of which goes into secondary increase plots; the annual plant cane area is 40,500 ha!

The performance of ratoons in Louisiana was seen as a complex of varietal performance in relation to stresses from severe winters (including frozen soil to 10 cm depth), waterlogged soils, damage to soil and stool from wet harvest, competition from weeds and RSD.

3.3 Brazil

Comments about ratooning in Brazil are restricted to mills within the COPERSUCAR group; COPERSUCAR is supported by 40 mills in São Paulo state, which represent 30% of the production area in Brazil. COPERSUCAR mills average 85 tc/ha, compared with 75 tc/ha for São Paulo and 65-70 tc/ha for Brazil. The COPERSUCAR group produces a plant crop and four ratoons, on average; actual cycle length is dependent on field assessment in relation to production quotas for cane supply. In general, more fertile fields have longer crop cycles.

Currently, data from the Catanduva mill in western São Paulo indicate a decline in yield from 115 tc/ha in plant cane to 82 tc/ha by third ratoon, on the sandy loam soils. However, Catanduva agronomists attribute an increase in the crop cycle from 3.5 to 4.5 ratoons to decreasing row spacing from 1.4 to 1.1 m to maintain stalk populations (Figure 1) and attention to calcium nutrition. This company is now using economic analysis to trigger plough-out decisions and has a goal to move to seven or eight ratoons at an average of 85 tc/ha.

The São Luiz mill (Dedini group) has 20% of its 18,000-ha plantation on volcanic soil, 50% on sandy loam and 30% on intermediate soils. The volcanic soil produces a plant crop and seven ratoons for 110 tc/ha, while the sandy soil produces a plant and five ratoon crops for 80 tc/ha. The length of the cycle is determined by productivity; fields are re-planted when ratoon yield falls below 80 and 75 tc/ha, respectively, for volcanic and sandy soils.

Figure 1. Cane planted on 1.1-m row spacing on sandy soils at Catanduva, São Paulo, Brazil

Most cane in the COPERSUCAR group was still cut by hand; thus harvest damage was not raised as an issue. There was strong interest in mechanical harvesting, because of increasing difficulty in obtaining cutters. This move will create difficulties in developing systems for narrow rows or multiple-row harvesting and machine stability on the higher slopes. Concern was expressed at compaction and stool damage from use of road transport trucks carrying 20-22 t loads in the field.

Yellow leaf disease was observed in many fields of the variety SP71-6163 with yield reductions of 15-20%; more pronounced symptoms were reported when cane was water stressed. RSD was not recognised as a major impediment to ratooning in the COPERSUCAR group where LHWT was not routine. RSD levels were monitored by a serological test and LHWT recommended if RSD infection was above a threshold (value unknown). Common rust also was recognised as a serious problem, as formerly resistant varieties were now taking increased levels of infection.

3.4 Argentina (San Miguel de Tucuman)

The Argentine sugar industry comprises 21 mills, six of which are located in Tucuman province and account for 70% of national production; the latter mills were reported to be in poor physical and financial condition. There are some 13,200 canegrowers in Tucuman; 75% of producers cultivate less than 5 ha and represent only 20% of the production area, while 41% of the production area is controlled by 1% of growers. Large growers manage their own holdings and lease aggregated parcels of land. These producers employ mechanised and contemporary production techniques, whereas small owner operators use primitive technology and have low yields.

A plant crop plus five or six ratoon crops is the average for the rainfed zone, but one more ratoon is grown with irrigation. A grower who manages 800 ha of irrigated cane achieves plant cane yields of 90 t/ha with first- and second-ratoon yields of 110 tc/ha. As only 20% of the Tucuman industry has access to irrigation water, average yields are lower than the latter data. Average production data for two Tucuman mills in 1991 are shown in Table 1. These data are similar to those supplied for 1991 for a 10,000 ha plantation to seventh ratoon; from 7th to 16th ratoon yields varied between 40 and 50 tc/ha. The large irrigated grower and Conception mill agronomists mentioned 45 and 50 tc/ha, respectively, as the economic threshold for re-planting.

Table 1. Average cane yield of different crop classes across two sugar mills in Tucuman in 1991

Crop class	Tonnes cane /ha
Plant	68.4
1R	78.4
2R	63.9
3R	64.4
4R	71.0
5R	63.1
6R	54.9
7R	49.3

Ratoon yield decline and need to replant are associated with severe water stress in spring, gaps from harvest damage, competition from Johnson and couch grasses, and severe frosts in 60% of winters. There is no coordinated approach to RSD management, or even recognition of its significance. Marked symptoms of pink blushes of nodal vascular bundles were observed in CP65-357. Leaf scald was reported to be increasing and I saw heavy infestation in one of the major variety selection stations. Competition from the above weeds and water stress were the major productivity limiting factors recognised by the growers. This influences their ability to make best use of the 5.5-month growing season in Tucuman.

3.5 South Africa

3.5.1 Eastern Transvaal

The Eastern Transvaal industry has two sugar mills supplied from milling-company plantations and private farms with cane and other enterprises such as citrus, lychee, mango or banana. This area of the low veldt is reliant on irrigation for survival; severe water stress was observed in October 1994 because water storages were not replenished in 1993-94. Average yield by crop class is shown for a 7-year period in Table 2; yields show a step reduction beyond sixth ratoon when tonnes sucrose/ha/year is used as the index. Reduction in the proportions of ratoons older than 5-6R shows that growers recognise this as an economic threshold; older ratoons are confined to more fertile and better-managed fields.

Table 2. Average yield by crop class from 1986 to 1993 for 39 Eastern Transvaal participants in the Field Record system of the South African Sugar Association

Crop class	% of fields	Cane yield (t/ha)		Sucrose yield		Age (months)
		Range	Mean	t/ha	t/ha/year	
Plant	13.8	27-184	110.1	14.17	13.3	12.8
1R	14.9	15-187	109.4	14.62	14.9	11.8
2R	14.3	10-188	107.7	14.49	14.6	11.9
3R	13.5	36-187	105.3	14.24	14.3	11.9
4R	12.8	26-184	103.2	14.12	14.0	12.1
5R	10.4	30-172	99.0	13.50	13.6	11.9
6R	8.9	23-154	96.6	13.22	13.1	12.1
7R	5.8	21-152	88.1	11.87	11.9	12.0
8R	3.2	15-140	87.0	12.00	11.9	12.1
9R	1.2	18-131	85.3	11.79	11.9	11.9
10R	0.6	55-125	90.2	12.26	11.9	12.4
11R	0.2	55-122	83.0	11.54	11.2	12.4

I visited two private growers in the Malelane area of the Eastern Transvaal. Grower A has farm average production of 120 tc/ha and yield of 5th to 10th ratoon ranges between 105 and 120 tc/ha. This grower questions the need for a percentage of ploughout; if yields are in the 100 to 105 tc/ha range and can be explained in terms of management shortfall, then the field is given a second chance. Grower B produces just above district average and has some ploughout each year when productivity falls below 90 tc/ha. On this farm, stony and gravely fields may be taken out of production in dry years.

On the plantations of Transvaal Suiker Berperk (TSB) the crop cycle is limited to a plant crop with five ratoons to guarantee yield and cane supply to the factories and to fit in with contracts to grow beans.

Major issues affecting productivity in the Eastern Transvaal are availability and management of water for irrigation and in-field compaction from cane transports; compaction is seen as a problem only in dry years.

3.5.2 Natal - North Coast

Cane is grown in the North Coast region of Natal largely under rainfed conditions, but with some supplementary irrigation, on sugar-mill plantations and family and company owned farms. Programs are in place to raise productivity on smaller farms run by the Zulu people within this area.

Yields and ploughout policy depends strongly on seasonal conditions, but the better family farms achieve 9-17 ratoons, while the Tongaat Mill plantation operates on 7-8 ratoons. Varieties and interactions with effects of the *Eldana* (stemborer) management program emerged as significant issues in length of the ratoon cycle. NCo310 was capable of producing 15-16 ratoons under supplementary irrigation in the Nkwalini Valley in a 2-year production system and NCo376 gave at least 10 ratoons on the better soils at 90-100 t/ha cane yields. The newer variety N12 averages 6-7 ratoons and up to 10 ratoons on better soils. The *Eldana* management program resulted in N12 replacing NCo376 and harvest of younger cane. The latter variety was also smut susceptible. SASEX variety testing suggests that ratoon performance of N12 should be similar to or better than NCo376.

3.6 Swaziland

The three sugar mills in Swaziland produce approximately 494,800 tonnes of sugar per year from cane supplied largely from mill plantations, a few non-miller plantations, and some smaller private farms of 60-120 ha. All cane is grown under irrigation in a high-radiation environment (Fig. 2).

Figure 2. Wide stools in older ratoons of NCo376 in Swaziland

The Mhlume mill plantations, in the north, have large areas of duplex and sodic soils that produce 4-5 ratoon crops; up to 20 ratoons are grown on smaller areas of better soil. The economic threshold for ploughout is 80-85 tc/ha. This usually means about 10% of the area is replanted annually, but better management of salinity and sodicity in the last 5 years has resulted in a smaller ploughout.

Tambankulu is a 3,000 ha estate adjoining the Mhlume plantations and averages 120 t/ha from an average cycle length of 14 ratoons. Longest ratoon cycles are achieved on the deep Hutton (R-set) soils, while shallow soils produce acceptable yield to 10th ratoon. A reasonably fixed ploughout level of 5% allows sugar and bean production quotas to be met.

The Simunye mill estates have around 25% of the area with crops older than tenth ratoon. Cane yields of 137 t/ha/year can be achieved on to 13th ratoon on deep soils, while only 3-5 ratoons are economic on the duplex soils. The ploughout is triggered when a yield threshold is not exceeded for 2 consecutive years and generally results in 7-10% ploughout.

Ubombo Ranches in the Big Bend area of southern Swaziland produces an estate average cane yield of 105 t/ha/yr from a plant and four ratoons on the vertic soils (cracking clays) and up to 25 ratoons on the deeper Hutton soils.

Distribution of ratoon stages by proportion of the cropping area for the three mills in Swaziland in 1992 (Table 3) shows a general decline in the areas of individual ratoons older than 3-6th, but ratoons older than 6th represent 27, 50 and 31% of the crop area for Mhlume, Simunye and Big Bend, respectively. As mentioned previously these crops are grown on the better soils.

Table 3. Distribution of ratoon crops (% area) in Swaziland sugar mill districts. (Source - Swaziland Sugar Association Extension Services Report May 1991 to April 1993)

Ratoon	Mhlume	Simunye	Big Bend	Industry
Plant	10.5	5.0	9.7	8.8
1R	10.8	5.1	10.2	9.1
2R	11.6	11.4	11.2	11.4
3R	11.4	12.3	7.0	10.0
4R	9.8	7.7	8.7	8.9
5R	9.6	4.2	8.7	7.9
6R	7.3	4.1	8.7	7.0
7R	6.0	7.6	4.1	5.7
8R	4.2	10.3	5.6	6.3
9R	3.3	4.2	5.2	4.2
10R	1.8	4.5	3.7	3.2
11R	1.9	3.6	2.8	2.7
12R	1.5	12.4	2.1	4.6
13R	0.9	7.3	1.1	2.6
14R	1.6	-	1.9	1.3
15R	0.4	-	0.8	0.4
>15R	6.1	-	4.0	3.7
Mixed	1.2	0.2	4.5	2.2

The major productivity issues in Swaziland were related to water management; avoiding over irrigation of the vertisols and getting adequate water into the duplex soils. Smut is still a significant issue, but the industry has committed to maintaining around 80% of the smut susceptible, but highly productive and ripener responsive, variety NCo376 by an intensive roguing campaign.

4.0 FACTORS AFFECTING YIELD AND LONGEVITY OF RATOON CANE

Due to the diversity of environments and management systems in the study areas, performance of ratoon cane will be discussed in relation to the generic issues of climatic stress, water management, soil management, crop management, and incidence of pests and diseases.

4.1 Climate

Cold winters, frost and a short growing season were significant in lower yield and short crop cycles in Florida, Louisiana and at Tucuman. The Talisman area in Florida is further from the warming influence of Lake Okeechobee than other cane areas in Florida, and suffers most from colder winters. This area also has the shallowest muck soils and was the first to introduce completely mechanised harvest. These stresses combine to restrict the crop cycle to a plant and one ratoon crop.

Frosting effects are so severe in Louisiana that wet soil in winter can freeze to a depth of 10 cm; in such situations the stool is usually lost. In most winters, plant cane and ratoon shoots are killed 3-4 times by frost. Even though two ratoon crops may be harvested, the buds producing the last crop may be equivalent to those of 6th or 7th ratoon! Third ratoons are produced only after mild winters. Wet harvest conditions, followed by winter freeze, is the worst combination of conditions for ratoon failure. Stubble shaving is practised widely, though not universally, in Louisiana to promote ratooning from deeper buds because of the perception that shoots of older ratoons from shallow buds are more susceptible to frost injury. Experimental data on this effect were compromised by heavy RSD infection; it is possible that stubble shaving provides a large secondary benefit of a good clean surface (Figure 3) for activity of pre-emergent herbicides.

Figure 3. Stubble shaved area (right) provides a clean surface for application of pre-emergent herbicides in Louisiana

Severe frosts occur 3 years in 5 in the Tucuman area, and affects cane quality more than ratooning.

Rainfall deficits and water stress were significant modifiers of ratoon yield and length of the crop cycle in Tucuman, and South Africa, where only supplementary irrigation supplies were available. Rainfall in São Paulo state was generally reliable and water stress was not considered a major variable. The role of water management in ratoon management will be discussed in section 4.2.

Managers in Swaziland emphasised the assessment of ratoon performance in relation to seasonal and known management inputs. Poor yield in one year due to lack of physical inputs or seasonal water shortage would not trigger ploughout, unless shoot populations were dramatically affected by the stress.

4.2 Water management

Effects of waterlogged soil and water stress on ratooning were significant in several of the study areas.

4.2.1 Water logging

Cane fields in Louisiana are saturated for most of the winter months, because of the passage of rain bearing fronts on a 5-6 day cycle. The Louisiana bank cultural system (Figure 4) was developed because cold and wet fields had an adverse effect on ratooning. Cade Carter has demonstrated economic benefits of subsurface drainage over two decades, but systems are not installed for reasons outlined in section 3.2; thus wet fields are significant for ratooning from both direct waterlogging impact on ratooning and the additional damage caused to stools during mechanical harvest in wet conditions.

Figure 4. Louisiana bank system, with banks or mounded rows on 1.8-m centres

A consistent picture of over irrigation emerged in Swaziland, particularly for the vertisol K-set soils. All estates reported improved yield and ratooning on these soils during recent droughts when there was insufficient water to meet projected duties. At Mhlume consideration was being given to moving the irrigation criterion from 50% use of total available moisture (TAM) to 75% of TAM on duplex, vertic and deeper rooting soils to decrease effects of waterlogging. Similarly, in the Eastern Transvaal and Swaziland it is likely that crop water use for irrigation scheduling will be estimated from a pan factor of 0.8 to 0.85 rather than 1.0, which has been the criterion for around 20 years. I was surprised at use of the latter criterion, as the literature back to the 1960s indicates that 0.85 was the most economic pan factor for irrigation scheduling to full canopied cane. It would appear that the factor of 1.0 may have been used to allow for inefficiencies in water application, but became excessive when allowance was made in pump duties for such losses.

The Florida industry currently manages watertables below the muck soils to provide subirrigation and minimise oxidation of the peat. Future environmental guidelines may require higher watertables to reduce peat oxidation and nutrient release to the Everglade Environmental Area. The USDA program at Canal Point will be looking for G by E interactions within the variety program to determine whether this move will affect productivity on muck soils and whether there is potential for clones better adapted to shallow watertables.

4.2.2 Water stress

Water stress was a significant factor for yield and length of the crop cycle in Tucuman, where around five irrigations were required annually, but low efficiency furrow irrigation systems could apply on average 1.6 irrigations, and in the Natal North Coast and Eastern Transvaal where drought and limited water storage can result in crop failure and ploughout. Even though water is in short supply in the latter area, it was claimed that a move from hand-moved dragline to centre-pivot irrigation systems resulted in more efficient use of water and better ratooning because of more even application of water.

Considerable attention is paid to water management of sugar cane during the maturation process in southern Africa. This is termed *dry-off management* and has the objectives of maintaining crop growth, optimising sucrose level at harvest, and avoiding long period of severe water stress that slow ratooning and reduce ratoon stalk populations. Full irrigation requirements are scheduled up to around 8 weeks before harvest or, more precisely, to the time in which average weather conditions would allow accumulation of a water deficit equal to twice TAM at harvest. Irrigation is reapplied after harvest. This technique is applied to some extent in the Burdekin area, where the crop is regarded as being fully irrigated. I believe that the Australian industry, particularly in supplementary irrigation areas such as Bundaberg and the Central district, needs to focus more on the benefits of such a policy to improve ratoon performance. Limited water supplies in these areas will constrain application of mature cane irrigation.

In Swaziland a TAM of 70 mm is recommended for planting of sugarcane and in South Africa soils with TAM of 50 mm are not regarded as irrigable with overhead irrigation because of the capital costs required to meet the irrigation schedule. Significant areas of sandy and strong duplex soils in the Australian industry fit into the latter category and are difficult to irrigate adequately because of limited capital investment and water supply. Thus, impact on yield and crop cycle length is anticipated.

4.3 Soil management

4.3.1 Soil type, CEC and clay

A consistent picture also emerged that productivity and length of ratoon cycle was linked to overall chemical and physical fertility of soils (see Soil compaction below).

COPERSUCAR have a comprehensive database of cultivar productivity (340,000 ha over 16 mill zones) in relation to climate regime and soil type and management. Results for four seasons 1988-89 to 1991-92 (Table 4) show a range of 26 t/ha across soil environments, but only 10 t/ha across cultivars. Situations where yield of cultivars exceeded expected performance were investigated and were found to be the result of management inputs, eg average yield of SP71-6163 in soil LVE-6 was 97 t/ha, but when vinasse and filter mud were used on this soil the yield increased to 116 t/ha (possibly due to improved supply of phosphorus on a high soil with high P-fixation potential). LR soils are red clay soils, LVE soils are dark red latosols, and LVA soils are sandy red yellow latosols.

Table 4. Average cane yield (t/ha) in four consecutive crops in relation to soil type and sugarcane variety in the 1988-89, 1989-90, 1990-91 and 1991-92 growing seasons (COPERSUCAR 1992/93 Annual Report).

Soil	Cultivar				
	SP71-6163	SP71-1406	SP70-1143	NA56-79	Mean
LR-1	108	104	95	93	100
LR-2	100	95	89	88	93
LR-2A	93	94	90	68	86
LR-3	91	97	91	86	91
LVE-1	98	100	90	100	97
LVE-2	98	96	91	83	92
LVE-3	95	85	100	78	90
LVE-5	107	94	88	82	93
LVE-6	97	94	87	86	91
LVE-9	-	87	80	83	83
LVA-6	95	84	87	78	86
LVA-9	93	92	88	83	89
TRE-1	109	101	88	97	99
PVA-25	97	92	88	96	93
PVA-27	89	86	83	82	85
PVA-28	77	74	62	82	74
AQ-3	-	84	72	74	77
Mean**	96	93	88	86	91

** Does not include LVE-9 and AQ-3 soil types.

Further analysis of the database that produced the Table 4 summary revealed a strong correlation between soil units classified under the COPERSUCAR classification system and productivity of the four cultivars. Highest productivity (tonnes cane/ha) was achieved on soils with fine texture and high base saturation, followed by soils with low base saturation and fine or medium texture.

Productivity data for fields by cultivar by crop class are analysed in relation to variable costs to produce and Annual Equivalent Value (AEV) term in US$/ha. Replanting decisions are made when the marginal return from a field is less than the AEV for its class. This system is superseding one based on productivity, ie ploughout when yield is <60t/ha. This analysis allows for longer ratoon cycles on more fertile soils, and for the converse on less fertile soils.

Data in Table 5 support discussion with Swazi agronomists, that, within the southern African system of manual harvest and mechanical loading, ratoons rarely progress beyond fourth ratoon on poor soils, while 6-8 ratoons are common place on the better soils.

Table 5. Generalised yield performance of sugarcane in relation to yield classification at Mhlume.

Soil category	Soil classification	Soil features	Yield loss in crop cycle
Poor soils	H set	Coarse sandy top soil, heavy texture subsoil, very poor drainage, high salinity and sodicity risk	38% over 5 years
Medium soils	K and T sets	Imperfect drainage, moderate to deep and medium-heavy texture, moderate structure	14% over 6 years
Good soils	R and S sets	(R) Deep, red, well structured medium-heavy	2% over 9 years

The more productive soils of Swaziland and the Eastern Transvaal region belong largely to the oxisol and vertosol soil orders with clay contents in the 40-60% range and cation-exchange capacity in the range 15-50 cmol(+)/kg. Soils in the Queensland sugar industry (Table 6) rate poorly in such a comparison, due largely to greater age and more severe weathering of soils. The Burdekin region compares most favourably, due to the illitic clay base of the alluvial soils in a lower rainfall environment. The illitic clays of the Central region also provide soils with good cation exchange capacity. Other regions of Queensland are dominated by kaolinitic clays of lower CEC.

Table 6. Cation-exchange capacity (cmol(+)/kg) for BSES soil-fertility monitoring sites

Parameter	Far north	Wet tropics	Herbert	Burdekin	Central	Bundaberg	South
Average CEC	3.34	2.67	4.65	12.28	7.32	7.21	8.39
Max CEC	8.68	5.57	6.92	19.36	17.64	37.89	16.86
Min CEC	1.53	0.78	1.92	2.80	1.17	0.23	1.08

The base saturated soils of Swaziland and the Eastern Transvaal do appear to have some productivity concerns when high levels of calcium and magnesium interfere with uptake of potassium. Poor productivity on otherwise highly fertile soils at Mhlume in the late 1980s to early 1990s was attributed to this effect. The ratio of (Ca + Mg)/K is now used by SASEX to improve potassium nutrition on base saturated soils in Swaziland and the Eastern Transvaal (Donaldson *et al.* 1990).

Similar productivity and crop cycle duration effects were also reported from Florida, where the high fertility muck soils (especially those close to Lake Okeechobee with a higher mineral content due to silt over-flow from the lake) support higher yields and longer crop cycles than do the sandy soils to the west of the Everglades Irrigation area.

Clay content and clay type (and soil depth) determine moisture-holding capacity and drainage characteristics and cation-exchange capacity, which in turn determines innate soil fertility and capacity to resist leaching of nutrients. The base-saturated high CEC soils are strongly buffered and generally are not affected by the consequences of soil acidity (low calcium and magnesium, high aluminium). These features combine to reduce the need for timely management intervention to prevent water and nutrient stress on cane. Productivity outcomes are, therefore, a reflection of the innate fertility of soil and/or success of management interventions to minimise the cumulative stresses on crop growth.

4.3.2 Soil acidity

Consequences of soil acidity emerged as a significant constraint to productivity in Brazil, but very successful management strategies are in place. The LVA (sandy red latosol) soils are particularly acidic, with potential for low calcium levels throughout the profile. Calcium and magnesium thresholds are very similar to those developed for Australian soils. However, the Brazilians also manage calcium deficiency in subsoil through application of gypsum. Subsoils are deficient in calcium if Ca < 0.6 cmol(+)/100 cm^3 (0.46 cmol(+)/kg for bulk density of 1.3 t/m^3). Up to 3 tonnes gypsum/ha is applied to third-ratoon crops on clay soils and 2 t/ha to second ratoons on sandy soils to manage subsoil calcium deficiency; lime is applied prior to planting. This strategy was developed after it was shown that the splitting of lime and gypsum applications increased yield of ratoon cane and gave longer crop cycles. High rates of gypsum are avoided because of potential for co-leaching of calcium and potassium.

Some 30% of soils outside the Burdekin region in Queensland have calcium deficient subsoils. This limitation could have significant implications for depth of root exploration, access to soil moisture and, therefore, crop water stress. This is another stress that could limit yield of ratoon cane and the length of the crop cycle (an R&D program in relation to management of subsoil acidity was established in Queensland in 1992).

Long-term responses to liming have been recorded in Louisiana, but tenant farmers apply little lime because short-term leases do not guarantee sufficient time for a return on the investment in lime (similar to the limitations to investment in improved drainage Section 2.2).

4.3.3 Nutrient management

Implications for ratoon yield of potassium management in base-saturated clays and calcium deficiency in acidic soils was discussed above. The only other significant nutritional issue to emerge was the use of silicon fertilisers in Florida. Calcium silicate slag (from elemental phosphorus manufacture in electric-arc furnaces) is applied at 4-6 t/ha to give cane yield responses in sugarcane of 15-20% on both muck and sandy soils. Initial responses in cane were noted after cane was replanted in rice fields to which calcium silicate had been applied prior to the rice crop. Response in rice seems to be related to lower incidence of fungal disease and greater resistance to lodging. The mechanism for cane yield response is not known, but is unlikely to be due to calcium because of the calcitic marl that underlies much of the Florida industry. While silicon has demonstrated capacity to increase yield of plant and ratoon cane, it is not directly implicated in increasing length of the crop cycle in Florida, because the short crop cycle was geared around cane/vegetable/rice rotations in 1994. If silicon can improve yield of ratoon cane in Australia, there is also a good prospect for a longer crop cycle (an R&D program with silicon was initiated in Australia with SRDC funding in 1999).

4.3.4 Soil compaction

An apparent plateau in sugar yield was evident for the Australian industry from about 1970 to the early 1990s, after which industry productivity increases were associated with expansion onto new lands. This situation led to the establishment of the Yield Decline Joint Venture (1994), which exposed a complex of soil health issues related to soil biology and poor physical conditions associated with the cane monoculture and the harvest/transport system. My study tour presented an opportunity to examine the impact of evolving harvest/transport systems on soil and crop response.

Harvest/transport in southern Africa is largely based on manual harvest and several systems of mechanical loading that results in defined transport lanes in fields. In 1994, both the Florida and Brazilian industries were in the early stages of a transition from manual harvest and mechanical loading to chopper harvesters and in-field transport. The sugar industry at Tucuman in Argentina was also evolving a new system; some 70% of cane was manually harvested but loaded mechanically, 10-15% of cane was processed by mechanised whole-stalk harvesters and loaders, and 15-20% was processed by chopper harvesters. The latter system was growing steadily, due to rising costs associated with other systems.

The mechanical loading systems in southern Africa vary from loading of 28-t road-transport trucks in the field (Figure 5), to the system at Simunye in Swaziland where J&L continuous loaders fill 11-t transporters, which in turn empty into 40-t road-train wagons on estate roadways. The Simunye system was introduced to minimise in-field compaction and there is very little tillage of inter-rows in ratoon crops. The heavy in-field transport in the Eastern Transvaal causes compaction in transport lanes and major damage to fields in wet years. Big Bend Plantation in Swaziland has winch loading of 2-3-t wagons (Figure 6), but each lane might be trafficked up to 10 times, resulting in severe compaction in wet periods. During very wet periods, Ubombo Ranches opt to have labour carry cane to the edge of fields for mechanical loading from headlands. However, ‘compaction response trials’ at TSB show that a response to relief of compaction by ratoon tillage is unlikely unless the annual sequence was wet followed by dry year. There was a clear distinction between effects on yield of compaction per se and of transport that damaged the stool.

Figure 5. Cameco loader and 28-t cane transporter

Figure 6. (Left) Winch-loaded trailers at Big Bend in Swaziland; (Right) Compaction of traffic lanes from winch trailers

Long-term experience in Swaziland has shown that the decline in ratoon yield is a strong function of the 'gappiness' of the stand. It is common practice to fill gaps in the stand up to fifth ratoon. Apart from transport damage on the loading lanes, there was no clear evidence of factors leading to the development of gaps in ratoons.

The harvest transport system in Florida was in its first full year of the chopper harvest system in 1994. The muck soils were not expected to present problems from compaction, but there were significant concerns about loss of stool and increased 'gappiness' after chopper harvest than with the manual-cut and continuous-loader system. Osceola Farms had instituted a policy of 'sub-soiling' with a coulter ripper to relieve post-harvest compaction (Figure 7).

Figure 7. (Left) Coulter ripper at Osceola Farms, Florida; (Right) After passage of coulter ripper where the leg penetrated to the full depth of the cane knife blade.

There was an enhanced state of awareness of the impact of compaction on soil properties within COPERSUCAR. Some 200 soil trenches had been opened since 1982 to observe root distributions in relation to bulk density of soil. This program established the concept of a critical bulk density for soil types (1.6, 1.4 and 1.3 t/m^3 for sand, clay loam and clay soils, respectively). This compares with a critical value of 1.8 t/m^3 developed by SASEX for the La Mercy site.

COPERSUCAR believes that compaction is one of the factors responsible for yield decreases in consecutive crops of sugarcane, and that increased use of mechanical chopper harvesters in the early 1990s has "contributed greatly to the increasing amount and extent of soil compaction". Effects were probably exacerbated by wet winters in the four harvest seasons between 1989-90 and 1992-93. Prior to the chopper-harvest system, whole-stalk cane was loaded into road-transport trucks with load capacities of 15-22 t. It is possibly this system and the use of large trucks as in-field distributors of planting material that led COPERSUCAR to the large investment in compaction research and advocacy of high-flotation/low-pressure tyres on transports for chopper-harvested cane.

COPERSUCAR plant breeders believe there are large differences between varieties in susceptibility to mechanical damage during harvest and transport operations, and that some varieties should not be harvested in wet weather.

While there are robust observations of the association between bulk density and root growth, results of compaction management trials have been variable in Brazil, as they were in southern Africa. Variability was associated with variation in conditions preceding and following the compaction event. Results in Table 7 demonstrate the dramatic effect of compaction on infiltration rate and, therefore, capacity of compacted soils to accept the limited rainfall in dry years; capacity to access moisture is also limited by the reduced exploration by roots of compacted soil. Field trials in 1992-93 that provided data in Table 7 also defined the shape of the compacted zone (Figure 8) and led to the conclusion that ratoon cultivation does not overcome effects of compaction, or improve yield if:

- there are areas with high infiltration in the ratoon cane row on flat terrain (eg the LVA soil in Table 7), or;
- if the alleviation of compaction in inter-rows is attempted with inadequate equipment, such as fertiliser rigs, or carried out under unsuitable moisture conditions.

Table 7. Effect of compaction and tillage on infiltration rate (mm/hr) for three Brazilian soils (source M. Santaella, COPERSUCAR)

Soil type	Infiltration rate (mm/h)		
	Cane row	Compacted inter-row	Cultivated inter-row
LR (clay)	80.5	3.2	40.7
LVE (clay loam)	80.5	3.5	155.6
LVA (sandy loam)	172.9	1.3	33.0

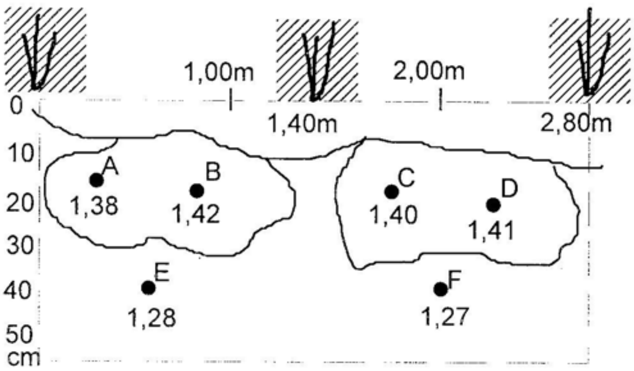

Figure 8. Bulk density and the compacted zone in ratoon cane in Brazil. Values at lettered points are bulk density (t/m^3) and shaded zones represent water infiltration areas. Source COPERSUCAR.

Gaps in ratoon crops (Figure 9) are recognised as a major issue for productivity and longevity of ratoons in Brazil. Development of gaps is associated with stool damage from cane-transport trucks, poor alignment of tillage equipment in dry conditions, and more recently from stool damage by cane harvesters.

Figure 9. Gaps in ratoons have a major effect on reducing cane yield

4.4 Crop management

4.4.1 Planting and ratooning systems

In Australia there has been a gradual move away from planting systems that include a fallow or legume rotation since the easing of regulation on percentage of assigned area that could be harvested each year (about 1970). This has led to wider adoption of the ploughout/replant system, which has been implicated by Yield Decline Joint Venture research as exacerbating the effects of long-term monoculture on declining productivity. What are other industries doing in relation to planting systems?

Almost 100% of caneland in Hawaii is managed in the succession or ploughout/replant planting system, where the gap between harvest and replanting can be a short as 7 days.

Approximately 80% of planting in Florida is succession planting. However, in the remaining area a vegetables/cane/rice/cane rotation is practiced. This sequence is designed more around managing the phosphorus content of land than for primary benefit to productivity of the cane system. High P rates are used on vegetables (includes sweet corn), the next cane cycle (plant + 2-3 ratoons) helps to lower soil P status, the flooded rice crop helps to manage weed and whitegrubs populations, and the final cane cycle further lowers P levels.

Over-winter and spring long fallow has been practiced in Louisiana. The fallow can be either a tilled and weedy fallow or a chemical fallow with Roundup. Persistence of stool material with the latter system is causing concern with carry over of RSD between crop cycles. There is, however, a trend to increased succession planting. Billet planting systems have not been adopted in Louisiana because cane is usually planted in August-September and billets do not contain enough buds to supply new shoots should there be an early frost or freeze. Use of overlapped whole stalks of cane allows the distal buds to provide the initial sprouts; leaf area of an autumn plant crop might be killed three to four times during the winter before a stable shoot population is established. Stubble shaving was a common practice in Louisiana, in the belief that the practice favoured development of deeper buds (provided additional soil was added to the mound after initial shoot emergence). Perceived benefits of stubble shaving cannot be substantiated by research in Louisiana, as in Australia. Now only some 50% of growers follow the practice in Louisiana, mainly to provide a clean soil surface for application of pre-emergent herbicides. Ironically, the success of the latter operation may have been the reason for perceived yield benefits.

Succession planting has been a long-term component of the production system within the South African sugar industry. Exceptions include parts of the TSB Estate in the Eastern Transvaal where commercial bean production is inserted as a rotation after 5th ratoon, and on smaller farms in the KwaZulu region, where intercropping or rotations have a significant economic role in production of food.

Similarly, succession planting has been the norm in the Swaziland industry, where fields scheduled for ploughout are harvested early in the season (May) and replanting takes place in late August or September. Significant effort is devoted to rejuvenation of the stool on some Swazi estates by pruning of lateral shoots on the stool, followed by addition of more soil to the stool ridge. Stool pruning appears to depress yield at the next harvest, but yield increases for subsequent harvests. Examples were presented of fields at 23rd ratoon where this system had been employed to manage ‘stool spread’. The practice of gap filling up to 5th ratoon is also instrumental in sustaining yield of ratoon cane in Swaziland.

An alternative planting system was being evaluated at the Mhlume Estate in northern Swaziland. Approximately 5% of the planting program had been converted to autumn planting after a summer green manure fallow. So far, this system has raised total yield of the field because of higher plant cane yield and by extra ratoon crop added to the cycle.

4.4.2 Varieties

A consistent message was portrayed from discussion in Florida, Louisiana, Brazil (COPERSUCAR) and South Africa that canes bred for the early sugar programs tended to have poorer ratooning characteristics than did later maturing cultivars. USDA geneticist Peter Tai noted that early sugar varieties in Florida tended to have lower fibre contents and were more susceptible to mechanical damage during harvest than were later maturing canes. The South Africans also commented that low-fibre high-sucrose canes ratooned less well than did higher fibre CP clones. There is, however, potential for an interaction between the early CCS ideotype and less favourable climatic conditions for ratooning early in the season in some localities, eg Louisiana and NSW.

Interactions between varieties and mechanical harvesting were emerging as significant issues in Florida in 1994, as there had been a switch from 25% mechanical harvest over the past 10 years to 90% chopper harvest in 1994. Poor root anchorage of stools in varieties adapted to muck soil was the identified problem. It was not clear if root size was a genetic issue or one of varietal adaptation to the high fertility and low-bulk-density soil. The stool area is subjected to post-harvest rolling to re-bed the stool and facilitate ratooning. Higher susceptibility of some clones to mechanical damage was also recognised in Brazil, where it is recommended that the more susceptible clones not be harvested mechanically during wet weather.

Two largely independent breeding programs operate in Florida. The UDSA program in Canal Point releases CP clones and the US Sugar Corporation program at Clewiston releases CL clones for company use only. The US Sugar program had a strong focus on early sugar for the muck soils, with no emphasis on ratooning, and may, therefore, require a change of focus if the above link to early sugar and ratooning under mechanical harvest is sustained. The CP program has focussed on crop cycle vigour since the 1960s.

Capacity of cultivars to produce high populations of thinner stalks as opposed to moderate populations of stalks with higher weight per stalk was also seen as an index of ‘better ratooning’ potential in Florida and Louisiana. This criterion will, however, tend to produce cane that is more susceptible to greater cane loss during mechanical harvest than the heavier stalk canes. There also appears to be a correlation between cold tolerance and ratooning ability (P. Tai). Accordingly an introgression program involving *Spontaneum, Miscanthus* and *Erianthus* has been operating since the early 1980s to increase tillering and ratooning capacity. However, no clones have so far progressed beyond stage 4 trials, due to low sugar levels.

The impact of variety on ratooning performance within the COPERSUCAR group of mills is determined from database records, rather than from experimental performance. Under this system, there is an emphasis on variety by soil type by environment for productivity and ratooning performance. Varieties such as SP71-6163 are recognised to have higher susceptibility to inadequate calcium and magnesium nutrition than most other clones, it also has a small root system. This compares with SP70-1143 that ratoons well across soil types and has a large root system and which is believed to assist with tolerance of several stresses (mechanical damage, water and nutrient stress). SP70-1284 is known to ratoon well only under good conditions. COPERSUCAR breeders noted that most varieties with 'lower capacity to ratoon' were selected on a high fertility breeding station, but the converse can also be demonstrated. The latter point suggests some genotype by environment interaction may be invoked for ratooning ability and that stresses early in the selection cycle may help in identifying clones with enhanced capacity to ratoon. South African breeders also commented on the G by E factor by noting capacity of POJ2878 to produce well in long ratooning cycles in Colombia, but the clone did not ratoon well in South Africa.

4.4.3 Harvest systems

A very clear, but qualitative, impression was developed of a strong link between the harvest/infield transport system and longevity of the ratoon cycle. Longest ratooning cycles in a high yielding environment were achieved in Swaziland, where the harvest was almost universally based on manual cutting of burnt cane in 1994 and where cane was either winched onto trailers (2-5 t), or windrowed cane was loaded by continuous loaders into 11-t high-flotation transporters or 28-30-t trucks. Concern was expressed about lower productivity from compacted transport rows.

The Tambankulu Estate in Swaziland instituted a program of chopper harvesting that lasted for approximately 5 years until there was a forced return to manual harvest after poor labour relations and political intervention. This estate reported an improvement in yield after the return to manual harvesting and several fields from this period were recently 'renewed' after the 18th-ratoon harvest.

The Tambankulu cane-transport system was based around 5-t infield transporters until the early 1990s, after which 20-t units were introduced to improve efficiency. However increased compaction in transport zone has resulted in planning to move to 10-t in-field units.

Growers and managers in the Eastern Transvaal also recognised the adverse effects of in-field transport on productivity and ratooning. This is particularly the case for fields harvested during wet weather, where both mechanical loaders and in-field transport trucks damage the stool.

Ray Ricaud has extensive experience with crop cycle research in Louisiana and considered the uprooting, splitting and 'rattling' of stools during mechanical harvest to be a more significant and adverse impact on ability to ratoon than stool rots that often occurred under the wet post-harvest conditions. Of course, physical damage to the stool may increase susceptibility to secondary rots.

There has been an earlier and more significant focus on the impact of compaction on productivity in the Brazilian R&D community, eg work at COPERSUCAR (section 4.3.4). At farm level, there was recognition of the impact of in-field loaders and transport on gaps in the stand and also the effects of compaction. However, in 1994 there was little evidence that in-field strategies were being developed to cope with consequences of increased compaction with the change to chopper harvesters. Row spacing varied from 1.1-1.5 m and was not suited to the track width of in-field machinery. There was clear evidence of traffic running on the stool. The only sign of forward thinking on this issue related to perception of need for harvesters with 2.2-m track-width to allow gathering of two rows of cane on 1.1-m centres in areas where the narrower row spacing was seen to be crucial for maintenance of productivity. COPERSUCAR were also promoting adoption of low-pressure Trelleborg tyres to minimise impact of in-field transport wagon trains on compaction. It would appear that the precursors are in place for Brazilian industry to experience some of the adverse effects of mechanised harvest that appear in Australia.

Growers in Argentina pointed to increased competition from weeds that establish in gaps in the stand that result from stool damage during mechanical harvest.

4.5 Pests and disease

Pests and diseases are relevant in this report because both can have an adverse effect on productivity and, therefore, the economic life of the cropping cycle.

4.5.1 Pests

Several species of canegrubs (whitegrubs) have an adverse effect on productivity and length of the crop cycle in most regions of Queensland; nematodes, wireworms and symphylans are also regarded as serious pests in some localities. None of the sugar industries visited in southern Africa or the Americas suffered to the same degree from soil-insect populations to the same degree as does the Australian industry. One species of whitegrub was present at yield-constraining levels in the Mhlume area in Swaziland and there are several species of whitegrubs in Brazil that can attack sugarcane, but are not regarded as serious pests. Whitegrubs can damage cane in Florida and populations are known to increase with the length of the crop cycle. Inter-crop cycle flooding of the muck soils to minimise peat oxidation and assist with weed control is also effective in reducing whitegrub populations. Close proximity to the Everglade wilderness results in high populations of herons, and it is common to see large flocks of these birds feeding on soil borne insects when there is major tillage of the soil.

Termites cause significant damage in a few localised areas of the São Paulo industry in Brazil.

Nematodes have caused significant damage on the sandy soils in coastal areas of the South African industry. However, the cost of nematode control and limited water-holding capacity has resulted in increasing areas of this soil type being converted to eucalypt plantations.

The eldana borer is a major pest of sugarcane in South Africa and has had an adverse impact on cane yield and sucrose content through effects of the physical damage and need to introduce annual harvests in more southern areas to minimise carryover of populations between years; cane is harvested at 12 rather than 16-18 months. *Diatraea* spp. borer is an important pest in Florida and Brazil, but control strategies appear largely effective.

4.5.2 Diseases

Ratoon stunting disease (RSD) is common to the Australian sugar industry and in all of industries visited. However, there was large variation in concepts of the significance of the disease and the adoption of strategies for its management.

In Florida, US Sugar was the only producer that has a regular policy of long-hot-water treatment (LHWT) of seed cane to reduce the incidence of RSD that was thought to be associated with loss of approximately 5% of yield beyond first ratoon, particularly on the sandier soils. US Sugar have adopted what they believe is a beneficial variation on the standard LHWT procedure by following the 2-h heat treatment with a 30-min cold soak in Tilt fungicide. This procedure halts the ‘cooking’ process and minimises thermal damage to buds, but the prophylactic effect of the fungicide is doubtful due to the large number of additional cut surfaces that are generated when cane is cut into billets in the furrow during manual planting; it may, however, have desired fungicidal benefits for LHWT of billet-length seed cane.

In Louisiana, RSD was recognised as a major problem. The inoculum had built up in the late 1980s with limited recognition of the significance of RSD, limited use of LHWT, and adoption of chemical fallows in which there was variable control of volunteer cane and persistence of solid stubble pieces. Two approaches to management are now in place. The Kleen-Tek company produces RSD-free plants by tissue culture for planting in secondary increase nurseries. This technology is favoured more by smaller growers. Kleen-Tek material is used to plant 1,620 ha of the 40,500 ha planted each year in Louisiana. Some of the larger growers have their own LHWT facilities. RSD is thought to have an additional impact on productivity in Louisiana, as RSD-infected cane shows less cold tolerance than does non-diseased cane. This effect may be similar to that seen in Australia where well-grown cane is less susceptible to damage from minor frosts. There is also the thought that stress effects are cumulative.

In Brazil, LHWT facilities are available at most estates, but LHWT is not a routine practice. Farms in the COPERSUCAR group rely on the COPERSUCAR serological test to identify RSD and only resort to LHWT when infection exceeds a certain threshold (value not recorded). The Brazilians are also developing tissue-culture technology to establish disease-free nursery areas of seed cane and for bulking up of new varieties.

In Argentina (Tucuman), application of LHWT to seedcane-increase schemes is not routine. Symptoms of RSD were seen in cane stalks of all (limited number) of field inspections at Tucuman. Large growers were more likely to have used LHWT than were the smaller growers.

In the Eastern Transvaal, the effects of RSD were thought to be seasonal in nature and to cause 10-15% more yield loss than did non-disease cane in drier years. RSD was quite widespread in the Mhlume mill zone in Swaziland, with 25% of survey samples returning a positive count.

Common rust was regarded as a serious disease in both Florida and Louisiana, where a yield loss of 10-20% was postulated. Breeders at COPERSUCAR were also concerned, as rust was apparently becoming more aggressive, as evidenced by varieties that originally had resistance ratings of 2-3 now supporting ratings of 6-7.

Leaf scald and mosaic were clearly widespread throughout commercial fields in the Tucuman region of Argentina. Leaf-scald infection was also quite high on one of the variety-selection substations.

Smut was present in most of the visited industries, but varietal selection programs have been in place for many years and seem to be producing the desired resistant varieties. However, the Swaziland industry places such a high value on NCo376 for its capacity to respond to chemical ripening that fields are rogued up to three time each year to remove smut whips and infected stools.

5.0 CONCLUSIONS

Many of the areas visited have been growing cane for as long as, or longer than, some districts in the Australian industry. In most cases, cane was grown as a monoculture, where succession rather than rotation or fallow-planting systems were the norm. Large areas of the Brazilian industry in São Paulo state were an exception in that soybeans or other legumes were used in a rotation; a rotation with rice and vegetables was also applied to large sections of the industry in Florida. However, I gained the impression that the monoculture system was not seen as a major impediment (in 1994) to continued productivity and length of the crop cycle.

Longest ratoon cycles (> 12 years) were achieved in southern African production systems still employing manual harvest systems on clay to clay-loam textured soils and in some cases still relying heavily on the cultivar NCo376. Similarly, long crop cycles have also been achieved in Florida in the warmer areas of very high fertility soil close to Lake Okeechobee. This result has also been achieved with manual harvesting.

In most industries the crop cycle varies from 4-8 years, with increasing tendency to shorter cycles as mechanised harvesting and weight of in-field transport vehicles that cause damage to stools and compact soil both increase

I conclude that the Australian industry has maximum exposure to the adverse effects of mechanised harvest (stool damage from the harvester) and damage to stool and soil from transport traffic. Our soils tend to be of lower clay content than most other sugar industries. This influences cation exchange capacity and, therefore, nutrient requirements. This factor also influences available water capacity of soils. Fertility and moisture characteristics combine to place greater pressure on farm managers for timeliness and effectiveness of operations. Our industry also has the greatest exposure to impact from yield-reducing soil-insect populations.

In summary:

Good ratooning & productivity = *f* (Genetics + Ambient environment + Plant condition + Harvest conditions + Management),
where, Genetics = varieties; Ambient environment = climatic factors; Plant condition = stress from water, nutrients, weeds, pests or disease; Harvest conditions = time of harvest re-climate, damage from harvest, and Management = Timeliness and effectiveness of operations.

I recommend that the Australian sugar industry move towards a harvest/transport system that minimises physical damage to the cane stool, while minimising soil compaction. These goals might be achieved by adopting a production system that keeps wheels in the centre of the interspace and, as far as possible, from the cane stool. Such a system would require expanding row spacing from about 1.5 m to at least 1.8 m in combination with a strategy to avoid the inevitable loss of cane yield that occurs if single rows of cane are wider than 1.65 m. The harvest strategy should also include optimisation of base-cutter height and speed for forward speed of the machine to minimise shattering and removal of stool.

Our production strategies should also continue to focus on improvements to weed control, removal of constraints from nutrition, water management, and pest and disease management.

6.0 ACKNOWLEDGMENTS

I thank SRDC and BSES for supporting this investigation. Thanks also to the many colleagues and contacts in the overseas sugar industries who freely gave of their time to meet and share information with me. This network of contacts has been maintained through periodic correspondence, E-mail and meetings at conferences and workshops.

7.0 REFERENCES

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APPENDIX 1 – ITINERARY

Date	Sector	Contacts
27/2/94	Brisbane – Los Angeles	
27/2/94	Los Angeles – Tampa	
28/2/94	Tampa – West Palm Beach	
1/3/94	USDA Canal Point, Osceola Farms	Jim Miller, Barry Glaz, Peter Tai, Modesto Ulloa
2/3/94	Florida Sugarcane League, Clewiston	John Dunckleman, James Shine
3/3/94	FSCL, Univ FL. EREC Belle Glade	David Anderson, Ron Cherry, Gaspar Korndorffer
4/3/94	Univ FL. EREC Belle Glade	
4/3/94	West Palm Beach – New Orleans	
5/3/94	New Orleans	
6/3/94	New Orleans – Houma	
7/3/94	USDA Sugarcane Unit Houma	Ben Legendre, Ed Richard, Mike Gresham, Bill White
8/3/94	USDA & Amer. Sugarcane League	Herman Waguespach, Geoff Hoy
9/3/94	Houma – Baton Rouge	
10/3/94	LSU Baton Rouge	Ray Ricaud, Scott Millington, Wade Faw, Fred Martin
11/3/94	Baton Rouge – Iberia Expt Stn – NO	Sonny Viator, David Grassguard
12/3/94	New Orleans – São Paulo	
13/3/94	São Paulo	
14/3/94	São Paulo – Piracicaba COPERSUCAR	
15/3/94	Piracicaba & Catanduva Mill	Miguel Santaella, Jorge Donzelli, Marcos Kazmierczak
16/3/94	Piracicaba COPERSUCAR	João Aledo
17/3/94	Piracicaba São Luiz Mill, Dedini	Bill Bernquist
18/3/94	Piracicaba – São Paulo - Iguacu	João Martins
19/3/94	Iguacu weekend	
20/3/94	Iguacu – Buenos Aires – Tucuman	
21/3/94	Estaçion Expt Agro-Indust. Obispo	
22/3/94	Colombres (EEAOC)	
23/3/94	EEAOC –Growers	Jorge Scandalaiaris, Eduardo Romero, Ignacio Olea
24/3/94	EEAOC – Conception Mill	Jose Ossa *et al*
25/3/94	Tucuman – BA – Miami	Daniel Vidal
26/3/94	Free	
27/3/94	Free	
28/3/94	Miami – Gainesville	
29/3/94	Univ FL. Gainesville	Prof. Tony Shih
30/3/94	Gainesville – Miami – London	
31/3/94	Leave	
1/4/94	Free (Easter)	
2/4/94	Free (Easter)	
3/4/94	Free (Easter)	
4/4/94	Free (Easter)	
5/4/94	Leave	
6/4/94	London - Australia	
7/4/94		
4/10/94	Brisbane – Singapore	
5/10/94	Singapore – Johannesburg	
6/10/94	Johannesburg – Nelspruit	David Exteen, Johann Krietzinger, Henning Radley
7/10/94	Malelane, TSB & Komatipoort Mill	Brian George
8/10/94	Free	
9/10/94	Free	
10/10/94	Malelane – Mhlume (Swaziland)	Patrick Henry, Jerry Natloovie
11/10/94	Mhlume – Tambankulu – Simunye	Greg Geldard, Patrick Malean, George White
12/10/94	Big Bend Umombo Ranches	Jerry Gosnell, David Shippley, Harry Rostron
13/10/94	Big Bend Estate	Graeme Todd, John Pigot
14/10/94	Big Bend – Manzini – Durban	
15/10/94	Free	
16/10/94	Free	
17/10/94	SASEX Mt Edgecombe	Peter Turner, Rob Donaldson, Jan Meyer
18/10/94	Durban – North Coast growers	Eric Hulbert, Gerry Barry, Dick Statham, John Penfold
19/10/94	Zululand growers	Cyril de Charmoy, Martin Eweg, Clive Curry
20/10/94	SASEX Mt Edgecombe	Geoff Inman-Bamber, Karl Nuss, Rian van Antwerpen
21/10/94	SASEX – Johannesburg – Singapore	
22/10/94	Singapore – Sydney	
23/101/9	Sydney - Brisbane	