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FINAL REPORT – SRDC PROJECT BSS221
ENVIRONMENTAL STIMULI FOR SUGARCANE SUCKERING IN THE WET TROPICS

by

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SUMMARY

The northern section of the industry has been in crisis for most of the years in the decade up to 2002 because of declining CCS. This decline has been due to increased extraneous matter levels due largely to increased sucker culm content of the crop. These have developed because of marked wet episodes during the harvest period in the majority of years in this period. This resulted in open canopy situations, because of sprawling and lodging, increased light penetration, and initiation and development of sucker culm populations.

A hypothesis was proposed that excessive mature-crop moisture, combined with continued excessive nitrogen use, particularly early in the decade were initiating variables for the problem. Observations suggested that light, via an open canopy situation, also was a driver.

The project tackled the problem with a preliminary series of experiments that allowed optimisation of management and data collection techniques for use in a main experiment proposed. The main experiment sought to establish the importance of levels of three environmental variables, light, nitrogen and moisture, on sucker initiation, and their interaction with each other and with two cultivars of known suckering propensity under commercial conditions.

The preliminary experiments allowed us to make the following recommendations for the design and methods for the main experiment:

1. The late nitrogen application of 70 kg N will be in late April early May if the weather is suitable and as soon as possible thereafter if the weather is too wet to allow the application at the desired time.
2. That spectroradiometry measurements will be made in the core plots at a height of 10 cm and 1 m to determine the effect of plant spacing on the spectral composition received. Photosynthetically active radiation measurements will also be made.
3. A similar soil sampling and nitrate measurement regime will be made in the main experiment as that in the preliminary experiment with the exception that more frequent smaller diameter cores will be taken to speed up sampling.
4. Sucker counting and other trial management will continue as originally proposed.
5. Applications of late N will be made in separate experiments on different cultivars and if possible to soils with low basal nitrate levels.

The main experiment was distinguished by its success in establishing good sucker populations in both crops. In the plant crop, the initiation of sucker culms was excellent relative to that observed in commercial fields in the area, but the initiation seemed delayed. This caused concern that a primary stimulant factor was possibly missing. However, even better sucker populations in the ratoon crop, and earlier initiation (85 day earlier to reach a mean of 10 culms per core plot) allayed this fear. The delayed onset in the plant crop may be associated with reduced resources for sucker initiation in sett-initiated stools, the year, or an interaction of these. Both the plant and first-ratoon crops were well grown, there was a response to irrigation, and CCS in the mature stalks was very acceptable.

The experiment also was distinguished by the wealth of significant effects, both main and interactions. The main effects of environments, cultivars and nitrogen rates were dominant. Light was of little consequence. There were a host of significant interactions, and these were dominated by those contain the main effect of nitrogen. A study of the key traits that were significant in both the plant and ratoon crops clearly showed that harvest-season moisture is important in initiating and facilitating sucker culm development. The interaction of the late application of nitrogen with post-monsoonal irrigation resulted in the key sucker components being even more strongly expressed.

This result allows a managed environment for screening of suckering propensity to be rather clearly detailed. This will be useful in classifying clones in the northern program, but such information may not necessarily be used for selection. A clearer understanding of the role of genotype by environment interactions for suckering propensity should be obtained. Knowledge of the suckering propensity of clones at the pre-cultivar stage may allow their recommendation for specific environments suited to their sucker propensity rating, e.g., one unsuited to a moist environment because of high suckering propensity may well have a place in a drier environment. Such information is envisaged primarily as an addition tool for correct choice and management of cultivars in the commercial context. The other major concern is that the genetic relationship between suckering propensity and ratoonability is unknown. This needs clarification. At the start of this project, the importance of major environmental variables as used in this experiment was unknown in terms of their impact on sucker culm initiation. This experiment has provided clarification of their importance. In a similar manner, we need to clarify the relationship between suckering propensity and ratoonability. The puzzle remains that light was a main factor of little consequence in the main experiment, despite being of importance in one of the preliminary experiments. This also defies every day observations, and requires further study.

In a practical sense, the use of recommended nitrogen rates, so that excess nitrogen is not available through into the mature crop phase, is important in managing sucker development. If excess nitrogen is available, and excess moisture becomes available in this period, suckering propensity as seen in the region for much of the past decade will again occur. Sensible nitrogen use also is required from an environmental viewpoint, and adherence to this would assist the avoidance of excessive sucker culm initiation and development. Given that we have shown that 10% suckering is equivalent to the loss of one unit of CCS, any reduction in suckering, and the automatic increase in CCS, will provide increased returns. With determinations of up to 50% of culm biomass being produced by sucker culms, the economic benefit is clear.

1.0 BACKGROUND

A serious, accelerated decline in CCS levels in the wet tropics in the five seasons leading up to this project was associated with record or near-record crops, significant harvest-period rain events, and continued use of excessive nitrogenous fertilizer. Less-than-erect crops, with open canopy conditions, and significant sucker development producing increased extraneous matter levels and dilution of mature-stalk CCS levels were the consequences. Farmer profitability diminished significantly, with many farmers in regions in the wet tropics claiming financial crisis as a result of reduced profitability.

Preliminary data have indicated that there are large differences (e.g., 4.4 units of CCS) between identical analyses of comparable clean cane samples and mill supply samples. These differences can be ascribed to extraneous matter, including suckers, in the mill supply. Associated work has revealed that suckers, or water shoots, can account for up to 50% by weight of culm biomass, and that for each 10% of the cane supply contributed by suckers, mill CCS is reduced by 0.7-1.0 CCS units. This depression is dependent upon the time of the year and the size and maturity of the suckers.

The physiology of sucker initiation and development in sugarcane is barely understood, despite the tillering process being widely studied and well understood in a broad range of cereal and pasture grasses. In some sense, suckers can be regarded as premature ratoon tillers, but the initiating mechanism for suckering, the interaction of environmental variables (light, moisture, nutrition) with this, and the relationship of the suckers to the host stool all have been little researched. The threshold levels for these variables, and their interactions, are unknown. Significant sucker development can occur under closed canopy conditions (Hurney 2003), indicating that reception of high light levels, presumably by the lower portions of the plant need not be a necessary condition for sucker development.

It was thought that a solution to the problem presented by suckers at the commercial level most likely would be genetic, as many of the then-current cultivars displayed a marked propensity to sucker under the changing agri-environmental conditions then prevailing. However, plant improvement was virtually powerless to respond meaningfully to this problem because of the lack of basic knowledge of suckering physiology. For example, any screening for suckering propensity would be most effectively done in a managed-environment format, and, while a best-bet approach could be taken as to the environmental parameters to manipulate, this could not be done in a rigorous manner.

Data on suckering, collected in a single final assessment trial conducted from Meringa in the lead-up to this project revealed that there was considerable variation for suckering propensity in the small sample of clones included, that broad-sense heritability for suckering propensity is higher than for yield itself, and that clones with high yield and low suckering propensity do occur. This gave added confidence that pursuit of a genetic solution, involving reduced propensity to sucker, and perhaps other ideotype traits, would be correct.

The project tackled the problem with a preliminary series of experiments that allowed optimisation of management and data collection techniques for use in a main experiment proposed. That experiment sought to establish the importance of levels of three environmental variables, light, nitrogen and moisture, on sucker initiation, and their interaction with each other and with two cultivars of known suckering propensity under commercial conditions.

This project linked to the SRDC-funded PhD studentship 'Environmental and varietal factors predisposing to suckering in sugarcane crops in the wet tropics', through James Cook University, and to projects BSS180 'Assessing clonal and nitrogen interactions on CCS in sugarcane in the wet tropics' and CTA030 'Overcoming constraints to high yield and CCS in large and lodged cane crops'. It formed part of BSES' northern Queensland improving productivity program.

2.0 OBJECTIVES

The project aimed to determine factors initiating suckering in sugarcane in the wet tropics to enable development of strategies to minimize the impact of suckering on CCS.

The specific objectives were:

1. To evaluate the role of light, nitrogen, and moisture as stimuli initiating suckering;
2. To determine the effect of interactions among these factors and cultivars studied on sucker initiation;
3. To provide specifications for the necessary environmental conditions to conduct screening of populations of clones for suckering propensity;
4. To develop research, crop-management, or crop-improvement strategies to address the problems caused by suckering.

All objectives were met. The project established a preliminary series of experiments that allowed optimisation of management and data collection strategies. These were then used in the main experiment that tested the importance of levels of three environmental variables, light, nitrogen, and moisture, on sucker initiation, and their interactions with each other and with two cultivars (Q138 and Q152) of known suckering propensity under commercial conditions.

Objective 1 - Evaluate the role of light, nitrogen, and moisture as stimuli initiating suckering.

Increased light, as facilitated by variable within-row stool spacing, plays a relatively minor role in initiating suckering relative to the other main effects assessed - cultivars, mature-crop moisture availability, and late availability of nitrogen.

The split nitrogen application had a pronounced and consistent effect on many traits. Cane yield did not differ for the split and single applications, but both were higher than the zero application. For sucker yield, % suckering and sucker weight, the split application produced the highest mean, although for sucker weigh there was no difference between the split and single application but both were superior to the zero application.

The split application resulted in the lowest CCS for mature stalks in both crops. For sucker-culm CCS, the split application was no different from the zero application and both were inferior to the single application. The split application produced the highest sucker-culm sugar yield in both crops. This was despite its impact on culm CCS. The effect the split application had on sucker yield was the variable driving this superiority in sugar yield.

Overall, the main effects of environment (post-monsoonal irrigation versus rain-fed), cultivars (Q138 versus Q152), and nitrogen rates (zero, single, and split) produced statistically significant differences in most of the traits examined, and these effects were relatively consistent over crops. Spacing was relatively unimportant as a major influence on sucker-culm initiation and development of traits associated with this culm class.

Objective 2 - Determine the effect of interactions among these factors and cultivars studied on sucker initiation.

Significant environment by cultivar interactions over both crops occurred in seven traits:

- Cultivar Q152 had the highest mature-stalk number and the highest sucker-culm number in the irrigated environment;
- Q138 had the highest sucker yield in the irrigated environment – this was achieved through significantly higher sucker weight despite the lower sucker-culm number;
- Q138 was clearly superior in the irrigated environment in terms of % suckering, the proportion of total culm yield produced by sucker culms;
- Q152 had the highest sucker-culm CCS in the rain-fed environment;
- Q152 had the highest sugar yield from sucker culms in the irrigated plant crop, but Q138 was highest in the irrigated ratoon crop.

In many of these instances, the other cultivar expressed the next highest level of the trait in the irrigated environment; this confirms the suitability of post-monsoonal irrigation to stimulating expression of many of these traits regardless of the genetics.

The split nitrogen application in the irrigated environment produced the strongest expression for the sucker-culm traits of number, yield, proportion of crop, and weight in terms of environments by nitrogen rates interactions. This was consistent over crops. Only for sucker-culm weight did the single application produce an equivalent mean to the split application. Sugar yield was highest for the split application in the irrigated environment in both crops.

The cultivar by nitrogen rates interaction was consistently significant over crops for sucker-culm CCS and sugar yield. Such interactions are expected, and, as they were not reflected in mature-stalk CCS, they probably are unimportant. The split application and Q138 produced the lowest CCS in both crops. For sugar yield from sucker culms, Q152 and Q138 gave the lowest CCS with the zero nitrogen application in the plant and ratoon crops, respectively.

Thus, late nitrogen application combined with moisture in the mature-crop stage successfully stimulates marked expression of many sucker-culm traits against which selection is required. The presence of moisture in the mature crop, as imposed by wet weather conditions experienced in the tropical region in many of the years in the decade to 2002, has had a pronounced effect on expression of suckering propensity. This was exacerbated by use of cultivars that express this trait under wet, mature-crop conditions.

Objective 3 - Provide specifications for the necessary environmental conditions to conduct screening of populations of clones for suckering propensity.

Soil moisture persisting in the mature crop is the key element for good expression of suckering propensity and the traits that can be measured on these, e.g., number, size, weight, proportion of crop, yield. This expression is clearly enhanced by the availability of nitrogen late in the crop development, e.g., in May.

Increased light penetration, as afforded by increased within-row stool spacing was not a prominent stimulatory variable in the main experiment. The reason for this is not understood, but it conflicts with evidence from the preliminary experiments.

Objective 4 - Develop research, crop-management, or crop-improvement strategies to address the problems caused by suckering.

Ideotype selection, as currently being practiced, is essential if wet conditions continue to occur in the tropical region. However, these conditions may not persist, and any negative implications associated with selection of low suckering propensity clones need to be considered. The genetic association between suckering propensity and ratoonability is unknown; we can successfully select clones with low propensity for suckering, but what, if any are the implications for ratoon productivity and profitability?

The extent of genotype by environment interaction for suckering propensity is unknown and this needs to be determined. This could be easily done in existing trials. This would enhance our understanding of the genetics of the trait, assessed across a broad range of environments. This also would provide guidance as to how information on suckering propensity could be used for the industry's benefit. For example, if a managed suckering screen was implemented, the results would not necessarily result in the automatic discard of all high-propensity clones. These may well have applicability to drier environments, but this needs conformation by enhancing our understanding of the extent of G by E interactions for suckering propensity.

The role of light in sucker initiation needs resolution. The observations strongly suggest that increased light penetration in a mature crop has serious implication in terms of stimulating suckering. However, in the main experiment, increased light penetration, as induced by increasing stool spacing, did not significantly increase suckering.

In crop management, the use of recommended nitrogen rates, so that excess nitrogen is not available in the mature-crop phase is critical in reducing suckering. If this occurs, and excess moisture becomes available in this period, suckering propensity is aggravated. Sensible nitrogen use also is required from an environmental viewpoint, and adherence to this would assist the avoidance of excessive sucker culm initiation and development.

Given that 10% suckering is equivalent to the loss of one unit of CCS, any reduction in suckering, and the concomitant increase in CCS will provide increased returns.

3.0 METHODOLOGY, RESULTS AND DISCUSSION

The project established five sets of preliminary field trials that allowed optimisation of management and data collection strategies. These trials focused on:

- parasitism of suckers on the stored sucrose sink of the host stool;
- manipulation of the light in the outside row of sugarcane;
- trash stripping and its influence on suckering;
- effect of delayed and staggered nitrogenous fertilization on sucker initiation;
- effect of a late nitrogen application on a strongly and a weakly suckering cultivar.

Findings from these were then used in designing the main experiment. This tested the importance of levels of three environmental variables, light, nitrogen, and moisture, on sucker initiation, and their interactions with each other and with two cultivars (Q138 and Q152) of known suckering propensity under commercial conditions.

3.1 Parasitism of suckers on the stored sucrose sink of the host stool

3.1.1 Introduction

Dilution of harvested material by suckers is well documented. Suckers would further reduce profitability if, during their growth, sucrose was utilized from the main stalks to aid their growth. The assertion that suckers derive nutrition from main stalks and that this is the cause of their rapid growth rates is made in the earlier summaries of suckering (Hes 1954; Barnes 1974). The main evidence given by Hes (1954) for the assertion was that the growth rate of an albino sucker was not impaired relative to the growth of a similar-aged sucker containing chlorophyll.

3.1.2 Methods

Treatments were imposed in an attempt to quantify the amount of sucrose removed, if any, from main stalks to support sucker growth. This experiment was established on Angelo Maifredi's property in the Tully region using cultivars Q138 and Q152. Treatments sampled were stalks that: (i) had never had a sucker; (ii) had suckers removed; (iii) had a sucker attached; (iv) had a sucker attached that had every second leaf removed.

Five replicates of each treatment in Q152 were harvested on 9 June 1999. Internodes 1 and 2 above where the sucker was attached and the first internode above ground were frozen in liquid nitrogen. Sugars were extracted from a sub-sample and analysed by HPLC. On 7 September, all treatments of Q152 were again sampled and analysed, but with an additional sampling of every fifth internode up the stem from the first above-ground internode. The same procedure was also used for Q138, except only the treatments with and without suckers were sampled.

3.1.3 Results

For the first sample, two-way analysis of variance using treatments and internodes as factors showed significant differences between treatments and internodes. When one-way analyses were performed on each internode in turn, similar results were obtained for sucrose concentration in both the internode from which the sucker was attached and the next internode up the stem. For these internodes, all treatments that had initiated a sucker, irrespective of how it was subsequently manipulated had significantly lower sucrose concentrations than corresponding internodes on stalks that had not initiated a sucker (Fig. 1). There was, however, no difference between the treatments that had initiated a sucker. There was also no significant difference between any of the treatments in the sucrose concentration in the first internode above ground. The above-ground internodes are the ones that are commercially harvested. Consequently, any losses in sucrose in these internodes would lead to a loss in harvested sucrose.

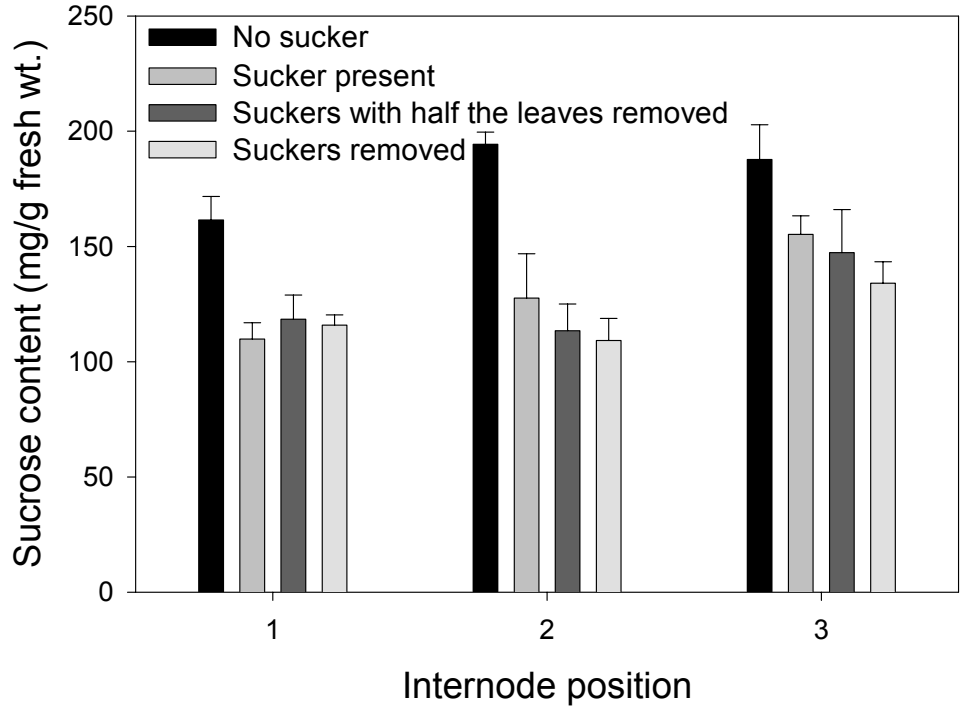

Figure 1: Sucrose content at 9 June 1999 of internodes of main stalks of Q152 with and without suckers, with a sucker removed and with a sucker on which every second leaf has been removed. Internode positions are: 1, first internode above the sucker; 2, second internode above the sucker; 3, first internode above ground.

In the second sampling, two-way analysis of variance (cultivar Q152) demonstrated that there was a significant difference between treatments and internodes along the stem (Table 1), but no significant interaction between internode position and treatment. There was no consistent order of the treatments for sucrose concentration for each internode. The average sucrose contents for stalks without a sucker, with a sucker intact, with a sucker with half leaves and which had initiated a sucker that was removed were 153, 170, 150 and 171 mg g^{-1} fresh mass, respectively. The stalks without a sucker and with a sucker with half leaves had sucrose concentrations significantly lower than the stalks with

a sucker growing intact and stalks with a sucker removed. Though the finding that the concentration of sucrose was lower in the stalks without suckers at this later harvest differed from the earlier harvest of Q152, it was similar to the result obtained from Q138 (Table 1). In Q138, the average sucrose concentration was 167 mg g^{-1} fresh mass for stalks with a sucker and 136 mg g^{-1} fresh mass for stalks without a sucker. Two-way analysis of variance demonstrated no difference between the internodes along the stem but a significant difference between the two treatments.

3.1.4 Discussion

The differences in sucrose concentration were not due to differences in moisture content. The mean moisture content of main stalks of Q152 for plants with no sucker, a sucker with half leaves present, a sucker allowed to grow normally and a sucker removed were 64.5%, 64.8%, 64.3% and 61.8%, respectively. Two-way analysis of variance gave a non-significant F ratio (LSD 2.57). For Q138, the mean moisture contents of the internodes of the main stalks with suckers and without suckers were 66.0% and 66.5%, respectively. Two-way analysis of variance gave a non-significant F ratio (LSD 1.46).

The effect of suckers on diluting the concentration of sucrose in the harvested material compared to harvesting main stalks alone, and consequently on profitability has been well documented. This is a more complex resource allocation problem than trying to achieve an increase in harvest index (in this case mass of sucrose as a proportion of the mass of main stalks). Allocation of carbon to suckers causes losses in profitability through two effects. Firstly, carbon allocated to suckers is not being directed towards sucrose storage in main stalks, and, secondly, it is having a further negative impact, when harvested, on the sucrose content that is stored in the main stalks by dilution.

The degree to which the carbon used in sucker growth would be directed to sucrose storage in the absence of suckers is not clear. Sucrose from the main stalk is consumed in the process of initiation of a sucker is one way in which the data presented in Table 1 could be interpreted. This does not seem unreasonable, as developing tillers are not initially autotrophic (Evans *et al.* 1964). The period of time required before they become autotrophic has yet to be determined for sugarcane suckers. As suckers are initiated below ground level and often grow, at least initially, below the main canopy, any contribution to their own growth would be a result of intercepting light not captured by the main stalks.

Table 1: **Mean sucrose concentration in internodes from which a sucker has initiated, the next internode up the stem and the first internode above ground level and the fifth internode above ground level and every fifth internode up the stem. For Q152 the data (means, n=5) for the treatments of a main stalks that had never initiated a sucker; initiated a sucker which was allowed to grow; initiated a sucker that had every second leaf removed; and had initiated a sucker which was removed. For Q138 (means, n=5) for the treatments of a main stalks that had never initiated a sucker; and initiated a sucker which was allowed to grow.**

Cultivar/Stalk type	Sucrose concentration mg g^{-1} fresh mass								LSD (internodes)
	Internode attached to sucker	Internode above attachment of sucker	1st above-ground	5th above-ground	10th above-ground	15th above-ground	20th above-ground	Mean (treatments)	
Q152									
No sucker	116.1	150.2	156.4	176.8	148.4	175.6	150.1	153.4a	
Sucker	130.9	149.0	181.4	176.2	179.5	190.8	187.1	170.7b	
Sucker with ½ leaves	124.1	151.2	145.7	170.0	186.9	134.3	140.7	150.4a	
Sucker removed	157.2	154.2	164.4	168.8	176.5	214.1	163.9	171.3b	
Mean (internodes)	132.1[a]	151.2[ab]	162.0[bc]	173.0[c]	172.8[c]	178.7[c]	160.5[b]		20.3
LSD (treatments)								15.4	
Q138									
No sucker	126.9	145.6	148.5	152.7	133.4	108.5	138.8	136.3[a]	
Sucker	152.2	149.1	182.5	169.3	165.1	178.3	172.9	167.1[b]	
Mean	139.5	147.4	165.5	161.0	149.2	143.4	155.9		24.1[#]
LSD (treatments)								12.8	

[a] means with different numbers within the same row or column and cultivar are significantly different at $P < 0.05$.
[#] Significance not indicated by F test

For the second set of sucrose measurements along the length of the stem, interpretation of the data is less clear cut. However, the data are internally consistent. The main stalks that had suckers with half their leaves removed had less sucrose in their internodes than stalks that had initiated a sucker that was removed and stalks that had a sucker with a full set of leaves. This seems logical, as a sucker with half its leaves removed would be less able to be self-sufficient in photosynthetic products. However, the data also show significantly less sucrose in main stalks that have not initiated a sucker. This is different from the first sampling, 3 months earlier, but in the intervening time the numbers of suckers had increased dramatically. The number of main stalks that did not have a sucker present was few. Other data indicate that younger stalks produce much fewer suckers than older stalks when grown in the same environment (see data for normal and slashed crops below). Van Dillewijn (1952) states that suckers "appear when the other tillers are already more or less full-grown". There does appear to be a certain maturity requirement for a stalk before it can initiate a sucker. Taking the increased number of suckers and the apparent requirement of a level of maturity of an individual stalk before it can produce a sucker together, the second set of sucrose experiments may be explained. If younger order tillers were the only main stalks that had not initiated suckers then the stalks used as a control would by virtue of their younger age contain less sucrose. Consequently, the main stalks without suckers in the second sampling were not a suitable control.

To fully determine how much assimilate is drawn from stored sucrose and from current assimilate to support sucker growth requires further experimentation. Showing the movement of labelled carbon from main stalks to suckers would provide a definitive answer. The size of sugarcane crops and the duration of the crop cycle, however, present challenges for this kind of experimentation. Consequently, it may require analysis of different stalks of the same age, manipulated with environmental cues that promote or inhibit suckering without altering carbon assimilation to establish unequivocally the carbon supplied to suckers. The stalks with suckers initiated earlier in the season (9 June 1999) and the stalks with suckers attached with half their leaves removed sampled later in the season indicates that suckers do withdraw carbohydrate from the stalks that they are attached to. Until the level of dependence of suckers on parental stalks is defined, however, the full impacts of suckering on profitability of sugarcane production will remain unknown.

3.2 Manipulation of the light in the outside row of sugarcane

3.2.1 Introduction

The outside row of a sugarcane crop contains a greater number of suckers than the second row of the crop (Bonnett *et al.* 2001). Edges of a crop, and areas with a disturbed canopy, typically have higher available light than the middle of a well-grown crop. However, the edges of the crop may also have increased access to nutrients and water due to their roots being able to exploit a greater area of soil. This means that a simple comparison between sucker number in the outside row of a crop and the middle of the crop is not sufficient to fully determine the role that light may have in suckering.

To test the hypothesis that increased suckering in the outside row of a cane crop was due to high light availability, an experiment was established where the below canopy region of the outside row of cane was shaded. Treatments were also designed to try to determine what part of the sugarcane stem was responsible for detecting changes in the light environment below the canopy.

3.2.2 Methods

The experiment was conducted at three sites (Table 2), Tully (18°00′S, 145°55′E), Babinda (17°30′S, 145°50′E) and Mulgrave (17°05′S, 145°42′E), using outside rows of commercial crops of cultivars Q138 and Q152. These cultivars were chosen as they both have a high propensity to sucker. This meant that suckering was highly likely to occur during the season. By shading the outside row, it could be determined if increased light was the cause of high suckering reported by Bonnett *et al.* (2001) in this region of the crop.

Table 2: Cultivar, previous harvest date, aspect, nitrogen fertilizer application, and date of treatment establishment for the six crops where light was manipulated in the outside row of cane.

District	Cultivar	Previous harvest	Aspect	Fertiliser	kg N/ha	Treatments established
Tully	Q138	20/7/98*	West	GF Organo130	60	30/3/99
	Q152	15/8/98	East	GF 402 Urea (GF)	140	30/3/99
Babinda	Q138	Not available	East	Not available	Not available	1/04/99
	Q152	1/10/98	West	Incitec CK220	110	1/04/99
Mulgrave	Q138	10/98	East	GF 501	145	8/4/99
	Q152	10/98	West	GF 501	145	8/4/99

* planting date.

Five treatments were established:

- T1. Shade cloth (99% visible light, 97% UV, Z16 Black, Knittex, South Africa) was erected alongside (as close as possible) the outside row of the crop (5 m per plot). This was done in order to prevent light from entering from the side, and possibly changing the light characteristics of that row to something more similar to an inside row. The cloth was suspended between two posts (PVC pipe) with wire, at the height of the oldest green leaf. PVC pipes were placed over star pickets in order to prevent them from bowing. The height of the shade cloth was adjusted as the crop grew. This was done by sliding the PVC pipe up the star picket, with wire used to prevent the pipe from sliding back down.
- T2. Individual stalks were shaded with shade cloth (same type as T1) to the lowest clasping leaf (2.5 m of row per plot). This was done by wrapping a strip of shade cloth around the stalk. The shade cloth was held in place with staples. The shade cloth was maintained at the height of the oldest green leaf.

- T3. All nodes on the stalk were wrapped with black insulation tape (2.5 m of row per plot). This was done in an attempt to determine which part of the stalk was responsible for detecting changes in light (should a response be found). Nodes of senesced leaves were wrapped with tape at regular intervals. This treatment was only established at the Tully sites because it was particularly labour intensive.
- T4. Dead leaf (trash) was removed from stalks, possibly increasing light reaching the stalk, and controlling for the removal of dead leaf in order to establish T2 and T3. For each T2 and T3 treatment, there was 2.5 m of row where trash was removed. Leaves were removed as they senesced during the study.
- T5. Control, the crop was not altered (5 m of row per plot).

The treatments were arranged in randomised-block designs replicated four times (Figure 2).

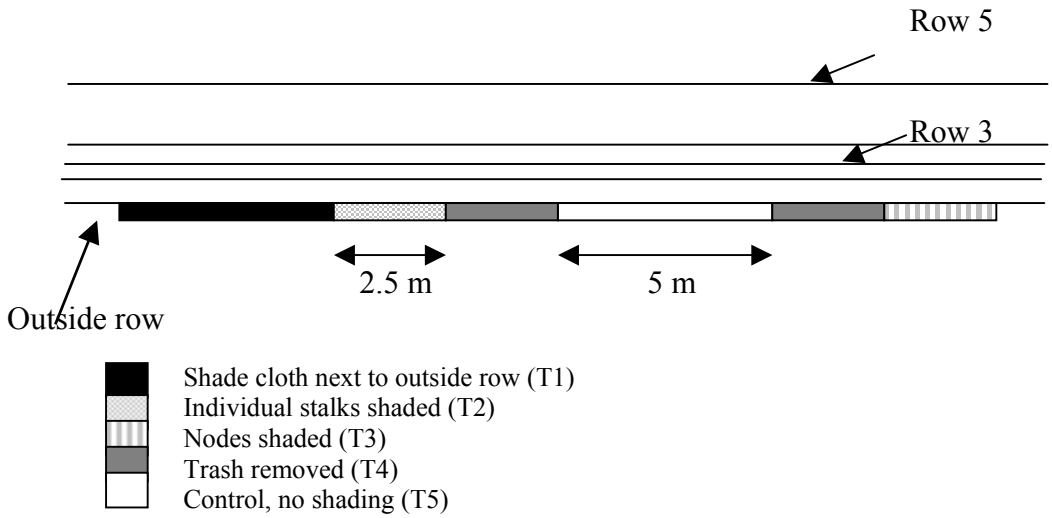

Figure 2: Experimental design used to manipulate light in the outside row of sugarcane crops. T3 was only established in Tully. The treatments were arranged randomly within each block.

Sucker counts were made approximately every 2 weeks at all sites. Prior to commercial harvest, the suckers were cut out, counted and weighed. On 19 July 1999, the sucker numbers in rows 3 and 5 in the 5 m sections directly adjacent to the control plots were counted. This was conducted at the Tully and Babinda sites in order to ascertain whether or not there was an outside row effect in the experimental crops.

Measurements of photosynthetically active radiation (PAR) were taken on 11 August 1999 in Tully, 11 August 1999 in Babinda and 10 August 1999 in Mulgrave. PAR was measured with a AccuPAR Linear PAR Ceptometer. Two measurements were taken at both 10 cm and 100 cm above ground in the control (T5) and side-shade treatments (T1). The measurements were taken directly behind the shade cloth, and in the inter-row space between rows one and two (Figure 3). Measurements were taken in equivalent positions for the control plots. The two measurements per height were averaged to give one reading per plot at each height in each position. For all measurements, an external probe was used

to take a measurement of PAR outside the crop at the same time as the measurement was being taken inside the crop. PAR within the canopy was expressed as a proportion of the total incident PAR (sunlight).

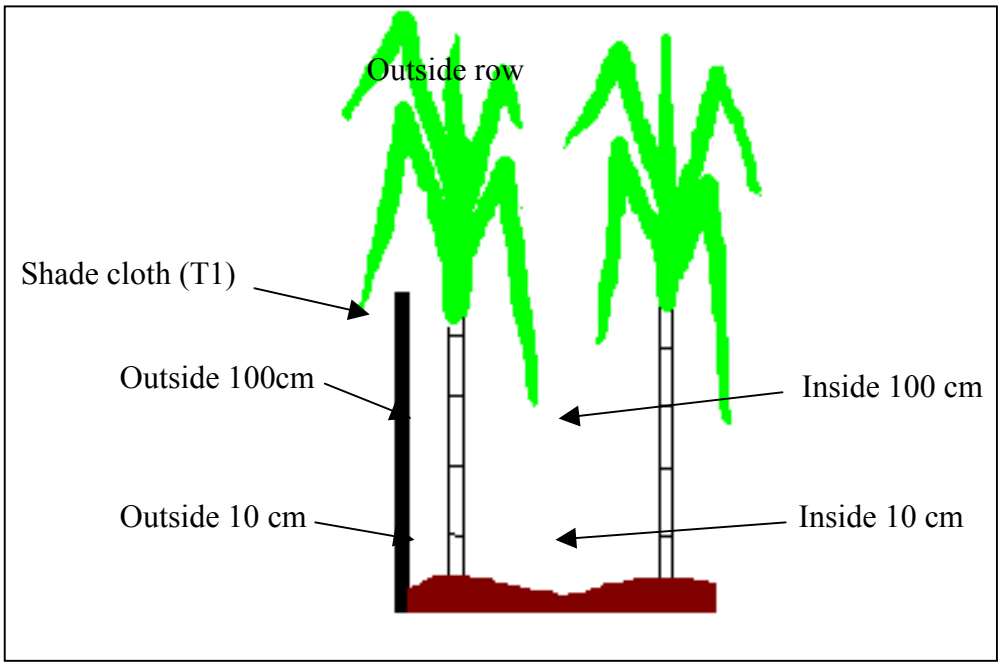

Figure 3: Position of PAR measurements taken in August 1999. Red/far-red ratio measurements were taken at the outside 10 cm position.

The red (660-680 nm)/far-red (720-740 nm) ratio of light was measured on the day of the final harvest for all crops, except Tully Q152 and Babinda Q152, where equipment failure prevented data collection. The ratio was determined by scanning between 300 nm and 1100 nm with a Licor LI-1800 portable spectroradiometer. The amount of light between 660 nm and 680 nm was then divided by the amount between 720 nm and 740 nm to give the ratio. Measurements were taken at 10 cm above ground, directly behind the shade cloth, for T1, and in an equivalent position for the control plots (T5) and trash removed plots (T4). Two scans were performed per plot, which were automatically averaged by the spectroradiometer.

On 3 March 1999, the red/far-red ratio of light passing through the shade cloth, leaf sheath (cultivar Q138) and green leaf (cultivar Q138) were also measured by placing the cloth or leaf material over the sensor and then scanning from 300-1100 nm. Measurements of the red/far-red ratio of sunlight were also taken as a control.

Temperature probes were used at the Tully Q152 site (block 2) to determine if the shading treatments affected temperature. Three thermocouples (type K) were placed about 10 cm above ground directly behind T1 (side shade), three thermocouple were placed about 5 cm below ground directly behind T1 (side shade), three thermocouples were placed about 10 cm above ground in the control plot (T5), three thermocouple were placed about 5 cm below ground in the control plot (T5), two thermocouple were placed about 5 cm below ground away from the crop on a headland as an outside control, and two thermocouples were placed at about 1.5 m above ground to give an indication of air temperature (outside

control). The thermocouples were installed on 26 August 1999 and were removed on 17 September 1999. Thermocouples were wired to a data logger and temperature was sampled every 10 seconds and an hourly average recorded.

Sucker counts were expressed on a per metre basis, and were square-root transformed prior to analysis in order to meet the assumption of a normalized distribution. Analysis was performed using a general linear model (GLM) for randomised block designs with repeated measures. Least significant differences were calculated to compare means following the analysis. LSDs were calculated by hand using the method described by Steel and Torrie (1980) for split-plot designs. Light quantity data were analysed using ANOVA with position within the row, height above ground and treatment as factors. The red/far-red ratio of light data were analysed using single factor ANOVA with treatments as factors. Temperature data were analysed using ANOVA with time of day as a repeated measure.

3.2.3 Results

The mean number of suckers per metre for the two crops grown in Tully is shown in Table 3. No significant difference was found between treatments for cultivar Q138 ($P > 0.05$) and cultivar Q152 ($P > 0.05$).

The mean number of suckers per metre for the two crops grown in Babinda is shown in Table 4. Significant differences were found between treatments for cultivar Q138 ($P < 0.01$) and Q152 ($P < 0.05$).

The mean number of suckers per metre for the two crops grown in Mulgrave is shown in Table 5. Significant differences were found between treatments for cultivar Q138 ($P < 0.01$) and Q152 ($P < 0.05$).

Sucker number increased significantly with time for all crops in all regions ($P < 0.01$).

The sucker counts taken on 19 July 1999 from rows three and five, for the 5 m directly adjacent to the control plots showed that the sucker number in row one was not significantly different from rows three and five at the Tully sites ($P > 0.05$) (Table 6), but significant differences were found at the Babinda sites ($P \leq 0.05$).

There was a significant difference in the available proportion of light between treatments (T1 and T5) at all sites for all cultivars (Table 7), except Q152 in Tully. There was significantly more light available at 100 cm than at 10 cm at all sites except for Q138 at Tully, where the difference was not significant. There was a significant row by treatment interaction at all sites except for Q152 in Tully. This was due to Tully Q152 having a lower amount of available light on the outside of the crop whether it was shaded or not. For the other five sites/cultivars, the significant interaction was mainly due to the shade cloth significantly reducing the amount of available light immediately behind it (outside-shade). Inside-shade and inside-control were only significantly different at the Babinda Q138 site. Therefore, at the other sites, the shading treatment was only lowering the amount of available light on one side of the row, as the light in the inter-row space between rows 1 and 2 was not affected by the shading treatment.

Table 3: Sucker number per metre appearing with time following the shading of the outside row of cane, cultivars Q138 and Q152, at Tully. Treatments were: Side shade (T1); Stalk shade (T2); Stalk clear (T4); Node shade (T3); Node clear (T4) and Control (T5).

Treatment	Time (Day of the year)												
	91	**112**	**131**	**146**	**159**	**175**	**190**	**200**	**216**	**236**	**244**	**250**	**260**
Q138													
Side shade	0.0	0.0	0.2	0.2	0.7	1.7	3.4	3.7	4.7	5.5	7.5		
Stalk shade	0.0	0.0	0.1	0.2	0.4	1.0	2.0	2.3	3.4	5.6	5.7		
Stalk clear	0.0	0.0	0.0	0.0	0.5	1.9	3.3	3.4	5.8	5.6	7.2		
Node shade	0.0	0.0	0.0	0.0	0.4	1.5	3.0	3.8	4.9	7.2	8.3		
Node clear	0.0	0.0	0.0	0.0	0.3	1.2	2.1	3.1	3.6	6.0	7.9		
Control	0.1	0.1	0.1	0.1	0.4	1.2	2.3	2.9	4.0	5.4	6.4		
(ns)													
Q152													
Side shade	0.5	0.6	0.4	0.8	1.4	2.2	5.3	6.2	8.1	9.4		15.8	22.7
Stalk shade	1.6	1.3	1.3	2.3	3.7	3.5	7.3	6.0	11.3	13.1		19.0	21.4
Stalk clear	1.3	1.7	1.5	3.3	4.0	4.4	7.6	5.8	8.4	13.7		21.7	23.1
Node shade	1.0	1.4	1.2	2.4	2.8	2.8	6.4	6.4	10.1	12.1		19.6	21.7
Node clear	1.4	1.5	1.3	2.6	2.4	3.4	5.9	7.4	10.1	11.1		14.8	15.5
Control	0.7	1.2	1.1	1.8	1.7	2.3	5.4	6.1	7.1	9.4		17.5	21.5
(ns)													

ns - F test not significant ($P > 0.05$)

Table 4: **Sucker number per metre appearing with time following the shading of the outside row of cane, cultivars Q138 and Q152, at Babinda. Treatments were: Side shade (T1); Stalk shade (T2); Stalk clear (T4); Node shade (T3); Node clear (T4) and Control (T5). Means followed by the same letter are not significantly different (P > 0.05).**

Treatment	Time (Day of the year)												
	90	112	130	146	159	175	190	200	215	236	243	249	253
Q138													
Side shade	0.8^{a}	1.7^{a}	2.2^{a}	3.2^{a}	3.8^{a}	4.8^{a}	7.4^{a}	6.5^{a}	7.5^{a}	8.5^{a}	12.7^{a}		
Stalk shade	0.9^{a}	2.0^{a}	3.2^{a}	5.3^{b}	6.8^{b}	7.8^{bc}	10.3^{b}	10.3^{b}	9.8^{ab}	12.2^{bc}	15.0^{a}		
Stalk clear	0.3^{a}	2.0^{a}	2.9^{a}	4.4^{ab}	5.7^{ab}	8.4^{c}	10.0^{ab}	10.1^{b}	11.3^{b}	13.4^{c}	14.5^{a}		
Control	0.5^{a}	1.6^{a}	2.5^{a}	3.6^{ab}	4.2^{a}	5.6^{ab}	7.4^{a}	7.2^{a}	8.5^{ab}	9.6^{ab}	12.1^{a}		
Q152													
Side shade	0.7^{a}	1.4^{a}	2.2^{a}	3.1^{a}	3.8^{a}	4.6^{a}	6.7^{a}	7.3^{a}	7.3^{a}	8.9^{a}		10.8^{a}	13.8^{a}
Stalk shade	1.2^{ab}	2.3^{ab}	3.2^{a}	4.3^{ab}	5.0^{a}	5.8^{ab}	6.9^{a}	7.7^{a}	7.5^{ab}	8.9^{a}		11.0^{a}	13.7^{a}
Stalk clear	1.5^{b}	3.5^{b}	5.1^{b}	5.6^{b}	6.9^{b}	6.6^{b}	7.8^{a}	9.4^{a}	10.0^{b}	10.4^{a}		12.6^{a}	13.7^{a}
Control	0.7^{ab}	2.1^{ab}	3.6^{ab}	4.4^{ab}	4.9^{ab}	5.6^{ab}	7.7^{a}	8.3^{a}	8.6^{ab}	9.8^{a}		12.1^{a}	13.7^{a}

Table 5: **Sucker number per metre appearing with time following the shading of the outside row of cane, cultivars Q138 and Q152, at Mulgrave. Treatments were: Side shade (T1); Stalk shade (T2); Stalk clear (T4); Node shade (T3); Node clear (T4) and Control (T5). Means followed by the same letter are not significantly different (P > 0.05).**

Treatment	Time (Day of the year)											
	99	112	130	146	159	175	189	200	215	236	249	265
Q138												
Side shade	1.2^{a}	1.4^{a}	2.8^{a}	5.3^{a}	7.0^{a}	7.3^{a}	10.8^{a}	9.0^{a}	10.3^{a}	10.5^{a}	11.2^{a}	16.0^{a}
Stalk shade	3.2^{b}	3.8^{b}	6.4^{b}	10.2^{bc}	12.5^{bc}	11.7^{b}	15.1^{b}	13.1^{b}	16.1^{b}	15.7^{bc}	14.5^{ab}	22.1^{bc}
Stalk clear	4.6^{b}	7.1^{c}	9.6^{c}	13.7^{c}	15.6^{c}	15.8^{c}	15.3^{b}	15.0^{b}	16.3^{b}	17.5^{c}	16.8^{b}	24.0^{c}
Control	2.8^{b}	4.0^{b}	5.7^{b}	7.7^{ab}	9.9^{ab}	10.5^{ab}	12.7^{ab}	12.0^{ab}	12.0^{ab}	12.5^{ab}	13.3^{ab}	17.1^{ab}
Q152												
Side shade	0.5^{b}	0.8^{ab}	1.9^{a}	4.4^{a}	5.2^{a}	5.5^{a}	13.3^{a}	10.5^{ab}	14.1^{a}	16.5^{a}	15.4^{a}	21.9^{ab}
Stalk shade	0.5^{ab}	1.3^{ab}	2.8^{a}	7.9^{b}	10.2^{b}	13.3^{b}	18.9^{b}	16.9^{c}	21.6^{b}	22.9^{b}	20.7^{b}	26.8^{b}
Stalk clear	0.1^{a}	0.8^{a}	3.2^{a}	6.6^{ab}	8.1^{b}	7.9^{a}	13.2^{a}	9.9^{a}	13.4^{a}	14.9^{a}	14.9^{a}	17.9^{a}
Control	0.7^{b}	1.5^{b}	2.8^{a}	6.6^{ab}	7.3^{ab}	7.8^{a}	15.1^{ab}	13.9^{bc}	15.7^{a}	17.4^{a}	18.2^{ab}	24.7^{b}

Table 6: Mean sucker number per plot (5 m of row) in rows one (control plots), three and five at Tully and Babinda.

Row	Tully		Babinda	
	Q138	Q152	Q138	Q152
1	14.25	30.25	35.75[b]	41.50[b]
3	19.75	24.50	27.75[ab]	25.50[a]
5	21.00	21.75	22.00[a]	32.25[ab]
	ns	ns		

ns - F test not significant (P > 0.05)

Table 7: Measurements of PAR as a proportion of sunlight for cultivars Q138 and Q152 at the Tully, Babinda and Mulgrave sites. Measurements were taken at 10 cm and 100 cm above ground on the outside of the crop and in the inter-row space between rows 1 and 2 in the inside of the crop. Means followed by the same letter are not significantly different (P > 0.05).

Treatment	Tully		Babinda		Mulgrave	
	Q138	Q152	Q138	Q152	Q138	Q152
Row						
Inside	0.47	0.48[b]	0.22[a]	0.49	0.65[b]	0.61
Outside	0.51	0.32[a]	0.29[b]	0.53	0.43[a]	0.55
	ns			ns		ns
Height						
10 cm	0.46	0.35[a]	0.23[a]	0.45[a]	0.48[a]	0.52[a]
100 cm	0.52	0.45[b]	0.28[b]	0.58[b]	0.59[b]	0.63[b]
	ns					
Treatment						
Shade (T1)	0.33[a]	0.36	0.14[a]	0.43[a]	0.46[a]	0.46[a]
Control (T5)	0.65[b]	0.43	0.37[b]	0.60[b]	0.62[b]	0.72[b]
		ns				
Row*Treatment						
Inside-Shade	0.45[b]	0.45	0.17[b]	0.46[ab]	0.62[bc]	0.60[b]
Outside-Shade	0.21[a]	0.28	0.12[a]	0.40[a]	0.30[a]	0.32[a]
Inside-Control	0.48[b]	0.51	0.28[c]	0.52[b]	0.69[c]	0.62[b]
Outside-Control	0.81[c]	0.36	0.46[d]	0.67[c]	0.55[b]	0.78[c]
		ns				

ns - F test not significant (p > 0.05)

There was a significant effect of the shading treatments on the red/far-red ratio of light at three of the four sites sampled (Table 8). At the Tully Q138 and the Mulgrave Q152 sites, the side shade treatment (T1) had significantly lower red/far-red ratio than the control (T5) and stalk clear (T4) treatments, as well as sunlight. The control and stalk clear treatments had significantly lower red/far-red ratios than sunlight, but not from each other. At the Mulgrave Q138 site, the three treatments, side shade (T1), stalk clear (T4) and control (T5) all had a significantly lower red/far-red ratio than sunlight, but not from each other. There was no significant difference in red/far-red ratio at the Babinda Q138 site (P > 0.05).

Table 8: Mean red/far-red ratio of light following the shading of the outside row of sugarcane. Means followed by the same letter are not significantly different (P > 0.05).

Treatment	Tully Q138	Babinda Q138	Mulgrave	
			Q138	Q152
Side shade (T1)	0.98[a]	1.04	1.06[a]	0.98[a]
Stalk clear (T4)	1.11[b]	0.97	1.17[a]	1.09[b]
Control (T5)	1.15[b]	1.03	1.17[a]	1.12[b]
Sunlight	1.33[c]	1.27	1.31[b]	1.27[c]
		ns		

ns - F test not significant (P > 0.05)

The red/far-red ratio of light passing through shade cloth and dry leaf sheath was measured to determine whether light quality was affected by the treatments (Table 9). The shade cloth was found to be spectrally neutral, with a red/far-red ratio of the light passing through it being similar to that of sunlight. Both green leaf and dry leaf sheath significantly reduced the red/far-red ratio, but green leaf reduced the ratio more than dry leaf sheath.

Table 9: Mean red/far-red ratio of sunlight and that of light passing through shade cloth, dry leaf sheath and green leaf (n = 4). Means followed by the same letter are not significantly different (P > 0.05).

Treatment	Red/Far-red ratio
Shade cloth	1.28[c]
Dry leaf sheath	0.89[b]
Green leaf	0.04[a]
Sunlight	1.30[c]

Shading the outside row of cane (T1) significantly reduced the temperature below ground (about 5 cm) compared to the control (T5) treatment (Figure 4). The below-ground temperature for treatments T1 and T5 were both significantly cooler than the outside control, which was not shaded by sugarcane during the day. Shading of the outside row of cane also significantly reduced the air temperature behind the shade cloth (T1). This effect on air temperature was small when compared to the effect on ground temperature. The outside control and the air temperature in T5 were significantly different at 9 and 10 am only.

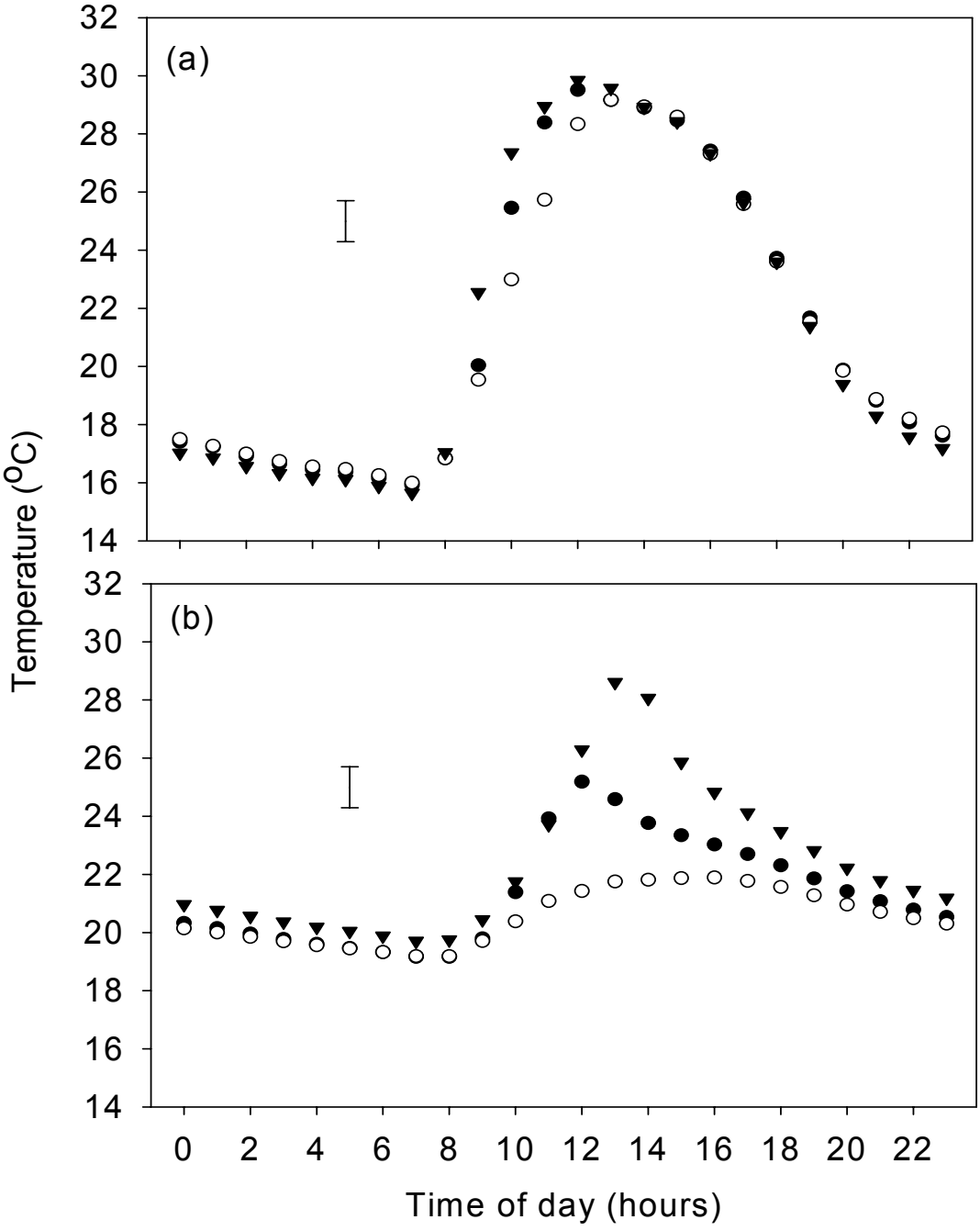

Figure 4: **Effect of shading the outside row of cane on (a) air and (b) soil temperature as measured by thermocouples at the Q152 site in Tully. Treatments were: ● Control (T5) ○ Side shade (T1); and ▼ Outside temperature. Average of 22 days. Error bars represent LSD ($P < 0.05$).**

3.2.4 Discussion

Shading the outside row of sugarcane by placing shade cloth alongside the row (T1) had very little effect on the number of suckers behind the shade cloth. There was virtually no difference between the T1 treatment and control for any of the crops. Where there was a difference, Mulgrave Q138, it appeared that this may have been due to a significant difference between the two treatments when the treatments were first established. This significant difference was initially maintained, but was then lost when sucker numbers increased later in the year.

The light measurements showed that the amount of light directly behind the shade cloth was significantly reduced, but they also revealed that for all sites except Babinda Q138, there was no difference in the amount of light in the inter-row space between rows 1 and 2. Therefore, while the treatment may have lowered light on one side of the stool, the light characteristics on the other side of the stool remained similar to the control. The treatment was designed to prevent light from entering the crop from the side. However, if sufficient light was passing through the canopy, then possibly there was sufficient light to prevent any differences between T1 and the control being expressed.

Differences were found in the red/far-red ratio of light between T1 and the control. However the measurements were only taken immediately behind the shade cloth, and given the PAR measurements, it appears likely that no difference would have been found in the inter-row space between rows 1 and 2. The red/far-red ratio difference may have been due to the T1 treatment reducing the amount of sprawling of the canopy, and thus the light would have passed through more green leaf before reaching the base of the stalks. Sprawling may have been reduced by the wire supports that were used to hold the shade cloth in place.

The sucker counts taken on 19 July 1999 showed that there was not a significant edge effect at the Tully site for both cultivars, but there was an edge effect at the Babinda site for both cultivars. The edge effect at the Babinda sites was not as pronounced as that found by Bonnett *et al*. (2001) in a crop grown in the Burdekin region. Bonnett *et al.* found that the outside row of the crop had on average 21 suckers per 3 m whereas the second row did not produce any suckers. This too could provide evidence for sufficient amounts of light passing through the crop canopy. Placing shade cloth alongside the outside row of a crop that had a good canopy such as those found in the Burdekin district may result in reduced suckering as the main source of light incident on the stalks in the outside row would be reduced due to the presence of the shade cloth. It should be noted that the Burdekin district generally produces big crops with good canopies, whereas crops in the wet tropics often have poor canopies due to poor weather conditions. Consequently the light environment of the outside and inside rows in the tropics would have been more similar than in the Burdekin. The lack of an edge effect at Tully is interesting considering that no effect of treatment was found for either cultivar at this site.

Placing shade cloth along the outside row of cane also had an effect on both soil and air temperature behind the shade cloth. This was not associated with differences in the number of suckers. While soil temperature was similar for T1 and T5 at night, during the day, T5 reached a maximum mean temperature of 25.2°C, whereas the maximum mean temperature behind the shade cloth only reached 21.9°C. There were also small differences in air temperature between treatments T1 and T5. This was mainly due to the

shade cloth reducing the temperature behind it during the morning. Once the sun was directly overhead (midday), the air temperature differences were lost. The crops facing west may have experienced this difference during the afternoon, as the temperature measurements were taken from a crop that faced east.

Rands and Dopp (1938) found an increase in tillering from 20°C to 30°C in sugarcane. However, this result may be dependent on the cultivar used, as Glasziou *et al*. (1965) found significantly higher tiller numbers at 18 and 22°C compared to 25, 30 and 34°C for the sugarcane cultivar Pindar. Ebrahim *et al*. (1998) found that tiller formation was greatest at 45°C and least at 15°C for cultivar H50-7209. The tillering response of cultivars Q138 and Q152 to different temperature treatments has not been reported. Therefore, it is difficult to determine whether temperature changes, found during the day only, following the shading of the outside row of cane, could have contributed to changes in suckering. Furthermore, it is not known whether suckering responds to temperature in a similar manner as tillering in sugarcane.

It was noted from this experiment that there was a trend that the two treatments where the dead leaf (trash) was removed from the stalk had a higher number of suckers than the treatments where dead leaf was left attached to the stalk. This was despite T2 being shaded after the trash was removed. Removing dead leaf would potentially expose more of the stalk to light, which could explain why the trash removed treatment tended to have higher number of suckers, but this would not be the case for the T2 treatment.

One explanation for this trend may be light quality. The data in Table 9 show the red/far-red ratio of light passing through dead leaf, shade cloth, green leaf and the red/far-red ratio of sunlight. These data show that while green leaf caused a significant reduction in the red/far-red ratio of the light passing through it due to the absorption of red light in photosynthesis, dead leaf also significantly reduced the ratio from that of sunlight and light passing through the shade cloth. The data only represents the reduction in red/far-red ratio due to one leaf sheath. Removing all the dead leaves from stalks in a crop could increase the red/far-red ratio even more than the data indicates due to incident light on stalks being affected by many dead leaves. Therefore, removing trash may have brought about an increase in the red/far-red ratio of the light incident on the stalks. Shading the stalks with shade cloth would have decreased the amount of light incident on the stalks but the red/far-red ratio would have remained high due to the removal of dead leaf and the shade cloth being spectrally neutral. Holmes and Wagner (1980) have shown that a number of phytochrome-mediated responses can occur when the amount of light is very low (night sky).

3.3 Trash stripping and its influence on suckering

The trend toward increased suckering with the removal of dead leaf from the stalk noted above was possibly due to changes in the light incident on the stalks. To test this hypothesis further, an experiment was established where dead leaf (trash) was removed from stalks of several sugarcane cultivars.

3.3.1 Methods

The experiments were established in existing BSES cultivar by nitrogen fertilisation trials, at Mulgrave and Tully (details in Table 10). The BSES trials contained five cultivars, four nitrogen rates (0, 60, 120 and 180 kg N/ha), with three replicates. The trials were arranged in a randomised block design. Plot size was four rows by 15 m. Trash (dead leaf) was removed from two 5 m sections of row in each plot (Figure 5). Two 5-m sections of row, where trash was left attached to the stalk, were marked as controls in each plot. The two 5 m sections per treatment were averaged before analysis. These subplots were established in the middle two rows of each plot. Dead leaf was left on the ground in the inter-row space. Suckers were counted at the Mulgrave site on 14 June and 21 July 2000 and at the Tully site on 24 July 2000.

Table 10: Dates of crop planting, nitrogen application, and the application of leaf trash removal treatments, in BSES experiments at Tully and Mulgrave involving five sugarcane cultivars.

Crop	Planted	Nitrogen application	Trash removed	Cultivars
Tully	21/7/99	27/10/99	14/3/00*	Q117, Q120, Q152, Q186$^{\phi}$, Q187$^{\phi}$
Mulgrave	22/7/99	1/11/99	10/5/00*	Q113, Q120, Q152, Q186$^{\phi}$, Q187$^{\phi}$

*Trash was removed at regular intervals following this date.

Figure 5: Stalks with their trash removed, Tully 2000

PAR was measured at the base of the stalks (10 cm above ground) on the date of the final sucker count in each district using a ACUPAR Linear PAR Captometer. The readings were taken in the middle of each subplot. The measurements for each subplot were averaged prior to analysis. This gave one measurement for trash removed and trash

present per plot. Measurements were also taken outside of the crop, and were used to calculate the proportion of light available beneath the canopy.

Sucker numbers were initially analysed using ANOVA. The data were also analysed using paired t-tests. This was done, as there was large variation in sucker numbers between plots, but trash removed treatments tended to have a higher number of suckers than trash present, whether or not the plot had a high or low number of suckers. The paired t-test removed the variation found between plots, possibly due to environmental factors, from the analysis.

3.3.2 Results

Analysis of variance for the sucker counts taken on 14 June 2000 at Mulgrave indicated that there was a highly significant difference in the number of suckers due to cultivar ($P < 0.01$) and a significantly greater number of suckers in the trash removed subplots ($P < 0.01$). There was no significant difference in the number of suckers due to nitrogen application rate and no significant interaction effects (Table 11).

Table 11: Mean sucker number per plot (5 m) in cultivar by nitrogen trials at Mulgrave and Tully. Data were square-root transformed prior to analysis. Means followed by the same letter are not significantly different (P > 0.05).

Main effects	Mulgrave		Tully
	14/6/00	21/7/00	24/7/00
Cultivar			
Q113	0.79[a]	8.65[b]	
Q117			0.06[a]
Q120	9.48[c]	15.94[c]	0.42[a]
Q152	10.98[d]	27.19[d]	18.94[b]
Q186(l)	0.58[a]	4.63[a]	0.35[a]
Q187(l)	3.00[b]	6.75[ab]	0.08[a]
Treatment			
Trash removed	5.67[b]	14.73[b]	3.97
Trash present	4.27[a]	10.53[a]	3.98
			ns
Nitrogen (kg/ha)			
0	4.62	12.18	3.95
60	4.43	11.20	4.03
120	5.83	14.83	4.28
180	4.98	12.30	3.62
	ns	ns	ns

ns - F test not significant ($p > 0.05$)

Analysis of variance for the sucker counts taken on 21 July 2000 at Mulgrave indicted that there was a highly significant difference in sucker number due to cultivar ($P < 0.01$) and a highly significant difference due to the removal of trash ($P < 0.01$). There was no significant difference in sucker number due to nitrogen application rate and no significant interaction effects (Table 11).

Analysis of variance for the sucker count from the Tully site indicated that there was a highly significant difference in sucker number due to cultivar ($P < 0.01$), but there was no significant difference due to the removal of trash or nitrogen application rates. There were no significant interaction effects. Suckering in all cultivars, except Q152, was very low at this site (Table 11).

Using paired t-tests, a significant difference was found between the trash removed and trash attached treatments at the Mulgrave site, but not at the Tully site (Table 12).

Table 12: Paired t-test of trash removed versus trash present at Mulgrave and Tully.

Site	**Mulgrave**				**Tully**	
Date	14/6/00		21/7/00		24/7/00	
Treatment	Trash removed	Trash	Trash removed	Trash	Trash removed	Trash
Mean	5.667	4.267	14.725	10.533	3.967	3.975
Mean difference	1.4		4.192		-0.008	
S.D. difference	2.696		4.683		2.603	
t	4.022		6.933		-0.025	
df	59		59		59	
Prob.	0.000		0.000		0.980	

Table 13: Differences between trash removed (rem) and trash present for five cultivars at the Mulgrave site on two dates using paired t-tests.

Cultivar	**Date**	**Treatment**	**Mean**	**S.D. difference**	**Prob.**
Q113	14/6/00	Trash (rem)	1.125	1.303	0.104
		Trash	0.458		
	21/7/00	Trash (rem)	10.375	4.984	0.035
		Trash	6.917		
Q120	14/6/00	Trash (rem)	10.208	3.421	0.168
		Trash	8.750		
	21/7/00	Trash (rem)	17.625	3.061	0.003
		Trash	14.250		
Q152	14/6/00	Trash (rem)	12.542	3.920	0.019
		Trash	9.417		
	21/7/00	Trash (rem)	31.375	6.161	0.001
		Trash	23.000		
Q186$^{\phi}$	14/6/00	Trash (rem)	0.833	0.929	0.089
		Trash	0.333		
	21/7/00	Trash (rem)	6.208	2.683	0.002
		Trash	3.042		
Q187$^{\phi}$	14/6/00	Trash (rem)	3.625	2.148	0.069
		Trash	2.375		
	21/7/00	Trash (rem)	8.042	3.728	0.035
		Trash	5.458		

Paired t-tests were used to analyse the effect of removing trash on each cultivar. The results of this analysis from the Mulgrave site are shown in Table 13. At the last date all cultivars showed a significant effect ($P \leq 0.03$). No significant differences were found at the Tully site, and therefore they have not been included in the Table.

Analysis of variance of the light measurements taken at Mulgrave and Tully revealed that significantly more light reaching the stalk bases in the trash removed subplots than the trash present subplots (Table 14).

Table 14: Proportion of light reaching stalk bases in the trash removed and trash present subplots at Mulgrave and Tully. Means followed by the same letter are not significantly different (P > 0.05).

Effect	Mulgrave	Tully
Treatment		
Trash removed	0.14[b]	0.13[b]
Trash present	0.07[a]	0.08[a]
Cultivar		
Q117		0.13
Q152	0.10	0.10
Q186[ф]	0.11	0.09
	ns	ns
Nitrogen (kg/ha)		
0	0.10	0.10
120	0.10	0.12
	ns	ns

ns - F test not significant (P > 0.05)

3.3.3 Discussion

Removing dead leaf from the stalks significantly increased suckering in all five cultivars in the Mulgrave district. However, the same treatment did not result in increased suckering at the Tully site. The lack of response at Tully seemed to be partly due to there being very limited suckering at the site, and therefore any difference between treatments was not expressed. However, cultivar Q152 which did sucker at Tully, did not show any significant difference in sucker number between trash removed and trash present treatments.

Light measurements indicated that removing dead leaf resulted in increased light availability at the base of the stalks at both sites. Therefore, this increase in available light may have caused the increase in sucker numbers at the Mulgrave site. Tillering in sugarcane has been shown to be affected by the amount of available light (Verret and McLennan 1927; Martin and Eckart 1933). The results from our experiment also suggest that the formation of late tillers is also similarly affected by the amount of available light. Why no difference was found at the Tully site is not known, but possibly other factors, which were causing very low sucker number at this site in all cultivars except Q152, were involved. If the Tully crop had a good canopy, then possibly removing dead leaf would have had little effect on the light incident on the stalks, as the crop canopy would be responsible for filtering more light than the removal of dead leaf. However, the amount of light reaching the stalk bases was similar at both sites. This would indicate a similar

canopy structure. The cause of the differences between the two locations is not known, but factors like temperature, or water availability may have been involved.

No effect on sucker number was found due to nitrogen application rate at either site. This evidence is similar to that found by Berding and Hurney (2000), where nitrogen application rates at the start of the growing season had no effect on sucker number. The Mulgrave site was partly waterlogged for much of the season, and this may have meant that differences between plots in terms of nitrogen application were lost due to leaching and other denitrification processes. As presented elsewhere there is evidence that nitrogen can play an important role in suckering.

While removing dead leaf increased sucker numbers at Mulgrave, it was not the primary factor in determining sucker number. Sucker number was highly variable between plots, due to some unknown factor(s), and the removal of trash increased the sucker number only slightly above this background level.

3.4 Effect of delayed and staggered nitrogenous fertilization on sucker initiation Q152

We used staggered applications of additional 70 kg ha^{-1} of nitrogen (as ammonium nitrate) to a crop of Q152 in Tully (property of Angelo Maifredi) to test the effect of delayed applications on sucker development.

3.4.1 Methods

Plot size was four rows by 5 m. Only the middle two rows were used to collect data. Row spacing was 1.5 m, and there was a 1 m buffer between plots. All plots were located in the outside four rows of the crop, as it was thought that this would be the area least affected by lodging. Lodging has been speculated to increase the presence of suckers and, if this were true, lodging could confound the interpretation of results. Plots were arranged in a randomised block design, replicated five times. Rainfall data were collected from the Bureau of Meteorology station in Tully (Weather station no. 32042), 8 km north of the trial site. Temperature data were taken from a weather station located at Feluga, approximately 16 km north of the trial site.

All plots received 150 kg N/ha after ratooning on the 4 October 1998. Three treatments were initiated where 70 kg N/ha equivalent was applied. In treatment 1, the additional nitrogen was applied on 10 May 1999; in treatment 2, on 8 June 1999; and in treatment 3, on 20 July 1999. The additional nitrogen was applied as ammonium nitrate (34.5% N, Pivot Ltd.).

Sucker numbers were counted in each plot regularly, after the additional N application, until the crop was harvested. A final sample was conducted on the 17 September 1999. All suckers in row 2 for three replicates only, were cut out of the plots, counted and weighed. Sampling suckers in all replicates and rows was not possible due to short notice of the unexpected harvest of the crop. Soil samples were taken on four occasions (28 May, 23 June, 20 July and 25 August) to determine whether the nitrogen application increased soil nitrate levels, an indication of plant available N. On each occasion two soil cores (50 mm diameter) to a depth of 50 cm were taken. Cores were separated into 10-cm

increments (0-10 cm, 11-20 cm, 21-30 cm, 31-40 cm and 41-50 cm). Only 0-10 cm, 21-30 cm, and 41-50 cm increments were collected at the final soil sampling.

Soils were kept at 4°C after sampling, and were later air-dried. Nitrate was extracted using 2 M KCl. Each extraction consisted of 4 g soil in 40 mL KCl. Soil nitrate concentration was determined using an adaptation of the method of Best (1976).

3.4.2 Results

The application of nitrogen, late in the growing season, resulted in an increase in sucker number in all treatments (Figure 6). The applications in May and July were followed by significant increases in sucker number, over the control, approximately 40 days after application. The June application only resulted in significant increases in sucker number after 85 days. The sucker number following the May application was significantly higher than the July application and control on the 1 September count (day 115, Figure 6). June and July applications were not significantly different to each other but were significantly higher than the control.

Sucker numbers nearly doubled between 1 September and the 17 September (compare Figure 6 and Table 15). There was no significant difference between the number of suckers, total fresh mass of suckers and average fresh mass of suckers for any of the treatments at the final harvest (Table 15). Despite only a proportion of the experiment being harvested on 17 September, the large increase in sucker number in the last 2 weeks was a real phenomenon. When analysed individually, both the middle rows of the plot, used to collect data, showed similar sucker numbers and were significantly higher than the control. Consequently, there was no evidence of a sampling error.

Table 15: Sucker number, fresh mass and average fresh mass at final harvest (17 September 1999). Data represent an average of three replicates from row 2. Differences are not significant (P = 0.05).

Treatment	Number of suckers	Total mass (kg)	Mass per sucker (g)
May application	152.0	121.2	79.8
June application	118.7	103.5	86.8
July application	142.7	124.0	86.5
Control	129.3	112.7	86.8

There were roughly 25 suckers per metre in the control plots at this final harvest, but many were obviously very small. While not all of these suckers were large enough to be included in a commercial harvest, it does given an indication of the potential extent of suckering.

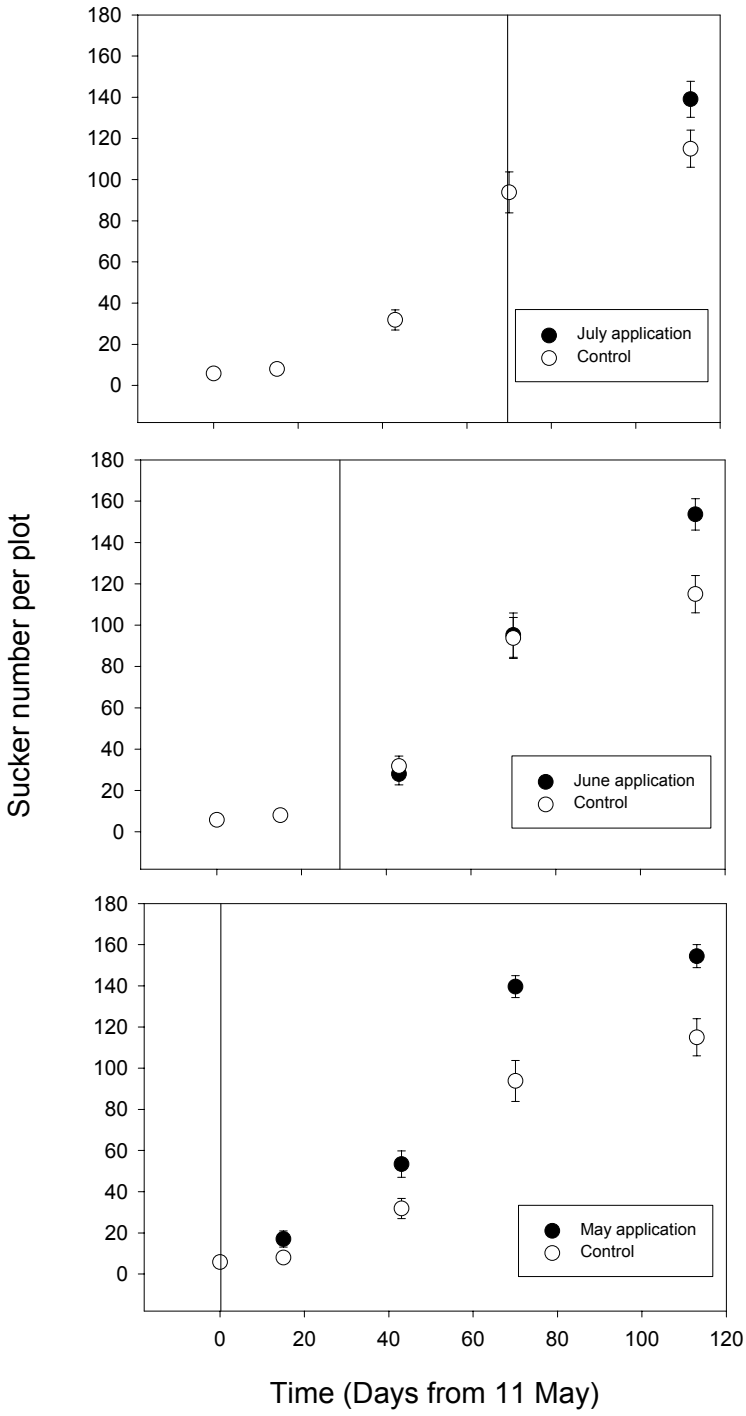

Figure 6: **Sucker numbers following nitrogen application. Vertical lines represent the time of application. Error bars represent ± standard error of the mean.**

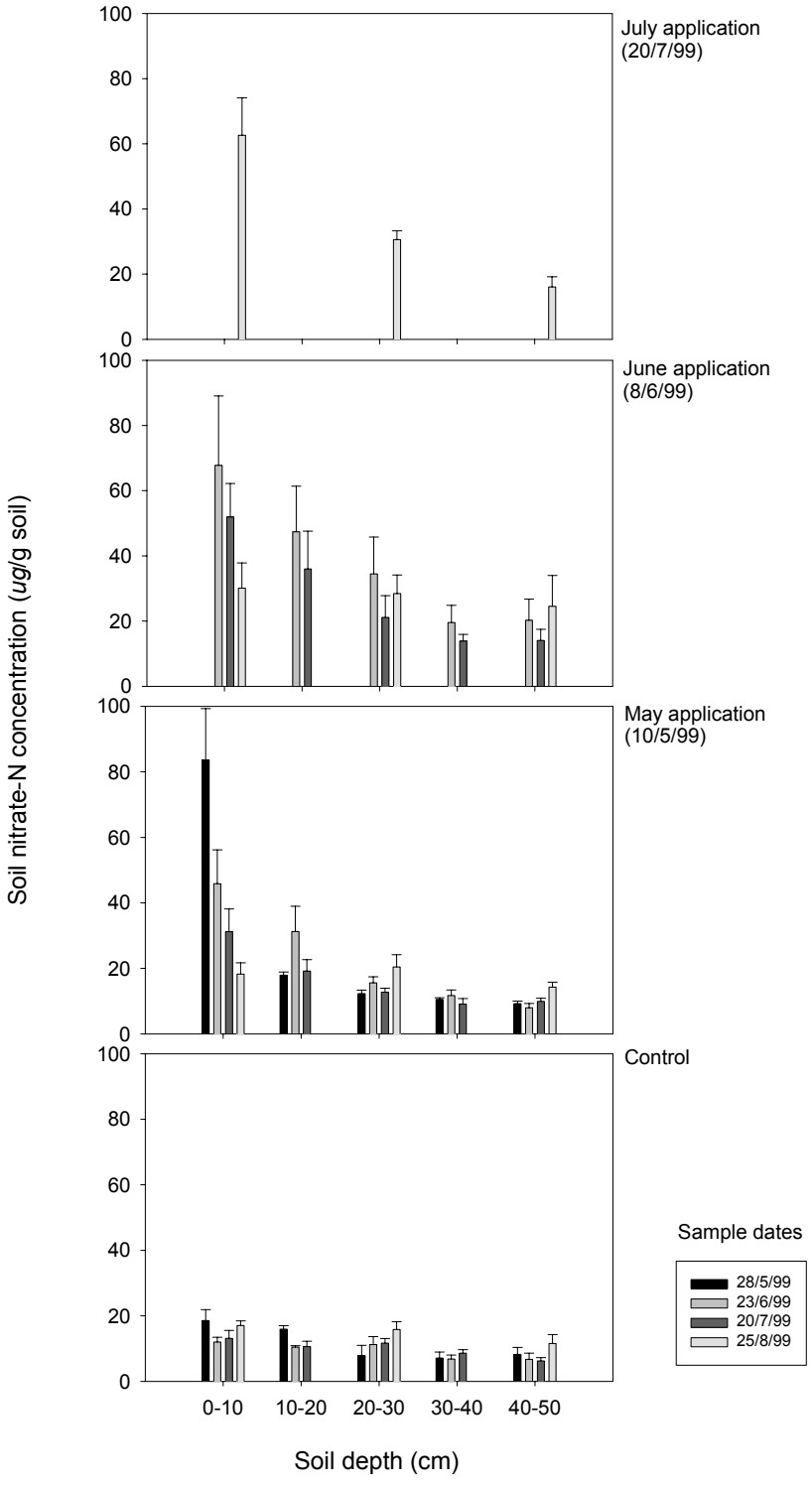

Figure 7: **Soil-nitrate concentrations following application of additional nitrogen fertiliser at three occasions late in the growing season. Error bars represent ± one standard error of the mean.**

The soil nitrate concentrations in each soil sample are shown in Figure 7. While soil nitrate does not represent total N in the soil available in the plant, it does give some indication as to whether or not N applications were having an effect on plant available N. Soil nitrate after the May application of N was significantly higher than the control in the first 10 cm of soil, on the 28 May and 20 July. The nitrate concentration after the June application of N was significantly higher than the control, in the first 10 cm of soil, on the 20 July and 25 August. The nitrate concentration after the July application of N was significantly higher than the control, in the first 10 cm of soil, on 25 August. These data show that the nitrogen application did raise the level of soil nitrate in the soil near the surface and consequently could be the stimulus for the additional suckers produced up to the beginning of September.

3.4.3 Discussion

The results show that an increase in the amount of plant-available nitrogen following the wet season increases sucker number and, thus, is a factor that either initiates or stimulates the development and/or growth of suckers.

3.5 Effect of a late nitrogen application on a strongly and a weakly suckering cultivar

A second experiment with delayed nitrogen application was conducted in an attempt to confirm the above results, see if the effect could be detected at lower rates of nitrogen fertiliser application, and to see if the effect was consistent across both strongly and weakly suckering cultivars.

3.5.1 Methods

The experiment was conducted on A. Zappalla's farm, approximately 15 km north of Babinda (17°30'S 145°50'E), in far-northern Queensland in the 1999-2000 season. Two cultivars were chosen, Q152 and Q181$^{\phi}$ (both first ratoon, last harvest 1 September 1999). Both crops received 100 kg N/ha following ratooning. Q152 is known to have a high propensity to sucker, whereas Q181$^{\phi}$ is known to have a low propensity to sucker. This comparison is based on observations rather than counts.

In both crops, plot size was 5 m by 4 rows, with a 1-m gap between plots. Plots were arranged in a randomised block design. Blocks were arranged linearly, in the same four rows of cane. It was not possible to use the outside four rows of the crop in this experiment, but neither crop lodged throughout the duration of the experiment. The two cultivars were grown adjacent to each other and experimental plots were separated by two rows of cane (Figure 8).

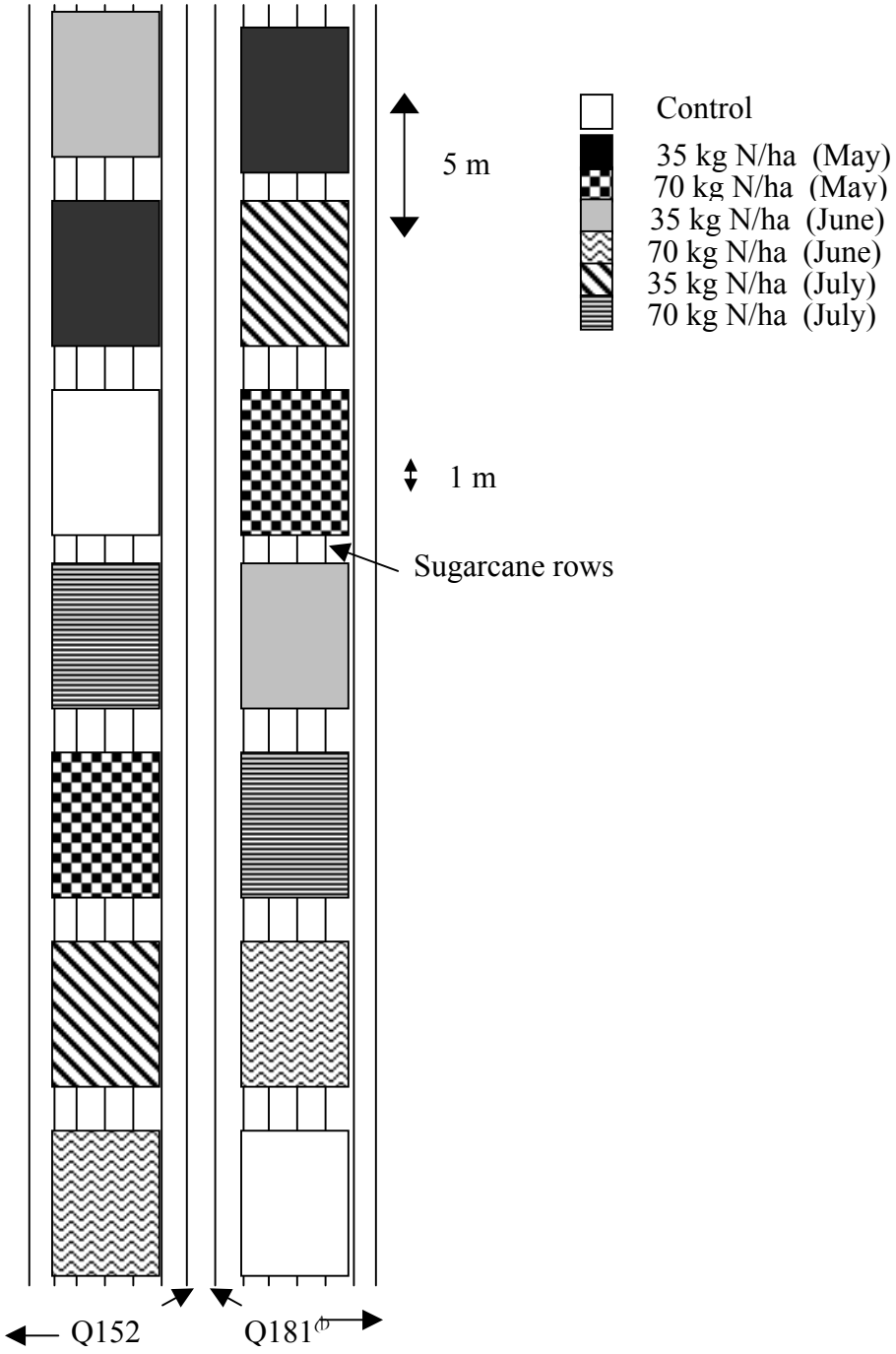

Figure 8: **Experimental design and plot layout for late nitrogen application to a strongly and weakly suckering cultivar. Seven treatments were initiated: 35 kg N /ha and 70 kg N/ha was added to different plots in May, June and July, as well as a control, which received no additional nitrogen. The figure depicts one of five replicate blocks.**

Seven treatments were initiated: 35 kg N /ha and 70 kg N/ha was added to different plots in May, June and July, as well as a control, which received no additional N. Fertiliser was applied to plots on 17 May 2000 (May applications), 23 June 2000 (June applications) and 26 July (July applications). Nitrogen was applied as ammonium nitrate (34.5% N, Pivot Ltd.) and was spread by hand.

Sucker counts were conducted in the middle two rows of each plot. A preliminary sucker count was taken on 17 May 2000, before any additional nitrogen had been applied. Further sucker counts were conducted on 23 June and 26 July 2000. No sucker counts were taken for the July application treatments due to the early commercial harvest of the crop. Early commercial harvest prevented a final sample of the experimental plots to determine sucker mass, mature stalk counts and nitrogen content of mature stalks. Commercial harvests occurred earlier than expected due to a short harvest season length in 2000. This was primarily due to poor yield in the wet tropics region.

Soil samples were taken on 11 May, 31 May, 5 July and 16 August 2000 using an auger. On 11 May 2000, 10 cores (20 mm diameter) to 50 cm were taken at random within the experimental area. This was done to ascertain the background level of nitrate-N and ammonium-N prior to the establishment of the experiment. On the other three sample dates, three cores (20 mm diameter) to 50 cm were taken from each plot. Cores from each plot were divided into 0-25 cm and 25.1-50 cm increments, pooled and stored at 4°C, until soil N extraction was conducted.

Soil nitrate-N and ammonium-N were extracted from the soil using 2 M KCl solutions. Soil nitrate concentration was determined using the method of Best (1976) and soil ammonium concentration was determined using an adaptation of the method described by Nelson (1983).

Sucker counts were analysed using a general linear model (GLM) for randomised block designs, with treatment and blocks as dependent variables, on each sample date. The sucker-number data were square-root transformed to meet the assumption of a normalised distribution. Sucker-number data were compared using orthogonal comparisons. Soil nitrate-N and ammonium-N data were analysed using two-way ANOVA on each sample date, with treatment and soil depth as factors. Post-hoc comparisons of means were conducted using Fisher's LSD ($P \leq 0.05$).

3.5.2 Results

The mean sucker numbers following a late nitrogen application of 70 kg N/ha and 35 kg N/ha to cultivars Q152 and Q181[ф] are shown in Table 16 and Figure 9. GLM analysis found a significant effect due to treatments and blocks on 28 June and 26 July for both cultivars.

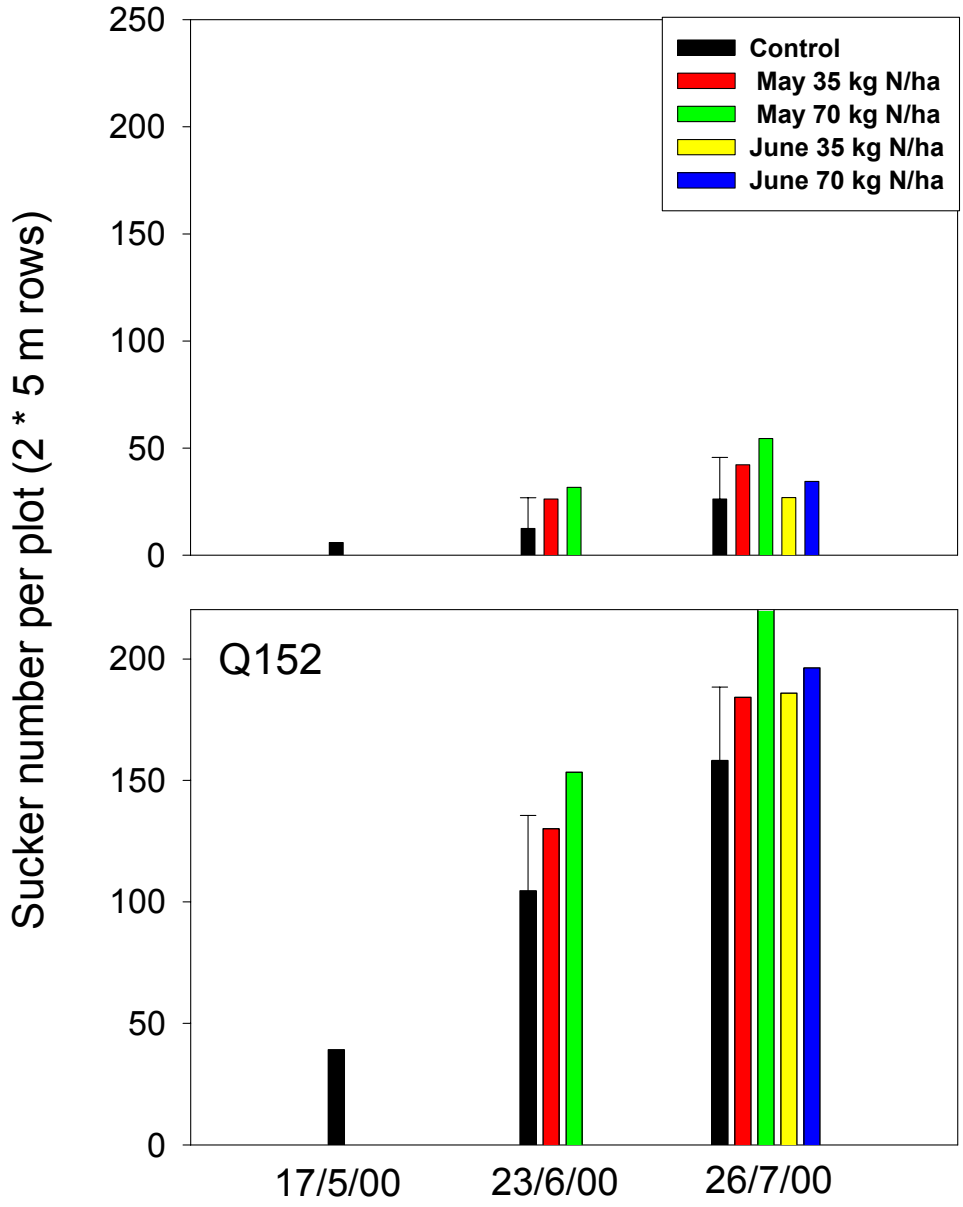

Figure 9: **Numbers of suckers following late N applications to a high (Q152) (lower) and low (Q181$^{\Phi}$) (upper) suckering cultivar. Bars represent LSD.**

Table 16: Sucker number per plot following the late application of nitrogen to cultivars Q152 and Q181$^{\phi}$ on 17 May, 28 June 2000 and 26 July 2000.

Cultivar	Treatment	Sample date		
		17 May	28 June	26 July
Q152	Control	39.2	104.6	158.2
	35 kg N/ha in May		130.2	184.2
	70 kg N/ha in May		153.4	220.4
	35 kg N/ha in June			186.0
	70 kg N/ha in June			196.4
Q181$^{\phi}$	Control	5.8	12.4	26.2
	35 kg N/ha in May		26.2	42.2
	70 kg N/ha in May		31.6	54.4
	35 kg N/ha in June			26.8
	70 kg N/ha in June			34.4

Orthogonal comparisons for the data taken on 28 June show a significant increase in sucker number due to nitrogen application, but there was not a significant difference ($P > 0.05$) between the two application rates. This was true for both cultivars.

As up to 10 comparisons can be made from the data taken on 26 July for each cultivar, the probability of a type I error is high. To control for this, the data were analysed using orthogonal comparisons. For both cultivars there was a significant increase in sucker number, over the control, due to the addition of nitrogen (Table 17). There was a significant difference in sucker number due to the application dates for Q181$^{\phi}$, but not for Q152, and there was a significant difference due to the application rates for Q152 in May, but not Q181$^{\phi}$. There was no significant difference in either cultivar due to application rate in June.

Table 17: Orthogonal comparisons between means for sucker number data taken on 26 July 2000.

Comparison					**Significance**	
Control	May 35 kg N/ha	May 70 kg N/ha	June 35 kg N/ha	June 70 kg N/ha	Q152	Q181$^{\phi}$
-4	1	1	1	1	*	*
0	-2	-2	2	2	ns	*
0	1	-1	0	0	*	ns
0	0	0	1	-1	ns	ns

* - F test significant ($P \leq 0.05$)
ns - F test not significant ($P > 0.05$)

No significant difference due to treatment was found in soil nitrate-N and soil ammonium-N on 31 May 2000 (Table 18). Significant differences due to treatment were found for both soil nitrate-N and ammonium-N on 5 July 2000. This was due to a significant increase in concentration in the 70 kg N/ha plots applied in June. This significant difference had dissipated by the final sample on 16 August 2000.

Table 18: Soil nitrate-N and ammonium-N following the additional application of nitrogen at three rates. Means followed by the same letter are not significantly different (P > 0.05).

Effect	Soil nitrate-N and ammonium-N (mg g^{-1} dry weight)							
	11 May		31 May		5 July		16 August	
	NO_3-N	NH^4-N	NO_3-N	NH^4-N	NO_3-N	NH^4-N	NO_3-N	NH^4-N
Depth (cm)								
0 - 25	1.2	8.2[a]	14.3	5.9[a]	12.5[a]	12.2[a]	13.4	4.5
25.1 - 50	4.4	3.8[b]	9.6	2.5[b]	5.9[b]	3.1[b]	10.6	3.4
	ns		ns				ns	ns
Treatment								
Control	2.8	6.0	11.4	3.4	7.8[a]	4.5[a]	11.3	3.9
35 kg N/ha May			10.4	4.6	6.2[a]	4.3[a]	12.8	3.2
70 kg N/ha May			14.2	4.6	5.9[a]	4.8[a]	9.1	3.6
35 kg N/ha June					5.8[a]	5.6[a]	9.9	4.5
70 kg N/ha June					20.5[b]	18.8[b]	16.8	4.6
			ns	ns			ns	ns

ns - F test not significant (P > 0.05)

3.5.3 Discussion

Increases in suckering due to late nitrogen applications were again demonstrated. The response to nitrogen was present in both a high and a low suckering cultivar, but even after the application of nitrogen, the difference in the number of suckers between the two cultivars remained, with Q152 producing more than Q181(ϕ). This suggests that the genetic differences in suckering propensity between these two cultivars are independent of the response to nitrogen.

Sucker numbers were found to increase following the May application despite significant differences in soil nitrogen not being found on 31 May 2000. This suggests that the plant responded to increased soil nitrogen, but other processes such as loss of nitrogen due to leaching, volatilisation and loss of nitrogen to the plant may have reduced the levels by the time the soil samples were taken. The soil samples were also only a small subsample of the whole plot, and this may not have allowed small changes to be detected above the natural variation within the plot. The application of 35 kg N/ha did not increase soil nitrate-N or ammonium-N above the levels found in the control plots on any of the sample dates. However, both cultivars had significantly more suckers in the May 35 kg N/ha treatment than in the control by the final count. This also shows that while significant increases in soil nitrogen were not detected, the plants were responding to the treatment, and must have had access to the additional nitrogen at some stage.

Q152 is a cultivar that produces high numbers of thin stalks whereas Q181(ϕ) produces fewer, thicker stalks. This may mean that one of the major differences in suckering potential between these two cultivars is the number of available buds beneath the ground. Potentially the number of suckers per stalk for both cultivars may have been similar. The unexpected early commercial harvest prevented the collection of data that may have elucidated the issue.

3.6 General discussion on preliminary experiments

After discussion of the results of the preliminary experiments by project staff and associates the following recommendations were made for the design and methods for the main experiment:

1. The late nitrogen application of 70 kg N will be in late April early May if the weather is suitable and as soon as possible thereafter if the weather is too wet to allow the application at the desired time.
2. That spectroradiometry measurements will be made in the core plots at a height of 10 cm and 1 m to determine the effect of plant spacing on the spectral composition received. Photosynthetically active radiation measurements will also be made.
3. A similar soil sampling and nitrate measurement regime will be made in the main experiment as that in the preliminary experiment with the exception that more frequent smaller diameter cores will be taken to speed up sampling.
4. Sucker counting and other trial management will continue as originally proposed.
5. Applications of late N will be made in separate experiments on different cultivars and if possible to soils with lower basal nitrate levels than those in the above experiments.

3.7 Main experiment

3.7.1 Methods

This experiment was planted at Tom Watters' property at Highleigh in the Mulgrave Mill district. The experiment tests the effects of three environmental variables, light (spacing), nitrogen and moisture, and their interactions in two cultivars (Q152 and Q138). The irrigated section was planted on 15-20 July 1999 and the rainfed section was planted on 26-28 July 1999.

The trial was established as two contiguous environments in parallel on an east-west axis. Each environment contained five replicates of a randomised complete-block, three-factor, factorial design. The factors were:

- Cultivars: Q138 and Q152;
- Nitrogen applications: plant crop: 0 kg N ha^{-1}; 140 kg N ha^{-1} applied in November 1999; 140 kg N ha^{-1} applied in November 1999 and supplemented with 70 kg N ha^{-1} applied in May 2000; first ratoon: 0 kg N ha^{-1}; 210 kg N ha^{-1} applied on 30-31 October 2000; 140 kg N ha^{-1} applied on 3-31 October 2000 and supplemented with 70 kg N ha^{-1} applied on 18-19 May 2001;
- Within-row plant spacings: 0.5 m two-sett bundles planted at 0.5, 1.0 and 1.5 m centre to centre within rows, 1.5 m apart.

Plots were six rows wide and 9.5 m long, and contained a marked, central 'core' area two rows wide and 3.0 m long on which all measurements were conducted. Each spacing treatment contained the following measurable sub-units:

- 0.5 m - two rows, six contiguous stools at 0.5 m spacing, treated as a unit;
- 1.0 m - two rows, three spaced stools at 1.0 m;
- 1.5 m - two rows, two spaced stools at 1.5 m.

Environmental conditions at the trial site were monitored with a Campbell Scientific (UT) data logger (Model CX10) fitted with dual temperature and humidity probes (HMP35C and HMP45C), a photosynthetic active radiation (PAR) sensor, and a tipping-bucket rain gauge. As indicated in the previous report, irrigation was scheduled using a A-pan evaporation tank built to Australian Bureau of Meteorology specifications in stainless steel. Data from this also were recorded.

In the plant crop, the environments were treated identically until June 2000. From 15 June until 24 August, one was trickle irrigated to maintain a field capacity of approximately 18% moisture, a level determined during a drying cycle following heavy monsoonal rain earlier in the year. Initially, the environment was brought to the desired field capacity with extended irrigation. A 3-day moving-mean moisture balance ratio, [(precipitation + irrigation)/evaporation], was kept at 1.0 to maintain this moisture level. Evaporation data were obtained from an A-pan evaporation tank. Soil moisture also was monitored with time domain reflectometry instrumentation. The other environment remained rainfed until harvest. In the first ratoon, a similar regimen was implemented from 17 May 2001.

In the plant crop, data were collected on five occasions: 27 January-1 February (182 days after planting (DAP)); 10-14 April (256 DAP); 16-18 May (292 DAP); 19-23 June (326 DAP); 15-22 August (383 DAP). In the first ratoon, data were collected on four occasions: 5-9 March 2001 (183 DAR); 9-10 May 2001 (246 DAR); 21-22 June (289 DAR); and 24-28 September 2001 (386 DAR). Mature stalks were counted at each sampling. Because the first count was done in a transitional period and the tiller population was being reduced through senescence, two classes of stalks were counted. Stalks with a last exposed dewlap about 1.4 m above ground were counted as ‘substantial stalks’. This number, together with stalks of lesser growth that were unlikely to survive until maturity, yielded a ‘total stalks’ count. The ‘substantial stalks’ in this first count equate to the ‘total stalks’ count in subsequent counts. The number of broken mature stalks was recorded at the third count. Sucker culms were present at the second count, although in low numbers, and these were counted from the second to the fifth count. At the fifth count in the plant crop, stools also were assigned a ‘movement rating’. This was because of the cyclonic conditions the trial had been subjected to on 27 February, early in the 2000 growing season. Each spacing unit was assigned a rating on a 0-3 scale, where:

- 0 = no visible movement between the stool and the surrounding earth;
- 1 = movement sufficient to reveal roots;
- 2 = movement between the stool and surrounding earth sufficient to open a crack > 30 mm wide but < 50% of the immediate root volume;
- 3 = stool had moved sufficiently to expose > 50% of the immediate root volume.

The guarded core plot areas were harvested by hand on 4-8 September 2000 in the plant crop and 1-4 October 2001 in the first ratoon. Mature stalks in each plot were cut, topped, and stripped, and weighed using a bipod and boom mounted spring scales, the bundles of cane being collected for weighing using a grab. Six stalks were taken at random for laboratory analyses. Sucker culms in the core area had all leaves above the last exposed dewlap removed. They were collected and weighed. These also were sent to the laboratory for analyses. Sucker weights in many plots were insufficient for analysis. In these cases, treatments were aggregated over replicates until sufficient material (about 3 kg) was available to allow conduct of analyses.

Material was analyses by methods employed routinely at BSES Meringa. Samples were fibrated using a Codistil Dedini disintegrator, mixed for 90 s, and presented with the large cassette (80 by 80 by 1,000 mm) module for scanned by a NIRSystems Model 6500 spectrophotometer. Spectral data in the range 800-2,200 nm were captured as an average of 95 spectral scans per cassette of plant-crop material and 48 spectral scans of the first-ratoon material. The spectral populations collected fitted comfortably, as judged by the global 'H' statistic, into the spectral population from which calibrations for brix, CCS, fibre, moisture and pol reading were developed. This latter population, which was temporally and spatially diverse, was collected over 2 years for mixed populations of samples of mature stalks and sucker culms. All these quality components were predicted for the mature stalk and sucker culm samples.

Data available for analyses for each crop were tonnes cane per hectare (TCH), tonnes sucker culms per hectare (TSuH), and the combined yield of these [T(C + Su)H]. The derived characters percent suckering [%Su = 100.TSuH/T(C+Su)H] and weight per 100 sucker culms [kg/100Su] were computed from these and the number of suckers present per core plot at 383 days after planting. Quality component data were available for brix, CCS, fibre, moisture, and pol reading. Sugar yield for the three crop fractions mature stalks, sucker culms, and the combination of these were computed from TCH, TSuH, and T(C + Su)H and the respective CCS values. The CCS value used for the combined crop fraction (mature stalks + sucker culms) was simply an arithmetically weighted average of the respective yield and CCS values for each plot.

Soil samples were taken in the plant crop on 4 July 2000 in the irrigated Q152 and analysed for soil nitrate-N concentration. Three cores (20-mm auger) were taken from each plot, and were pooled for analysis. All cores were taken as close as possible to the stool. Cores were taken to 50 cm and divided into 0-25 cm and 25.1-50 cm increments for analysis. In the ratoon crop, similar samples were taken 249, 302 and 370 DAR (days after ratooning); prior to the application of the additional 70 kg N ha^{-1} to the 140 + 70 kg N ha^{-1} treatments in May, only the 0 kg N ha^{-1} and 210 kg N ha^{-1} plots were sampled. Following the additional nitrogen application in May, soil samples were taken from plots of all three nitrogen treatments. Three soil cores to 50 cm below ground level were taken per plot with an augur of 2.5 cm diameter. The cores were divided into two depths, 0-25 cm and 25.1-50 cm. The three cores per plot were pooled prior to soil N analysis. Soil nitrate N was determined using standard methods.

Measurements of light were made to determine whether the three stool spacings (0.5, 1.0 and 1.5 m) produced different light environments beneath the canopy. In the plant crop, measurements were taken at 10 and 100 cm above ground (both cultivars, both environments, 140 kg N/ha nitrogen rate). Measurements were taken in the inter-stool space, or at random in the 0.5 m spacing plots due to no obvious inter-stool space. Two measurements were made. The red (660-680 nm)/far-red (720-740 nm) ratio of light was determined on the 28 March 2000 and 25 May 2000 using a Licor 1800 portable spectroradiometer. Photosynthetic active radiation (PAR) was also measured on 25 May 2000 using an ACUPAR Linear PAR Captometer and comparison to an external PAR reference located on a weather station next to the crop. This measurement gives an indication of light quantity, whereas the R/FR ratio gives an indication of light quality. In the ratoon crop, similar measurements were made at 199, 247, 302 and 372 days after ratooning.

In the ratoon crop, sugar measurements were made to compare the composition of the sugars in the suckers and mature stalks from some treatment combinations. Juice was analysed from Q152 at 0.5-m spacings for the 140 + 70 kg N ha^{-1} and 0 kg N ha^{-1} treatments for both the rainfed and irrigated environments. Measurements were made after separating the sugars in the juice by HPLC (Bonnett *et al.* 2001).

In the plant crop, two analyses of variance formats were used. The first equates to a subsampling analysis where, for each spacing, an analysis was conducted over environments, replicates, cultivars and nitrogen levels for data presented on the basis of the spacing unit, i.e., as collected. In the second analysis, mature stalk and sucker culm data were totalled over the spacing units within each plot, and represented the number present in a plot two rows wide and 3 m long, and analysed over environments, replicates, cultivars, nitrogen levels, and spacings. For the stool movement data, the plot mean, and not the total was the basis of the analysis. Analyses of variances were conducted using MSTAT-C V.2.1. Missing plot values were estimated using the routine for this purpose in this package. Missing plots numbers estimated in the three spacings were 2, 20, and 10 for the 0.5, 1.0, and 1.5 m spacings, respectively. Post-hoc comparisons of means were conducted using Fisher's least significant difference (LSD using $P \leq 0.05$).

The efficacy of the subsampling structure used in each plot spacing was assessed using an error ratio test (ERT). The whole plot error less the sampling error ($r\sigma_e^2$) was expressed relative to variation among the sampling units (σ_s^2), i.e., the ERT = $r\sigma_e^2/\sigma_s^2$. An acceptable threshold for this test is a value of 3.0. Values less than this indicate that the variation among sampling units is excessive to that expressed in the numerator error term, indicating use of a greater number of subsampling units would be beneficial.

Soil nitrogen was analysed using ANOVA with nitrogen rate, stool space, and sample depth as independent variables. Light data were analysed using ANOVA with height of sample above ground, environment, cultivar, and stool spacing as independent variables. Measurements of the percentage of available PAR beneath the canopy were $\log_n$ transformed as the data did not have a normal distribution. Post-hoc comparisons of means were conducted using Fisher's least significant difference (LSD using $P \leq 0.05$).

3.7.2 Plant-crop results

3.7.2.1 Mature stalks

The mean values for the different spacings are not comparable (Table 19), but are presented to give indicative numbers for each spacing unit. Over the measurement period from 182 to 383 DAP, changes in the values were relatively minor, with all decreasing marginally. For the 0.5 m spacing, the number of stalks declined from 42.1 substantial stalks per 6 contiguous stools at 182 d to 38.6 stalks at 383 d. The number of mature stalks per stool moved from 13.1 per stool to 12.6 for the 1.0 m spacing and from 17.6 stalks per stool to 16.9 for the 1.5 m spacing, over the period from 182 to 383 DAP (Table 19). Overall, the dynamics of the stalk population were relatively stable over the measurement period.

Table 19: Summary statistics and significant mean squares from subsampling analyses of variance of mature stalk numbers collected on five occasions from the plant crop.

Stool spacing	Statistic[1]	Days after planting					
		182		256	292	326	383
		Substantial	Total	Total	Total	Total	Total
0.5 m	$\bar{x}$	42.1	45.5	41.1	40.5	40.1	38.6
	C.V.%	12.34	11.82	9.59	11.16	10.50	10.56
	ERT	1.23	1.61	0.96	1.19	1.05	0.24
	MS - E	-	-	-	51.88*	50.18*	-
	MS - C	-	554.70**	184.02**	134.62*	241.97**	307.20**
	MS - NR	116.18*	100.23*	110.59**	77.08*	74.92*	-
	MS - Error	26.92	28.90	15.50	20.39	17.74	16.56
1.0 m	$\bar{x}$	13.1	13.9	13.2	13.2	13.1	12.6
	C.V.%	20.12	19.26	17.74	20.81	17.59	17.73
	ERT	0.0	0.0	0.0	0.0	0.0	0.0
	MS - C	-	35.47*	-	-	44.52**	75.90**
	MS - E by C	-	35.47*	49.58**	52.90**	43.96**	23.05*
	MS - NR	41.20**	27.62*	23.70**	31.23**	29.25**	25.95**
	MS - C by NR	32.93*	32.17*	-	24.21**	-	11.58*
	MS - Error	6.93	7.21	5.49	7.55	5.32	5.02
1.5 m	$\bar{x}$	17.6	18.3	17.5	17.7	17.5	16.9
	C.V.%	19.89	19.42	22.88	17.07	16.84	17.47
	ERT	0.14	0.16	0.47	0.0	0.0	0.09
	MS - E	45.94**	58.02**	-	-	36.12*	52.73*
	MS - C	-	-	-	-	52.73*	124.27**
	MS - E by C	-	-	-	45.76*	-	-
	MS - Error	12.24	12.65	10.90	9.15	8.71	8.74

[1] $\bar{x}$ = mean value; C.V.% = coefficient of variation = $_{100.\sqrt{(\sigma_s^2 + s\sigma_e^2)}/\bar{x}}$; ERT = error ratio test = $s\sigma_e^2 / \sigma_s^2$; MS - E = mean square for environments; MS - C = mean square for cultivars; MS - E by C = mean squares for environments by cultivars interaction; MS - NR = mean square for nitrogen rates; MS - C by NR = mean square for cultivars by nitrogen rates interaction, and MS - Error = mean square for error = $\sigma_s^2 + s\sigma_e^2$.

*Significant at P < 0.05; **Significant at P < 0.01.

The data were variable, as indicated by the C.V.% values, but more so for the 1.0 and 1.5 m spacings. In line with the decrease in the means over the measurement period, the C.V.% values also decreased marginally over the period for all spacings. The measurement of the efficacy of the subsampling strategy used, the ERT, clearly showed none of the strategies was acceptable. The 1.0 m spacing was the worst, followed by the 1.5, and then the 0.5 m spacing. In all cases, the variance between or among the subsampling units used was large relative to the plot-to-plot error variance less the subsampling error. The core area of two rows by 3.0 m length was a fully guarded portion of a plot six rows wide by 9.5 m long. Obviously, to reduce the variation among subsampling units relative to the plot to plot error less the subsampling, or increase the ERT values over the desired 3.0 threshold, requires use of more subsampling units. This would mean a larger core area, and therefore a larger plot format than used in this research.

The picture for significant main effects and interactions was variable (Table 19). The environments term was significant in two of six (2/6) analyses at 0.5 m, 0/6 at 1.0 m, and 4/6 for the 1.5 m spacing. The cultivars term was significant for 5/6 analyses at 0.5 m, 3/6 at 1.0 m, and 2/6 at the 1.5 m spacing. The effect of nitrogen rates was most consistent at the 0.5 and 1.0 m spacings, with 5/6 and 6/6, respectively, but was not a significant effect in any analysis at 1.5 m. No interaction term was significant in any analysis at 0.5 m. However, the environments by cultivars term was significant in analyses for the 1.0 (5/6 analyses) and 1.5 m spacings (1/6). Only in the 1.0 m spacing was the remaining interaction of cultivars by nitrogen rates significant (4/6 analyses).

The analyses of total mature stalk number per core area over spacings revealed a slight decline over the measurement period from 77.7 substantial, or 82.6 total stalks at 182 DAP, to 73.5 stalks at 383 DAP (Table 20). The precision of the analyses based on totals was acceptable, with C.V.% values ranging from 8.8 to 7.3% from the worst to best value. The picture of significant main and interaction effects was pleasingly consistent over the analyses reported. The effect of environments on mature stalk numbers was not significant in any analysis, and intuitively this is sensible given that the environmental differential commenced on 15 June. There were consistent, highly significant effects of cultivars (5/6 analyses), nitrogen rates (6/6), and spacings (6/6) upon mature stalk numbers (Table 20). The environments by cultivars interaction also was consistent (6/6), although its significance varied. The remaining significant interactions were far from consistent, and included the environments by spacings interaction (2/6), cultivars by spacings interaction (1/6), and one second order interaction of cultivars by nitrogen rates by spacings (1/6) (Table 20).

Table 20: Summary statistics and significant mean squares from analyses of variance of mature stalk numbers collected on five occasions from the plant crop.

Statistic[1]	Days after planting					
	182		256	292	326	383
	Substantial	Total	Total	Total	Total	Total
$\bar{x}$	77.7	82.6	77.2	77.0	76.3	73.5
C.V.%	8.83	8.67	7.50	7.42	7.33	7.38
MS – C	-	938.45**	473.04**	413.75**	931.61**	1,560.56**
MS - E by C	228.94*	317.34*	329.67**	633.56**	433.38**	308.90**
MS – NR	394.55**	260.17**	285.24**	329.24**	278.89**	193.37**
MS – S	2,868.45**	4,731.81**	2,300.86**	1,732.97**	1,788.76**	1566.36**
MS - E by S	-		-	-	124.92*	92.01*
MS - C by S	-	205.22*	-	-	-	-
MS - C by NR by S	-	-	-	-	-	73.90*
MS – Error	46.98	51.30	33.58	32.66	31.28	29.48

[1] $\bar{x}$ = mean value; C.V.% = coefficient of variation = $100.\sqrt{\sigma_E^2} / \bar{x}$; MS - C = mean square for cultivars; MS - E by C = mean squares for environments by cultivars interaction; MS - NR = mean square for nitrogen rates; MS - S mean square for spacings; MS - E by S = mean square for environments by spacings interaction; MS - C by S = mean square for cultivars by spacings interaction; MS - C by NR by S = mean square for cultivars by nitrogen ratings by spacings interaction;. and MS - Error = mean square for error = σ_E^2.

*Significant at P < 0.05; **Significant at P < 0.01.

Q152 consistently had more total stalks than Q138 (Table 21) across all counts. In the post-monsoon irrigated environment, Q152 maintained a significantly greater number of mature stalks than in the rain-fed environment for all counts except total stalks at 182 DAP. A significant difference between environments only occurred for Q138 for total mature stalks at 292 DAP, with the rain-fed environment having the larger number of stalks.

Stalk numbers for plots receiving 140 kg N ha^{-1} were significantly higher than plots receiving no nitrogen for all counts except that for 383 DAP. Plots receiving 140 + 70 kg N ha^{-1} were significantly higher only for counts at 292 and 383 DAP. In all cases, the latter counts were significantly higher than those for plots receiving no nitrogen (Table 21).

Stalk numbers for plots planted with stools spaced at 1.0 m were significantly lower than plots with stools spaced at 0.5 m only for the 182 (substantial and total) and 256 DAP counts, but no counts later in the season (Table 21). Stalk numbers for all plots with stools spaced 1.5 m were significantly lower than those with stools spaced at 1.0 m, and therefore also were significantly lower than counts for plots with stools spaced at 0.5 m (Table 21).

Table 21: Mean values and least significant differences for number of mature stalks in the plant crop.

Effect	Contrast[1]	Days after planting					
		182		256	292	326	383
		Substantial	Total	Total	Total	Total	Total
Cultivars	Q138	77.5	80.3	75.6	75.5	74.1	70.6
	Q152	77.8	84.9	78.8	78.5	78.6	76.5
	$lsd_{(0.05)}$	-	2.1	1.7	1.7	1.6	1.6
Environments by cultivars	Irrig. by Q138	77.1	79.1	74.9	74.2	73.1	70.2
	Irrig. by Q152	79.8	86.4	80.8	80.9	80.8	78.7
	RF by Q138	77.8	81.6	76.3	76.8	75.0	71.0
	RF by Q152	75.9	83.5	76.9	76.1	76.5	74.3
	$lsd_{(0.05)}$	2.8	3.0	2.4	2.4	2.3	2.2
Nitrogen rates (kg)	0	74.9	80.4	75.0	74.6	74.1	72.0
	140	78.2	83.1	77.3	77.1	76.6	73.1
	140 + 70	79.9	84.5	79.3	79.3	78.3	75.5
	$lsd_{(0.05)}$	2.5	2.6	2.1	2.0	2.0	1.9
Spacings (m)	0.5	84.1	90.9	82.1	80.9	80.3	77.1
	1.0	78.5	83.7	79.2	79.2	78.6	75.9
	1.5	70.4	73.3	70.3	70.9	70.1	67.7
	$lsd_{(0.05)}$	2.5	2.6	2.1	2.0	2.0	1.9

[1]Irrig. = post-monsoonal irrigation 15 June - 24 August 2000; RF = rain fed; $lsd_{(0.05)}$ = least significant difference = $t_{(0.05,\infty)}\sqrt{2.\sigma_E^2 / n}$, where n = number of observations contributing to each of the contrasted means.

3.7.2.2 Sucker culms

Sucker culms were not present at the first count at 182 DAP. Their numbers at the second count at 256 DAP were so low (mean = 0.067 sucker culms per core plot) that no effects were significant in analyses of individual spacings (0.5, 1.0 and 1.5 m) or in combined analyses over spacings. Similarly, no effects attained significance for the analyses of individual spacings at 292 DAP (mean = 2.0 sucker culms per core plot). Therefore, these are not reported.

Analyses for sucker culm data for individual spacings collected at 326 and 383 DAP reveal a significant increase in numbers between these counts, by a factor of about three, and this was consistent over spacings. The data were variable, as indicated by C.V.% values (Table 22), although those for the 383 DAP data were markedly better than those were for the 326 DAP. In all instances, the ERT values were below the threshold value of acceptability of 3.0, indicating the subsampling strategy used in these data collections was unacceptable. This conclusion also was applicable to the mature stalk data (Table 19).

Table 22: Summary statistics and significant mean squares from subsampling[1] analyses of variance of sucker culm numbers collected on two occasions in the plant crop.

Stool spacing	Statistic[1]	Days after planting	
		326	383
0.5 m	$\bar{x}$	5.6	17.4
	C.V.%	101.01	46.70
	ERT	2.57	0.75
	MS - E	-	3,366.56**
	MS - C	265.82**	-
	MS - NR	-	747.16**
	MS - E by NR	-	389.05**
	MS - Error	32.32	65.80
1.0 m	$\bar{x}$	1.9	6.3
	C.V.%	135.94	54.24
	ERT	1.04	0.51
	MS - E	-	1,010.03**
	MS - E by C	-	51.98*
	MS - NR	22.55*	408.18**
	MS - Error	6.48	11.80
1.5 m	$\bar{x}$	3.17	8.90
	C.V.%	92.62	41.58
	ERT	0.455	0.0
	MS - E	93.13*	844.88**
	MS - C	39.45*	421.62**
	MS - E by C	76.05**	-
	MS - NR	113.77**	429.49**
	MS - Error	8.59	13.67

[1] $\bar{x}$ = mean value; C.V.% = coefficient of variation = $100.\sqrt{(\sigma_s^2 + s\sigma_e^2)}/\bar{x}$; ERT = error ratio test = $s\sigma_e^2/\sigma_s^2$; MS - E = mean square for environments; MS - C = mean square for cultivars; MS - E by C = mean squares for environments by cultivars interaction; MS - NR = mean square for nitrogen rates; MS - E by NR = mean square for environments by nitrogen rates interaction, and MS - Error = mean square for error = $\sigma_s^2 + s\sigma_e^2$.

*Significant at $P < 0.05$; **Significant at $P < 0.01$.

The environments term was only significant for the 1.5 m spacing in 326 DAP analysis, but was significant for all spacings at 383 DAP (Table 22). The cultivars term was significant for the 0.5 and 1.5 m spacings at 326 DAP, but only for the 1.5 m spacing at 383 DAP. The nitrogen rates effect was significant for all analyses except the 0.5 m spacing in the 326 DAP data. A number of interactions also were significant in these analyses, but they presented an inconsistent picture. The environments by cultivars interaction was significant for the 1.0 and 1.5 m spacings in the 383 and 326 DAP analyses, while the environments by nitrogen rates term was significant only for the 0.5 m spacing in the 383 DAP analysis.

Analyses of sucker culm data on a core plot basis, over all factors (Table 23) shows the dramatic increase in their numbers over the period from 292 to 383 DAP, with the data becoming markedly less variable. The C.V.% values dropped from 123% at 292 DAP to 26% at 383 DAP. The main effect of nitrogen rates was the only one consistently significant over the three analyses. The environments and cultivars effects were significant only at 383 DAP, and the spacings effect only at 292 and 326 DAP. Other than the environments by cultivars interaction, which was significant for all three analyses, interaction effects presented a variable picture. Environments by nitrogen rates

was significant for the 383 DAP data while cultivars by spacings interaction was significant for the 326 and 383 DAP analyses (Table 23).

Table 23: Summary statistics and significant mean squares from analyses of variance of sucker culm numbers collected on three occasions from the plant crop.

Statistic[1]	Days after planting		
	292	326	383
$\bar{x}$	2.0	11.7	36.1
C.V.%	123.0	56.8	25.8
MS - E	-	-	15,846.57**
MS - C	-	-	688.75**
MS - E by C	27.22*	242.21*	555.11*
MS - NR	19.91*	672.57**	5,552.93**
MS - E by NR	-	-	640.95**
MS - S	20.69*	216.26**	-
MS - C by S	-	317.30**	617.39**
MS - Error	5.92	44.30	86.83

[1] $\bar{x}$ = mean value; C.V.% = coefficient of variation = $100.\sqrt{\sigma_E^2} / \bar{x}$; MS - E = mean square for environments; MS - C = mean square for cultivars; MS - E by C = mean squares for environments by cultivars interaction; MS - NR = mean square for nitrogen rates; MS - E by NR = mean square for environments by nitrogen rates interaction; MS - S mean square for spacings; MS - C by S = mean square for cultivars by spacings interaction; and MS - Error = mean square for error = σ_E^2.

Mean data are presented for all significant main effects and interaction terms for sucker culms for the final count at 383 DAP (Table 24). On average, the irrigated environment produced about 1.7 times more sucker culms than the rain-fed environment. This result supports the hypothesis that moist conditions during the winter harvest period encourage suckering. Although the mean number of suckers produced by Q138 and Q152 were significantly different, the means were relatively close. The cultivars were chosen for this research because of their high suckering propensity. Whilst these data suggest they are similar, no objective statement can be made as to their propensity relative to other cultivars, but one can assume this would be high based on other observations. The environments by cultivars interaction means show that while Q138 and Q152 has similar suckering propensity in the rain-fed post-monsoonal environment, Q152 has a significantly greater suckering potential under post-monsoonal irrigated conditions.

Table 24: Mean values and least significant differences for the number of sucker culms at 383 DAP in the plant crop.

Effect	Contrast	Statistic
Environments	Irrigated	45.5
	Rain fed	26.7
	$lsd_{(0.05)}$	4.8
Cultivars	Q138	34.2
	Q152	38.1
	$lsd_{(0.05)}$	2.7
Environments by cultivars	Irrigated by Q138	41.8
	Irrigated by Q152	49.2
	Rain fed by Q138	26.5
	Rain fed by Q152	26.9
	$lsd_{(0.05)}$	3.9
Nitrogen rates (kg ha^{-1})	0	27.4
	140	34.5
	140 + 70	46.4
	$lsd_{(0.05)}$	3.3
Environments by nitrogen rates (kg ha^{-1})	Irrigated by 0	34.4
	Irrigated by 140	42.5
	Irrigated by (140 + 70)	59.6
	Rain fed by 0	20.5
	Rain fed by 140	26.4
	Rain fed by (140 + 70)	33.3
	$lsd_{(0.05)}$	4.7
Cultivars by spacings (m)	Q138 by 0.5	35.8
	Q138 by 1.0	36.3
	Q138 by 1.5	30.3
	Q152 by 0.5	33.6
	Q152 by 1.0	39.7
	Q152 by 1.5	40.9
	$lsd_{(0.05)}$	4.7

Nitrogen applications of 140 kg N ha^{-1} in November, and this plus 70 kg N ha^{-1} in May, both significantly increased suckering propensity over zero applied nitrogen (Table 24). The differential between zero nitrogen and the application of 140 kg N ha^{-1} in the irrigated and rain-fed environments was 8.1 versus 5.9 sucker culms, respectively, while that between zero nitrogen and the application of 140 + 70 kg N ha-1 was 25.2 and 12.8 sucker culms, respectively. Not surprisingly, suckering response to winter moisture is enhanced by the availability of nitrogen. While the latter was deliberately supplied in this research, a parallel must be drawn between this result and the continued use of nitrogen at above recommended rates in the northern region until very recent years.

The surprising result from this research is the non-significance of stool spacing within plots (Table 24). However, the cultivars by spacings interaction was significant (Figure 10). Suckering propensity for Q138 at 0.5 and 1.0 m stool spacing did not differ (35.8 and 36.3), but both were significantly greater that that recorded at 1.5 m spacing (30.3). This is in contrast with the means recorded for Q152. Here, suckering propensity at 1.0 and 1.5 m spacing did not differ (39.7 and 40.9), but both were significantly greater that suckering observed at 0.5 m spacing (33.6).

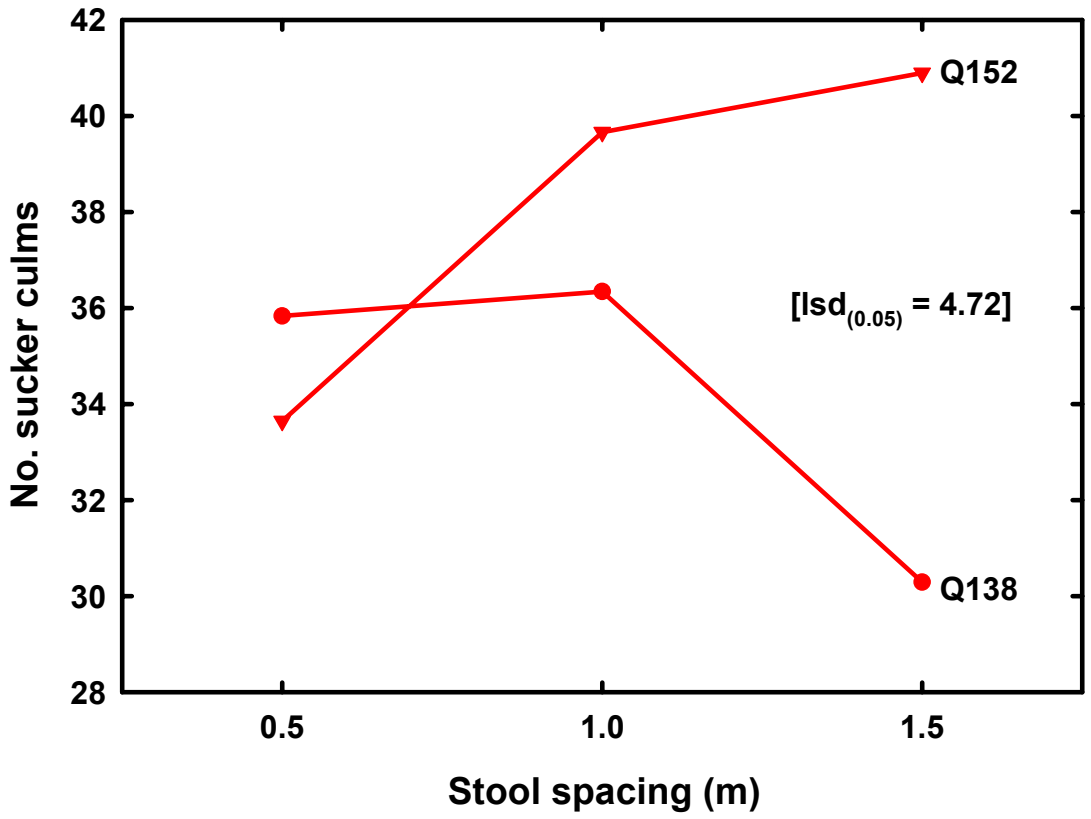

Figure 10: Cultivar by stool spacing interactions for the number of sucker culms present in the plant crop 383 days after planting.

An alternative way of analysing these data uses the character 'number of suckers per mature stalk', obtained by dividing the number of suckers per stool recorded at 383 days after planting, by the number of mature stalks per stool. Obviously data for 'number of sucker culms per stool' consist of small numbers that have a non-normal distribution so, their analysis may be aided by use of a square-root (SQRT) transformation. Results of subsampling analyses for 'number of suckers per stool' and the SQRT of these data (Table 25) show that the C.V.% values are all reduced with the transformed data. This is common on use of such a transformation function. Significance of main effects remains unchanged. Notably, interactions for 'environments by nitrogen rates' (0.5 m spacing) and 'environments by cultivars' (1.0 m spacing), highly significant and significant, respectively, in the raw data, lose all significance in the transformed data. We conclude from this that analysis of raw data for this trait overstates the significance of interaction effects. A more objective test than this is difficult to conduct with a complex design of this nature.

Table 25: Summary statistics and significant mean squares from subsampling analyses of variance for the number of suckers (Su) and number of suckers per mature stalk (MS) in the plant crop at 383 days after planting, and square root (SQRT) transformations of these data.

Stool spacing	Statistic[1]	# Su	SQRT(# Su)	# Su/MS	SQRT(# Su/MS)
0.5 m	$\bar{x}$	17.4	4.0	0.453	0.644
	C.V.%	46.70	27.70	51.69	29.05
	ERT	0.748	1.200	1.115	1.333
	MS - E	3,366.56**	54.08**	2.073**	1.281**
	MS - NR	747.16**	9.03**	0.349**	0.173*
	MS - E by NR	389.05**	-	0.180*	-
	MS - Error	65.80	1.22	0.055	0.035
1.0 m	$\bar{x}$	6.33	2.37	0.51	0.67
	C.V.%	54.24	35.43	47.3	36.45
	ERT	0.514	0.747	0.432	0.765
	MS - E	1,010.02**	51.18**	6.867**	4.30**
	MS - E by C	51.98*	-	-	-
	MS - NR	408.19**	18.26**	1.994**	1.136**
	MS - Error	11.80	0.704	0.079	0.060
1.5 m	$\bar{x}$	8.90	2.87	0.528	0.701
	C.V.%	41.58	21.90	41.6	22.25
	ERT	0.0	0.0	0.0	0.0
	MS - E	844.88**	26.05**	2.219**	1.17**
	MS - C	421.62**	11.97**	0.71**	0.36**
	MS - NR	429.49**	12.99**	1.36**	0.71**
	MS - Error	13.67	0.395	0.048	0.024

[1] $\bar{x}$ = mean value; C.V.% = coefficient of variation = $100.\sqrt{(\sigma_s^2 + s\sigma_e^2)}/\bar{x}$; ERT = error ratio test = $s\sigma_e^2/\sigma_s^2$; MS - E = mean square for environments; MS - C = mean square for cultivars; MS - NR = mean square for nitrogen rates; MS - E by NR = mean square for environments by nitrogen rates interaction, and MS - Error = mean square for error = $\sigma_s^2 + s\sigma_e^2$.

*Significant at P < 0.05; **Significant at P < 0.01.

In a data set from a simple randomised complete block design, one can simply test the effectiveness of a transformation by conducting an error ratio test (ERT) using analyses of variance of the top and bottom 25% of entries, based on mean values, for raw and transformed data. The loss of significance for the ERT is a clear indicator of the validity of transformation use.

Similarly, subsampling analyses for the 'number of suckers per mature stalk' (Table 25) show that 'environments' and 'nitrogen rates' were highly significant in all spacings, and the 'cultivars' term highly significant only in the 1.5 m spacing. The only significant interaction effect was for 'environments by nitrogen rates' in the 0.5 m spacing. Again, use of the transformation reduced the C.V.% in all analyses, significance of the main effects remained unchanged, and significance for the only significant interaction effect disappeared. Therefore, a similar picture to that obtained for 'number of suckers per stool, emerged.

Analyses for raw data for 'number of suckers per mature stalk' on a core-plot basis (Table 26) revealed the main effects of 'environments' and 'nitrogen rates were highly significant, and 'spacings' significant. The latter is in marked contrast to the analysis of 'number of suckers' where a surprising result was that 'spacings' were not significance in the analysis of 'number of suckers'. This result was indeed puzzling. However, expression of number of suckers in terms of the number of mature stalks now reveals significance for this assumedly important effect. The interaction effects 'environments by nitrogen rates' and 'cultivars by spacings' were significant and highly significant, respectively. The analysis of SQRT-transformed data for 'number of suckers per mature stalk' (Table 26) revealed the main effects of 'environments', 'nitrogen rates', and spacings were all highly significant. In terms of interactions effects, that for 'environments by nitrogen' disappeared, while that for 'cultivars by spacings' remained highly significant.

Table 26: Summary statistics and significant mean squares from analyses of variance of the number of suckers (# Su) per mature stalk (MS) in the plant crop at 383 days after planting[1], and a square root (SQRT) transformation of these data.

Statistic[1]	# Su/MS	SQRT(# Su/MS)
$\bar{x}$	0.491	0.683
C.V.%	27.45	14.82
MS - E	2.59**	1.43**
MS - NR	0.83**	0.42**
MS - E by NR	0.07*	-
MS - S	0.08*	0.06**
MS - C by S	0.13**	0.08**
MS - Error	0.02	0.01

[1] $\bar{x}$ = mean value; C.V.% = coefficient of variation = $100.\sqrt{\sigma_E^2}/\bar{x}$; MS - E = mean square for environments; MS - NR = mean square for nitrogen rates; MS - E by NR = mean square for environments by nitrogen rates interaction; MS - S mean square for spacings; MS - C by S = mean square for cultivars by spacings interaction; and MS - Error = mean square for error = σ_E^2.

*Significant at P < 0.05; **Significant at P < 0.01.

The irrigated environment produced significantly more suckers per mature stalk than did the rain-fed environment (0.611 versus 0.371; Table 27). Number of suckers per mature stalk increased with increasing nitrogen rates (0.381 - 0.477 - 0.615), with each all levels being significantly different (Table 27). Number of suckers per mature stalks did not differ for the 1.0 and 1.5 m spacings, but these differed from the 0.5 m spacing. In terms of 'cultivars by spacings' interactions there were no differences among the three spacings for Q138, but each of these differed significantly for Q152. The differences between Q138 and Q152 for interactions with stool spacings for number of suckers and number of suckers per mature stalk are dramatic (Figure 11). The behaviour for Q138 was puzzling, with the number dropping dramatically at 1.5 m spacing. However, for number of sucker culms per mature stalk, differences among spacings for Q138 are not significant. In contrast, the pattern over spacing for Q152 for the two traits differed little, but these are spectacularly different to the pattern observed for Q138. The wider the spacing, and

hence the greater the light penetration into the crop for Q152, the greater the number of suckers observed.

Table 27: Mean values and least significant differences for the number of suckers (Su) per stalk (MS), in the plant crop at 383 days after planting, and a square root transformation of these data.

Effect	Contrast	# Su/MS	SQRT(# Su/MS)
Environments	Irrigation	0.611	0.772
	Rain-fed	0.371	0.594
	$lsd_{(0.05)}$	0.062	0.053
Nitrogen rates (kg N ha^{-1})	0	0.381	0.605
	140	0.477	0.674
	(140 + 70)	0.615	0.770
	$lsd_{(0.05)}$	0.048	0.036
Environments by nitrogen rates	Irrig. by 0	0.476	-
	Irrig. by 140	0.584	-
	Irrig. by (140 + 70)	0.773	-
	RF by 0	0.287	-
	RF by 140	0.370	-
	RF by (140 +70)	0.457	-
	$lsd_{(0.05)}$	0.068	-
Spacings (m)	0.5	0.451	0.649
	1.0	0.501	0.690
	1.5	0.521	0.710
	$lsd_{(0.05)}$	0.048	0.036
Cultivars by spacings	Q138 by 0.5	0.486	0.679
	Q138 by 1.0	0.501	0.691
	Q138 by 1.5	0.464	0.668
	Q152 by 0.5	0.416	0.619
	Q152 by 1.0	0.502	0.689
	Q152 by 1.5	0.578	0.752
	$lsd_{(0.05)}$	0.068	0.051

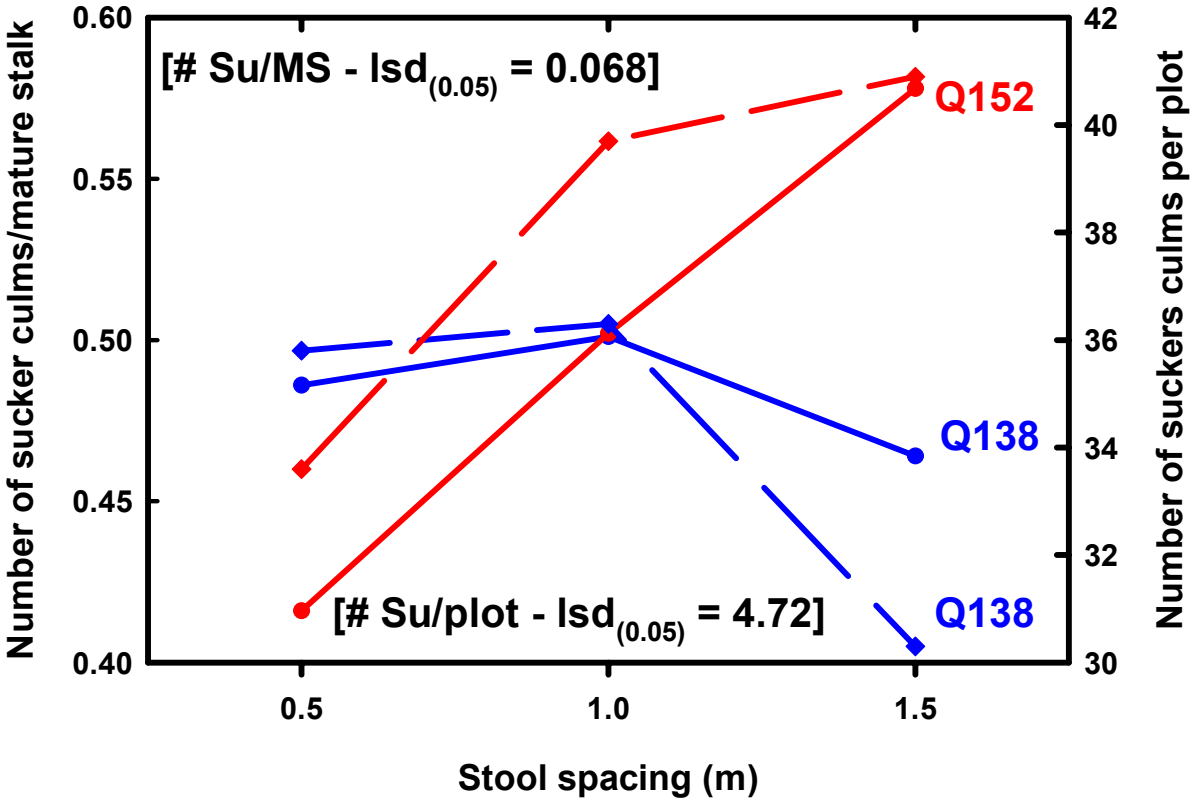

Figure 11: **Cultivar by stool spacing interactions for the number of sucker culms per mature stalk (solid lines) and the number of sucker culms (dashed lines) present in the plant crop 383 days after planting.**

3.7.2.3 Stool movement

Analyses for stool movement data revealed that the data were very variable, as indicted the C.V.% values (Table 28). There was only one significant mean square in the analyses, this being the environments term for the 1.0 m spacing. The combined analysis over spacings was less variable than the individual analyses for the spacings, with a C.V.% of 45.6% (Table 28). The spacings effect was the only significant main effect in the analysis. The only significant interaction was that for environments by spacings.

Table 28: Summary statistics and significant mean squares from subsampling analyses of variance, over environments, of stool movement ratings in the plant crop 383 days after planting.

Statistic[1]	Stool spacing (m)			Core area mean
	0.5	1.0	1.5	
$\bar{x}$	0.32	1.31	1.91	1.18
C.V.%	232.88	96.32	63.28	45.6
ERT	2.512	3.324	0.552	n.a.
MS - E	-	20.02*	-	-
MS - S	n.a.	n.a.	n.a.	38.97**
MS - E by S	n.a.	n.a.	n.a.	1.87**
MS - Error	0.545	1.602	1.464	0.290

[1] $\bar{x}$ = mean value; C.V.% = coefficient of variation $=100.\sqrt{(\sigma_s^2 + s\sigma_e^2)}/\bar{x}$, for subsampling analyses, and = $100.\sqrt{\sigma_E^2}/\bar{x}$ for the means analysis over spacings; ERT = error ratio test $=s\sigma_e^2/\sigma_s^2$; MS - E = mean square for environments; MS - S = mean square for spacings; MS - E by S = mean square for environments by spacings interaction; and MS - Error = mean square for error = $\sigma_s^2 + s\sigma_e^2$, for subsampling analyses, , and = σ_E^2 for the means analysis over spacings.

*Significant at P < 0.05; **Significant at P < 0.01.

The mean stool movement rating for 0.5 m spaced stools (0.317) was lowest of the three stool spacings, and the ratings for the 1.0 m (1.304) and the 1.5 m spacing (1.912) were significantly higher, as well as being significantly different from each other (Table 29). Again, there were interesting interactions. Differences between spacings within environments were all significant. The differentials between 0.5 and 1.0 m spacings and 0.5 and 1.5 m spacings were larger in the rain-fed regime (1.3 and 1.9) than in the irrigated regime (0.7 and 1.3). There was no significant difference between environments for the 0.5 m spacing. However, the ratings for both the 1.0 and 1.5 m spacings were significantly higher in the rain-fed environment. The differentials between the 1.0 and 1.5 m spacings across environments were similar. However, what was observed here must be due to a phenomenon that occurred some time after establishment, but before the imposition of the environmental differential - irrigation from 15 June. The trial was subjected to extreme monsoonal conditions from 1 January to 30 April, receiving 2,350 mm in this period, as well as being buffeted by cyclonic winds on 27 February that disturbed the crop's structure. For example, Q138 suffered more stalk breakage than Q152, yet plots of the latter were physically more disturbed, sprawling to varying degrees through to lodged. The phenomenon obviously was confounded with the environment that later was designated as rain fed, yet this did not effect tiller dynamics directly. In none of the analyses of stalk number reported did the main effect of environments feature as a significant effect (Table 20). However, an indirect consequence was that the environments by cultivars interaction was significant in all analyses of stalk number. One could hypothesize that stools were not as well anchored in the rain-fed environment, conceivably because of shallower and harsher soil in this section of the field. If this was the case, why did this not affect tiller dynamics to some extent?

Table 29: Mean values and least significant differences for stool-displacement rating in the plant crop at 383 days after planting, for the significant main effect of spacings and the interaction of environments by spacings

Effect	Contrast	Statistic
Spacing (m)	0.5	0.317
	1.0	1.314
	1.5	1.912
	$lsd_{(0.05)}$	0.166
Environments by spacings (m)	Irrigated by 0.5	0.400
	Irrigated by 1.0	1.078
	Irrigated by 1.5	1.706
	Rain fed by 0.5	0.233
	Rain fed by 1.0	1.549
	Rain fed by 1.5	2.118
	$lsd_{(0.05)}$	0.272

3.7.2.4 Yields

Average core plot cane yield was high (102.5 t ha^{-1}) and sucker culms yield were relatively low (4.8 t ha^{-1}; Table 30). Consequently, the portion of culm yield contributed by sucker culms also was low (4.4%). Suckers on average were small (11.4 kg per 100 sucker culms; Table 30). There were highly significant ($P < 0.01$) effects of 'environments', 'cultivars', and 'nitrogen rates' for all five yield traits except for nitrogen rates for cane yield, which was significant ($P < 0.05$). The main effect of 'spacings' was highly significant for cane yield and total culm yield only. The interaction of 'environments by nitrogen rates' was significant or highly significant for all five traits (Table 30). The 'environments by cultivars' and 'environments by cultivars by nitrogen rates' interaction terms were significant, or highly significant, for the three traits not involving cane yield (TSuH, %Su, and kg/100Su). The interaction terms for 'environments by cultivars by spacings' and environments by nitrogen rates by spacings' were significant only for TCH and T(C +Su)H (Table 30). Analyses for non-sucker culm traits [TCH and T(C +Su)H] were precise, with coefficients of variation approaching 10%. The same could not be said for sucker traits, and this reflects earlier experiences at Meringa.

Table 30: Summary statistics and significant mean squares from analyses of variance of five traits[1] measured at harvest of the plant crop.

Statistic[2]	TCH	TSuH	T(C + Su)H	%Su	kg/100 Su
$\bar{x}$	102.5	4.84	107.35	4.38	11.43
C.V.%	10.09	37.71	10.18	34.10	30.05
MS - E	2,091.56**	874.77**	5,671.49**	568.60**	1,085.05**
MS - C	3,926.54**	199.78**	2,355.03**	210.43**	1,881.77**
MS – E by C	-	17.19*	-	14.69*	78.38*
MS - NR	466.88*	235.47**	1,356.77**	143.90**	145.89**
MS – E by NR	357.72*	88.11**	745.49**	43.33**	140.79**
MS – E by C by NR	-	12.47*		9.22*	37.30*
MS - S	518.80**	-	519.33*	-	-
MS – E by C by S	538.29**	-	551.02*	-	-
MS – E by NR by S	321.81*	-	314.70*	-	-
MS - Error	107.07	3.33	119.52	2.23	11.80

[1]TCH = tonnes of cane per hectare; TSuH = tonnes of suckers per hectare; T(C + Su)H = tonnes of cane and suckers per hectare; % Su = 100(TSuH/(T(C + Su)H; kg/100Su = kilograms per 100 suckers.

[2] $\bar{x}$ = mean value; C.V.% = coefficient of variation = $100.\sqrt{(\sigma_s^2 + s\sigma_e^2)}/\bar{x}$; MS - E = mean square for environments; MS - C = mean square for cultivars; MS - E by C = mean square for environments by cultivars interaction; MS - NR = mean square for nitrogen rates; MS - E by NR = mean square for environments by nitrogen rates interaction; MS - E by C by NR = mean square for environment by cultivars by nitrogen rates interaction; MS - S = mean square for spacings; MS E by C by S = mean square for environments by cultivars by spacings interaction; MS - E by NR by S = mean square for environments by nitrogen rates by spacings interaction, and MS - Error = mean square for error.

*Significant at $P < 0.05$; **Significant at $P < 0.01$.

As expected, the irrigated environment produced a significantly higher mean for all five yield traits than did the rain-fed environment. Q152 produced more TCH, and more T(C + Su)H, than did Q138. The latter, however, produced more TSuH, a higher %Su, and heavier suckers than did Q152 (Table 31). The split application of nitrogen (140 + 70 kg N) produced significantly more TCH than either the zero or 140 kg applications, and these did not differ from each other. Each increment of nitrogen produced significantly higher TSuH, demonstrating the impact of residual excessive nitrogen on sucker development. All levels of nitrogen also differed significantly for total culm yield (stalks + suckers) (Table 31).

In terms of interactions, Q152 responded more to irrigation in terms of sucker yield (300%) than did Q138 (247%; Table 31), yet response in terms of sucker size was similar. Response to nitrogen in terms of the moisture regime was interesting. For TCH, any nitrogen treatment differed significantly from no nitrogen, whereas in the rain-fed environment no significant responses existed. This pattern also was evident for sucker size (kg/100Su). However, for TSuH there were significant differences among all levels [0 - 140 - (140+70)] in the irrigated environment, but in the rain-fed environment only the highest rate differed significantly. This pattern also was displayed for %Su (Table 31).

The late nitrogen application produced a significant response relative to the November application alone for TSuH and %Su, but not sucker size, for Q138 and Q152 in the irrigated environment. However, there were no significant differences among nitrogen treatments for either cultivar in the rain-fed environment. The availability of late nitrogen together with post-monsoonal moisture had a profound effect upon expression of many sucker related traits.

Q138 produced significantly greater TCH at 1.0 m stool spacing than at 0.5 m spacing in the irrigated environment, whereas there were no differences among stool spacing for Q152 in this environment. In the rain-red environment, TCH for Q138 at 0.5 and 1.0 m spacings did not differ, but that at 1.5 m was significantly less (Table 31). For Q152 in the rain-fed environment, TCH at 1.0m spacing was significantly greater than at 1.5 m spacing, and almost significant from the 0.5 m spacings. Interactions of the cultivars at different stool spacings differed markedly between the moisture regimes for TCH and T(C + Su)H.

Within the irrigated environment, there were no significant differences among stool spacings within each nitrogen treatment for TCH (Table 31). This statement also was true for the zero applied nitrogen in the rain-fed environment. However, both the 0.5 and 1.0 m spaced stool produced significantly more TCH than did the 1.5 m spacing at 140 kg N treatment. With the delayed nitrogen application (140 + 70), the 1.0 m spacing produced significantly more TCH than only the 1.5 m spacing.

Table 31: Mean values and least significant differences for five harvest traits[1] measured in the plant crop for consistently significant main effects and interactions.

Effect	Contrast	TCH	TSuH	T(C + Su)H	%Su	kg/100 Su
Environment	Irrigated	105.9	7.0	113.0	6.2	13.9
	Rain fed	99.1	2.6	101.7	2.6	9.0
	$lsd_{(0.05)}$	2.89	1.58	3.36	1.34	2.90
Cultivars	Q138	97.8	5.9	103.7	5.5	14.7
	Q152	107.2	3.8	111.0	3.3	8.2
	$lsd_{(0.05)}$	3.02	0.53	3.19	0.44	1.00
Nitrogen rates (kg)	0	99.5	2.9	102.4	2.8	9.7
	140	103.0	4.8	107.9	4.4	12.1
	(140+70)	105.0	6.8	111.8	5.9	12.6
	$lsd_{(0.05)}$	3.70	0.65	3.91	0.53	1.23
Spacings (m)	0.5	102.0	-	106.9	-	-
	1.0	105.7	-	110.5	-	-
	1.5	99.8	-	104.6	-	-
	$lsd_{(0.05)}$	3.70	-	3.91	-	-
Environments by cultivars	Irrig. by Q138	-	8.4	-	7.5	17.8
	Irrig. by Q152	-	5.7	-	4.8	10.0
	RF by Q138	-	3.4	-	3.4	11.6
	RF by Q152	-	1.9	-	1.8	6.4
	$lsd_{(0.05)}$	-	0.75	-	0.62	1.42
Environments by nitrogen rates	Irrig. by 0	100.2	3.8	103.9	3.7	10.4
	Irrig. by 140	108.3	7.3	115.6	6.3	15.7
	Irrig. by (140+70)	109.3	10.1	119.4	8.5	15.6
	RF by 0	98.8	2.0	100.8	2.0	9.0

Effect	Contrast	TCH	TSuH	T(C + Su)H	%Su	kg/100 Su
	RF by 140	97.7	2.4	100.1	2.4	8.5
	RF by (140+70)	100.7	3.5	104.3	3.4	9.5
	$lsd_{(0.05)}$	5.24	0.92	5.53	0.76	1.74
Environments by cultivars by nitrogen rates	Irrig. by Q138 by 0	-	4.4	-	4.5	13.8
	Irrig. by Q138 by 140	-	9.3	-	8.2	20.5
	Irrig. by Q138 by (140+70)	-	11.5	-	9.9	19.1
	Irrig. by Q152 by 0	-	3.1	-	2.8	6.9
	Irrig. by Q152 by 140	-	5.3	-	4.5	10.9
	Irrig. by Q152 by (140+70)	-	8.7	-	7.0	12.2
	RF by Q138 by 0	-	2.5	-	2.7	12.0
	RF by Q138 by 140	-	2.7	-	2.8	10.1
	RF by Q138 by (140+70)	-	4.9	-	4.8	12.6
	RF by Q152 by 0	-	1.4	-	1.3	5.9
	RF by Q152 by 140	-	2.1	-	2.0	6.8
	RF by Q152 by (140+70)	-	2.2	-	2.1	6.5
	$lsd_{(0.05)}$	-	1.31	-	1.07	2.46
Environments by cultivars by spacings	Irrig. by Q138 by 0.5	95.5	-	104.3	-	-
	Irrig. by Q138 by 1.0	105.1	-	113.3	-	-
	Irrig. by Q138 by 1.5	102.3	-	110.5	-	-
	Irrig. by Q152 by 0.5	112.1	-	117.5	-	-
	Irrig. by Q152 by 1.0	111.0	-	116.8	-	-
	Irrig. by Q152 by 1.5	109.5	-	115.4	-	-
	RF by Q138 by 0.5	99.5	-	103.2	-	-
	RF by Q138 by 1.0	98.1	-	101.5	-	-
	RF by Q138 by 1.5	86.6	-	89.5	-	-
	RF by Q152 by 0.5	101.1	-	102.7	-	-
	RF by Q152 by 1.0	108.5	-	110.3	-	-
	RF by Q152 by 1.5	100.9	-	103.2	-	-
	$lsd_{(0.05)}$	7.41	-	7.82	-	-
Environments by nitrogen rates by spacings	Irrig. by 0 by 0.5	100.5	-	104.0	-	-
	Irrig. by 0 by 1.0	101.6	-	105.8	-	-
	Irrig. by 0 by 1.5	98.4	-	101.9	-	-
	Irrig. by 140 by 0.5	105.7	-	113.1	-	-
	Irrig. by 140 by 1.0	112.2	-	118.7	-	-
	Irrig. by 140 by 1.5	107.1	-	114.9	-	-
	Irrig. by (140 + 70) by 0.5	105.2	-	115.5	-	-
	Irrig. by (140 + 70) by 1.0	110.4	-	120.7	-	-
	Irrig. by (140 + 70) by 1.5	112.2	-	122.0	-	-
	RF by 0 by 0.5	100.1	-	102.2	-	-
	RF by 0 by 1.0	97.1	-	99.0	-	-
	RF by 0 by 1.5	99.3	-	101.2	-	-
	RF by 140 by 0.5	102.8	-	105.1	-	-
	RF by 140 by 1.0	99.8	-	102.3	-	-
	RF by 140 by 1.5	90.6	-	92.9	-	-
	RF by (140+70) by 0.5	97.9	-	101.6	-	-
	RF by (140+70) by 1.0	112.9	-	116.4	-	-
	RF by (140+70) by 1.5	91.4	-	94.8	-	-
	$lsd_{(0.05)}$	9.07	-	9.58	-	-

[1]TCH = tonnes of cane per hectare; TSuH = tonnes of suckers per hectare; T(C + Su)H = Tonnes cane and suckers per hectare; % Su = 100(TSuH/(T(C + Su)H; kg/100Su = kg per 100 suckers.

3.7.2.5 Quality components

Analyses of variance for quality component of mature stalks revealed significant differences between environments for all except fibre, significant differences between cultivars for all except brix and pol reading, and significant differences among nitrogen rates for all except fibre (Table 32). Significant interactions among main effects were limited.

Table 32: Summary statistics and significant mean squares from analyses of variance of five quality components of three crop fractions determined at harvest of the plant crop.

Crop fraction	Statistic[1]	Component				
		Brix (g kg^{-1})	CCS (g kg^{-1})	Fibre (g kg^{-1})	Moisture (g kg^{-1})	Pol reading (°Z)
Mature Stalks	$\bar{x}$	220.4	135.4	134.0	678.9	79.4
	C.V.%	2.74	5.44	4.89	1.27	4.02
	MS - E	12,760.2**	10,449.9**	-	10,702.3**	2,830.3**
	MS - C	-	540.2**	1,883.4**	930.4**	-
	MS - NR	581.2**	1,342.0**	-	832.9**	238.8**
	MS - E by NR	112.1*	-	-	-	-
	MS - E by C by NR	-	-	-	310.8*	-
	MS - E by C by S	-	-	375.0**	524.0**	-
	MS - E by C by NR by S	-	-	132.4*	244.6*	-
	MS - Error	36.39	54.38	42.93	74.25	10.21
Sucker culms	$\bar{x}$	83.8	-23.1	115.8	819.4	6.1
	C.V.%	4.53	-23.0	2.69	0.59	34.76
	MS - E	42,806.4**	17,660.2**	16,394.6**	102,397.6**	4,213.4**
	MS - C	1,021.1**	2,886.4**	7,028.1**	10,625.1**	297.5**
	MS - E by C	373.2**	739.1**	44.0*	-	20.9*
	MS - NR	679.0**	172.1**	136.7**	609.2**	26.7**
	MS - E by NR	1,307.5**	828.5**	659.1**	3,475.9**	162.0**
	MS - C by NR	-	16.5*	94.4**	388.4**	-
	MS - E by C by NR	227.0**	-	273.4**	652.6**	-
	MS - S	603.3**	1,147.0**	344.9**	1,377.2**	161.2**
	MS - E by S	704.2**	719.8**	461.1**	1,656.2**	145.3**
	MS - C by S	222.6**	257.7**	521.2**	1,361.7**	45.1**
	MS - E by C by S	167.1**	-	480.2**	841.3**	-
	MS - NR by S	219.3**	403.7**	213.6**	628.7**	49.4**
	MS - E by NR by S	222.2**	328.3**	106.5**	509.2**	51.4**
	MS - C by NR by S	284.4**	-	194.0**	777.3**	13.6*
	MS - E by C by NR by S	247.2**	-	225.6**	717.6**	14.8*
	MS - Error	14.39	28.30	9.72	23.07	4.49
Mature stalks + sucker culms	$\bar{x}$	214.3	128.5	132.9	685.5	76.2
	C.V.%	2.77	5.67	4.73	1.23	4.16
	MS - E	22,332.9**	20,081.2**	-	21,776.2**	5,073.4**
	MS - C	672.0**	2,298.0**	1,194.5**	-	290.5**
	MS - E by C	169.6*	286.5*	-	-	46.9*
	MS - NR	1,530.8**	2,993.3**	203.6**	2,108.7**	556.9**
	MS - E by NR	423.1**	482.9**	-	393.5**	96.3**

	MS - C by NR	-	220.9*	-	-	31.2*
	MS - E by C by NR	204.1**	-	-	434.1**	36.1*
	MS - E by C by S	-	-	362.2**	452.4**	-
	MS - E by C by NR by S	-	-	121.4*	257.7**	-
	MS - Error	35.11	53.0	39.48	70.91	10.07

[1] $\bar{x}$ = mean value; C.V.% = coefficient of variation $=100.\sqrt{(\sigma_s^2 + s\sigma_e^2)}/\bar{x}$; MS - E = mean square for environments; MS - C = mean square for cultivars; MS - E by C = mean square for environments by cultivars interaction; MS - NR = mean square for nitrogen rates; MS - E by NR = mean square for environments by nitrogen rates interaction; MS – E by C by NR = mean square for environment by cultivars by nitrogen rates interaction; MS-S = mean square for spacings; MS E by S = mean square for environments by spacings interaction; MS C by S = mean square for cultivars by spacings interactions; MS E by C by S= mean square for environments by cultivars by spacings interaction; NR by S = mean square for nitrogen rates by spacings interaction; E by NR by S mean square for environments by nitrogen rates by spacings interaction; C by NR by S = interaction for clones by nitrogen rates by spacings interaction; MS - E by C by NR by S = mean square for environments by cultivars by nitrogen rates by spacings interaction, and MS - error = mean square for error.
*Significant at $P < 0.05$; **Significant at $P < 0.01$.

In contrast, analyses for sucker components revealed an almost full list of significant main and interaction effects (Table 32), e.g., all main effects were highly significant for all quality components. Only three of the 30 possible first-order interaction terms were not significant, with only three of these 27 not being highly significant. Five second-order interactions terms of a possible 20 were not significant, with all bar one of these 15 being highly significant. Finally, only one of five possible third-order interaction terms was not significant. The response of the suckering process in terms of the quality components analysed was very responsive to all the main effect treatments imposed, and interactions among these.

The contrast between component values is marked, but this is not surprising given earlier comparative analyses conducted at BSES Meringa on mature stalk and sucker culms. Values for brix (220.4 versus 83.8 g kg^{-1}), CCS (135.4 versus -23.0 g kg^{-1}), moisture (678.9 versus 819.4 g kg^{-1}), and pol reading (79.4 versus 6.1°Z) demonstrate this clearly. The differential between the two crop fractions for fibre is less marked (134.0 versus 115.8 g kg^{-1}), but can be explained by the nature of the samples for each fraction. Samples of mature stalks were clean, i.e., trash free, whereas the sucker culms merely had their leaves above the last exposed dewlap (LED) excised, if they were large enough, and clinging trash also would have been removed. However, given the generally small size of the sucker culms overall, the addition of the green leaf sheaths to the overall sucker culm samples would elevate fibre levels substantially relative to sucker culm tissue uncontaminated with leaf sheath material.

The analyses for weighted culm components (mature stalk and sucker culm) reflect those of the mature stalks, but with the number of significant first-order interaction terms increasing from one to nine. Relative to mature stalk means, mean weighted values were moderated by the sucker component values, e.g., values are decreased for all components except moisture. Precision of analyses, as reflected by C.V.% values, again was excellent (Table 32).

There were extensive significant differences for a majority of main effects, and in particular for interaction effects among these for quality components (Table. 32). However, the interaction effects are so extensive, that presentation of means for these is

considered excessive, and so main-effect means only are presented (Table 33). As expected, there were marked differentials for quality components when differences between the irrigated and rain-fed environments were significant. Brix, CCS and pol readings were higher, and moisture content lower (Table 32). Overall, Q152 had a higher CCS (137.2 versus 133.7 g kg^{-1}), had a lower fibre, and a higher moisture content (Table 33). Brix values and pol reading decreased significantly with each increment in nitrogen rate. Moisture content for the split nitrogen application (140 + 70 kg N ha^{-1}) was significantly higher than both the zero and the single application (140 kg N ha^{-1}). The latter did not differ significantly.

The differences among all main effects for quality components of sucker culm were marked in most cases. The rain-fed environment had higher values for brix, CCS, fibre, and pol reading, and lower moisture content (Table 33). There was no significant effect for fibre for mature stalks. The significance for fibre content of sucker culms may be an artefact. Rain-fed sucker culms were smaller, and as discussed earlier, only leaves above the LED leaf were removed. The proportion of leaf sheath material remaining on the sucker culms, relative to culm tissue, therefore would be higher in the rain-fed samples. Fibre levels would be inflated simply because of the differential fibre content of the two tissues.

Q152 also had higher component values for sucker culms for brix, CCS, fibre, and pol reading, but had a lower moisture content (Table 33). Responses to nitrogen applications were more complex. The nitrogen applications did not differ for brix, but both were significantly greater than zero nitrogen. The single nitrogen application had a higher pol reading than the split application, which in turn was significantly greater than zero nitrogen. Fibre content was highest at zero nitrogen, with the value for the split application being significantly greater than this, and the single rate value significantly greater again. Values for CCS were highest for the single nitrogen application (Table 33), with this differing significantly from the value for the split application but not the value recorded for the zero nitrogen.

The effects of stool spacing on sucker culm components are interesting (Table 33). Highest brix (86.9 g kg^{-1}) was recorded at the closest stool spacing (0.5 m), followed by the widest spacing (1.5 m), which in turn was significantly greater than the intermediate spacing. This pattern also was displayed by fibre and pol reading. CCS also was greatest for the narrow row spacing, this being significantly greater than CCS values for the intermediate and wide spacings, which did not differ from each other. As expected, moisture showed the inverse pattern to fibre (and brix and pol reading), with the highest value (824.4 g kg^{-1}) being recorded by the intermediate stool spacing.

Values for weighted plot means for the components reflect the obvious, high values for all except moisture for mature stalks being moderated by the lower values of the sucker culms, with the opposite occurring for moisture content. Brix and pol. reading of Q152 now is significantly higher than the values for Q138, while fibre for Q138 is significantly higher than that for Q152. Moisture levels for the cultivars did not differ significantly. Fibre levels for the zero nitrogen treatment (134.9 g kg^{-1}) differed significantly from the split application (131.2 g kg^{-1}), but the fibre values for the intermediate nitrogen rate differed from neither.

Table 33: Mean values and least significant differences for main effects only for five quality components of three crop fractions determined at the harvest of the plant crop.

Crop fraction	Effect	Contrast	Component				
			Brix (g kg^{-1})	CCS (g kg^{-1})	Fibre (g kg^{-1})	Moisture (g kg^{-1})	Pol reading (°Z)
Mature stalks	Environments	Irrigated	212.0	127.8	-	686.6	75.5
		Rain fed	228.8	143.1	-	671.2	83.4
		$lsd_{(0.05)}$	2.72	2.51	-	4.65	1.26
	Cultivars	Q138	-	133.7	137.3	676.6	-
		Q152	-	137.2	130.8	681.2	-
		$lsd_{(0.05)}$	-	2.16	1.92	2.52	-
	Nitrogen rates	0	223.2	140.1	-	675.4	81.4
		140	220.8	135.5	-	678.5	79.6
		(140 + 70)	217.1	130.7	-	682.8	77.4
		$lsd_{(0.05)}$	2.16	2.64	-	3.56	1.14
Sucker culms	Environments	Irrigated	68.4	-33.0	106.2	843.2	1.3
		Rain fed	99.2	-13.2	125.3	795.5	10.9
		$lsd_{(0.05)}$	1.29	1.16	1.66	1.94	0.53
	Cultivars	Q138	81.4	-27.1	109.5	827.0	4.8
		Q152	86.2	-19.1	122.0	811.7	7.4
		$lsd_{(0.05)}$	1.11	1.55	0.99	1.40	0.62
	Nitrogen rates	0	80.0	-23.2	115.7	822.8	5.5
		140	85.3	-21.4	117.3	816.5	6.8
		(140 + 70)	86.2	-24.8	114.3	818.7	6.0
		$lsd_{(0.05)}$	1.36	1.90	1.12	1.72	0.76
	Spacings	0.5	86.9	-18.1	117.7	814.8	7.9
		1.0	80.6	-25.6	113.1	824.4	4.8
		1.5	83.9	-25.7	116.5	818.9	5.6
		$lsd_{(0.05)}$	1.36	1.90	1.12	1.72	0.76
Mature stalks + sucker culms	Environments	Irrigated	203.2	117.9	-	696.5	70.9
		Rain fed	225.4	139.0	-	674.5	81.5
		$lsd_{(0.05)}$	3.18	3.42	-	4.53	1.56
	Cultivars	Q138	212.4	124.9	135.5	-	75.0
		Q152	216.2	132.0	130.3	-	77.5
		$lsd_{(0.05)}$	1.73	2.13	1.84	-	0.93
	Nitrogen rates	0	219.1	135.5	134.9	679.8	79.2
		140	214.7	128.6	132.7	685.0	76.3
		(140 + 70)	209.1	121.4	131.2	691.6	73.1
		$lsd_{(0.05)}$	2.12	2.61	2.25	3.01	1.14

3.7.2.6 Sugar yields

Analyses of sugar yields (TCH or TSuH by CCS) revealed good precision for the mature stalk and the weighted analyses (CV% = 10.7, Table 34), but a much less precise analysis for the sucker culms. This lack of precision for the sucker data has been commented on before, and simply reflects the variability associated with expression of sucker propensity.

Main effects of environments and cultivars were statistically significant for mature stalks and the weighted plot analysis. Interaction effects for environments by spacings and environments by cultivars by spacings were significant for both analyses, but the interaction term for environments by nitrogen rates by spacings significant for only the weighted plot analysis (Table 34).

The significance pattern for the sucker culm sugar yield differed from the above sugar yield components, but this is not surprising as the mean for the trait is near zero (-0.14 t ha^{-1}; Table 34). All main effects except spacings were significant (Table 34). Interaction effects of environments by cultivars, and a suite of three involving nitrogen rates (environments by, cultivars by, and cultivars by environments by) were significant (Table 34). Each of the three significant main effects participated in three significant interactions, with the absence of spacings in any of these being notable.

Table 34: Summary statistics and significant mean squares from analyses of variance of sugar yield data for three crop fractions determined at harvest of the plant crop.

Statistic[1]	Mature stalks	Sucker culms	Combined
$\bar{x}$	13.85	-0.14	13.70
C.V.%	10.65	-53.57	10.68
MS - E	18.61*	2.13**	33.23**
MS - C	122.33**	0.50**	138.47**
MS - E by C	-	0.28**	-
MS - NR	-	0.33**	-
MS - E by NR	-	0.28**	-
MS - C by NR	-	0.04**	-
MS - E by C by NR	-	0.03**	-
MS - E by S	12.74**	-	12.54**
MS - E by C by S	10.68**	-	10.69**
MS - E by NR by S	-	-	5.29**
MS - Error	2.18	0.006	2.14

[1] $\bar{x}$ = mean value; C.V.% = coefficient of variation = $100.\sqrt{(\sigma_s^2 + s\sigma_e^2)}/\bar{x}$; MS - E = mean square for environments; MS - C = mean square for cultivars; MS - E by C = mean square for environments by cultivars interaction; MS - NR = mean square for nitrogen rates; MS - E by NR = mean square for environments by nitrogen rates interaction; MS – C by NR = mean square for cultivars by nitrogen rates interaction; MS – E by C by NR = mean square for environment by cultivars by nitrogen rates interaction; MS E by S = mean square for environments by spacings interaction; MS E by C by S= mean square for environments by cultivars by spacings interaction; E by NR by S mean square for environments by nitrogen rates by spacings interaction, and MS - error = mean square for error.
*Significant at $P < 0.05$; **Significant at $P < 0.01$.

The rain-fed environment had higher sugar yield for all three measures than did the irrigated environment (Table 35). Similarly, Q152 was a superior performer than Q138 in all these measures; the differentials of 1.7 t ha-1 and 1.8 t ha^{-1}, for mature stalk and weighted plot mean sugar yield, respectively, were substantial (Table 35). For mature-stalk sugar yield there were no differences among spacings in the irrigated environment, but the 1.5 m spacing produced a significantly lower sugar yield than the closer spacings in the rain-fed environment. The latter also was true for the irrigated environment for weighted sugar yield, but the yield for the closest spacing (0.5 m) differed significantly from the widest spacing (1.5 m) (Table 35).

The pattern for the second order interaction of environments by cultivars by spacings for mature stalk sugar yield was complex. For Q138 in the irrigated environment, the yield at 0.5 m spacing was significantly less than that either 1.0 m and 1.5 m spacing Table 35). Yet in the rain-fed environment, the same treatment at 1.5 m spacing was significantly superior to either the 0.5 or 1.0 m spacing. For Q152, sugar yield in the rain-fed environment at the 1.0 m spacing was significantly superior to either of the other spacings. The pattern for weighted plot yield, with one exception, was similar to that discussed for mature-stalk sugar yield (Table 35).

The only significant difference among treatments within the irrigated environment for the environment by nitrogen rates by spacings interaction was between 0.5 and 1.5 m spacings at the split nitrogen rate (140 + 70 kg N). Again, in the rain-fed environment, the response pattern was different. Sugar yield at the 1.5 m spacing was significant better than at the 0.5 m spacing at 140 kg N. With the split application of 140 + 70 kg N ha^{-1}, sugar yield at 1.0 m spacing was significantly superior to that at the 0.5 m and 1.5 m spacings (Table 35). Differences among treatments for sucker-culm sugar yield were numerous, but detailed discussion of these is not warranted given the small magnitude of all these effects (Table 35).

Table 35: Mean values and least significant differences for sugar yield data for three crop fractions determined at harvest of the plant crop.

Effect	Contrast	Mature stalks	Sucker culms	Combined
Environments	Irrigated	13.5	-0.25	13.3
	Rain fed	14.2	-0.03	14.1
	$lsd_{(0.05)}$	0.45	0.053	0.45
Cultivars	Q138	13.0	-0.20	12.8
	Q152	14.7	-0.09	14.6
	$lsd_{(0.05)}$	0.43	0.022	0.43
Environments by cultivars	Irrig. by Q138	-	-0.34	-
	Irrig. by Q152	-	-0.16	-
	RF by Q138	-	-0.05	-
	RF by Q152	-	-0.02	-
	$lsd_{(0.05)}$	-	0.032	-
Nitrogen rates	0	-	-0.07	-
	140	-	-0.14	-
	140 + 70	-	-0.22	-
	$lsd_{(0.05)}$	-	0.027	-
Environments by nitrogen rates	Irrig. by 0	-	-0.11	-
	Irrig. by 140	-	-0.25	-
	Irrig. by (140 + 70)	-	-0.40	-
	RF by 0	-	-0.03	-
	RF by 140	-	-0.2	-
	RF x(140 + 70)	-	-0.05	-
	$lsd_{(0.05)}$	-	0.039	
Cultivars by nitrogen rates	Q138 by 0	-	-0.10	-
	Q138 by 140	-	-0.19	-
	Q138 by (140 + 70)	-	-0.30	-
	Q152 by 0	-	-0.05	-
	Q152 by 140	-	-0.08	-
	Q152 by (140 + 70)	-	-0.14	-
	$lsd_{(0.05)}$	-	0.039	-

Environments by cultivars by nitrogen rates	Irrig. by Q138 by 0	-	-0.15	-
	Irrig. by Q138 x140	-	-0.36	-
	Irrig. by Q138 by (140 + 70)	-	-0.52	-
	Irrig. by Q152 by 0	-	-0.07	-
	Irrig. by Q152 by 140	-	-0.14	-
	Irrig. by Q152 by (140 + 70)	-	-0.27	-
	RF by Q138 by 0	-	-0.05	-
	RF by Q138 by 140	-	-0.02	-
	RF by Q138 (140 + 70)	-	-0.07	-
	RF by Q152 by 0	-	-0.02	-
	RF by Q152 by 140	-	-0.02	-
	RF by Q152 (140+70)	-	-0.02	-
	$lsd_{(0.05)}$	-	0.055	-
Environments by spacings	Irrig. by 0.5	13.1	-	12.8
	Irrig. by 1.0	13.7	-	13.4
	Irrig. by 1.5	13.8	-	13.6
	RF by 0.5	14.3	-	14.3
	RF by 1.0	14.8	-	14.7
	RF by 1.5	13.4	-	13.4
	$lsd_{(0.05)}$	0.75	-	0.74
Environments by cultivars by spacings	Irrig. by Q138 by 0.5	11.8	-	11.5
	Irrig. xQ138 by 1.0	12.8	-	12.5
	Irrig. by Q138 1.5	13.2	-	12.8
	Irrig. by Q152 by 0.5	14.3	-	14.1
	Irrig. by Q152 by 1.0	14.6	-	14.4
	Irrig. by Q152 by 1.5	14.5	-	14.2
	RF by Q138 x0.5	14.2	-	14.2
	RF by Q138 by 1.0	13.8	-	13.7
	RF by Q138 by 1.5	12.3	-	12.2
	RF by Q152 by 0.5	14.4	-	14.4
	RF by Q152 by 1.0	15.7	-	15.7
	RF by Q152 by 1.5	14.6	-	14.5
	$lsd_{(0.05)}$	0.75	-	1.05
Environments by nitrogen rates by spacings	Irrig by 0 by 0.5	-	-	13.1
	Irrig by 0 by 1.0	-	-	13.4
	Irrig by 0 by 1.5	-	-	13.3
	Irrig by 140 by 0.5	-	-	13.3
	Irrig by 140 by 1.0	-	-	14.0
	Irrig by 140 by 1.5	-	-	13.7
	Irrig by (140 + 70) by 0.5	-	-	12.0
	Irrig by (140 + 70) by 1.0	-	-	13.0
	Irrig by (140 + 70) by 1.5	-	-	13.7
	RF by 0 by 0.5	-	-	14.6
	RF by 0 by 1.0	-	-	14.4
	RF by 0 by 1.5	-	-	14.4
	RF by 140 by 0.5	-	-	14.6
	RF by 140 by 1.0	-	-	14.1
	RF by 140 by 1.5	-	-	13.0
	RF by (140 + 70) by 0.5	-	-	13.7
	RF by (140 + 70) by 1.0	-	-	15.6
	RF by (140 + 70) by 1.5	-	-	12.8
	$lsd_{(0.05)}$	-	-	1.28

The summary statistics and mean squares obtained from the current trial are summarized and contrasted with results obtained from earlier research on suckering conducted in the context of final assessment trials (FATs) (Table 36). These contrasts are on unequal bases, using only to cultivars in the current trial versus many cultivars/cultivars in the FATs. Despite this, the purpose is to contrast the data presented here with broader assessments for measured traits obtained from the FATs. The cultivars term for the yield based traits (T(C+Su)H, TCH, TSuH, and %Su) was significant in all trials. As discussed earlier, the main effect of nitrogen rates was significant for all yield traits in the irrigated environment of this trial, but spacings was not significant for any trait. In contrast, nitrogen rates were significant for the sucker based yield traits (TSuH, and %Su), and spacings significant for the non-sucker based traits (T(C+Su)H and TCH). Coefficients of variation values for the yield based traits in the existing experiment tended to be lower than those recorded in the FATs, and CV % values for sucker based traits were considerably higher than non-sucker based traits. However, CV% values for the rain-fed environment in the existing experiment were almost double those recorded for the irrigated environment, and were above the values recorded for the fats. Mean values for TSuH in the FATs (11.4 and 13.7) were greater than the mean for the irrigated (7.05 TSuH) and rain-fed (2.6 TSuH) environments. However, the maximum values recorded for the FATs overshadowed the maximum values from treatments in this trial. Mean values for Su% obtained from this trial also were lower than those obtained from the FATS.

Some explanation for these results comes from contrasting data for sucker number and size collected from this trial with that obtained for the 1999 FAT harvest. The cultivars term was not significant for number of suckers per hectare recorded in this trial (Table 36), but this is not surprising given only two cultivars were used, and these were selected for high suckering propensity. Again, nitrogen rates were significant for number of suckers in both environments in this trial. Values for CV% for sucker number were comparable to the sucker-based traits discussed earlier, and therefore were inflated relative to the non-sucker based traits. The mean number of suckers in the environments of this trial (≈ 51,000 and 30,000 for irrigated and rain-fed environments) was greater than the mean number recorded for the 1999 FAT (24,000). However, the maximum value recorded in the irrigated environment approximated that of the 1999 FAT. We conclude that of the stimuli explored in this trial, environment (post-monsoonal irrigation versus rain-fed) and nitrogen rates were the only main effects for which significant variation was observed. Overall, however, mean numbers were comparable to those observed in the 1999 FAT, containing much greater genetic variation, subjected only to commercial management.

The cultivars term was significant for all three analyses for sucker size, expressed as kg/100Su (Table 36). Nitrogen rates and spacings were significant main effects in the irrigated environment of this trial, with the former also being significant in the rain-fed environment. The mean for sucker size (kg/100Su) in the 1999 FAT (54.3) was substantially greater than that for the irrigated environment (13.9) and the rain-fed environment of this trial (9.0).

Although stimulation of sucker numbers was successful, the onset of the response in 2000 was delayed so that sucker size at harvest was well below that recorded in the 1999 FAT. While this reflects the general observation in commercial fields in the region, this does suggest that a vital stimulatory element was missing. Intuitively, successful mimicking of

key natural stimulatory elements would result in the number and size of resulting suckers approximating values observed in a year of high suckering propensity, e.g., 1999. The results obtained suggest that stimulation of numbers was successful but the onset of development of these was delayed, and reflected natural phenomena.

Table 36: Comparative summary statistics[1] and relevant main-effect mean squares for mature stalk and sucker culm data collected in final assessment trials (FATs) in 1998 and 1999 and in the plant crop of this trial.

Trial	Statistic	TCH	TSuH	T(C+Su)/H	%Su	No. sucker culms/ha	Kg/100 Su
1998 FAT[1]	MS - C	753.0**	96.0**	720.7**	77.1**	-	-
	C.V.(%)	17.5	41.6	15.3	47.1	-	-
	Mean	102.8	11.4	114.1	10.2	-	-
	Minimum	59.3	0.7	79.0	0.5	-	-
	Maximum	175.8	31.2	182.8	25.1	-	-
1999 FAT[1]	MS - C	561.0**	130.0**	828.4**	98.0**	346,097,072.**	531.5**
	C.V.(%)	16.8	37.7	14.7	36.8	35.3	21.3
	Mean	76.7	13.7	90.4	14.9	24,495.0	54.3
	Minimum	33.7	0.7	38.4	0.9	2,431.0	26.5
	Maximum	125.0	43.8	149.0	33.4	72,569.0	101.8
This - irrigated	MS - C	2,209.0**	167.1*	1,161.0**	168.2**	-	1364.1**
	MS – NR	755.1**	303.7**	1,953.4**	171.0**	6,104,273.**	278.7**
	MS – S	-	-	-	-	-	33.4**
	C.V.(%)	9.3	25.4	9.2	23.4	21.5	15.3
	Mean	105.9	7.1	113.0	6.2	50,549.0	13.9
	Minimum	87.4	3.0	91.6	2.6	30,333.0	6.1
	Maximum	116.0	11.8	124.8	10.6	73,444.0	23.1
This - rain fed	MS - C	1,732.0*	49.9**	1,194.1*	57.0**	-	24.8*
	MS – NR	-	19.9**	-	16.2**	1,542,494.**	596.0**
	MS – S	705.1**	-	724.2**	-	-	-
	C.V.(%)	9.4	51.5	9.5	45.6	37.5	17.9
	Mean	99.1	2.6	101.7	2.6	29,699.0	9.0
	Minimum	84.1	1.3	86.2	1.2	18,178.0	5.3
	Maximum	116.6	5.7	118.6	5.4	45,444.0	15.3

[1]TCH = tonnes of cane per hectare; TSuH = tonnes of suckers per hectare; T(C + Su)H = tonnes of cane and suckers per hectare; % Su = 100(TSuH/(T(C + Su)H; kg/100Su = kilograms per 100 suckers.
[2]Berding & Hurney (2000).
*Significant at $P < 0.05$; **Significant at $P < 0.01$.

3.7.2.7 Environmental data

Data for ambient temperature and humidity, rainfall, and photosynthetically active radiation (PAR), collected from the on-site weather station, are shown in Figure 12. The break in these data resulted because the weather station used suffered a catastrophic mother-board failure, probably from ant activity. The failure could not be repaired readily, 18 weeks passing before data were again recorded. The intensity of the monsoonal season is graphically illustrated, with > 1,600 mm of rain recorded in a 14-week period (weeks 11-24). In addition to the serious flooding this produced at the trial site, the trail was physically compromised because of the wind damage inflicted by the

passage of three cyclones adjacent to the Cairns coast. In addition to sprawling and lodging caused by these winds in a large crop located in saturated conditions, extensive stalk breakage also resulted.

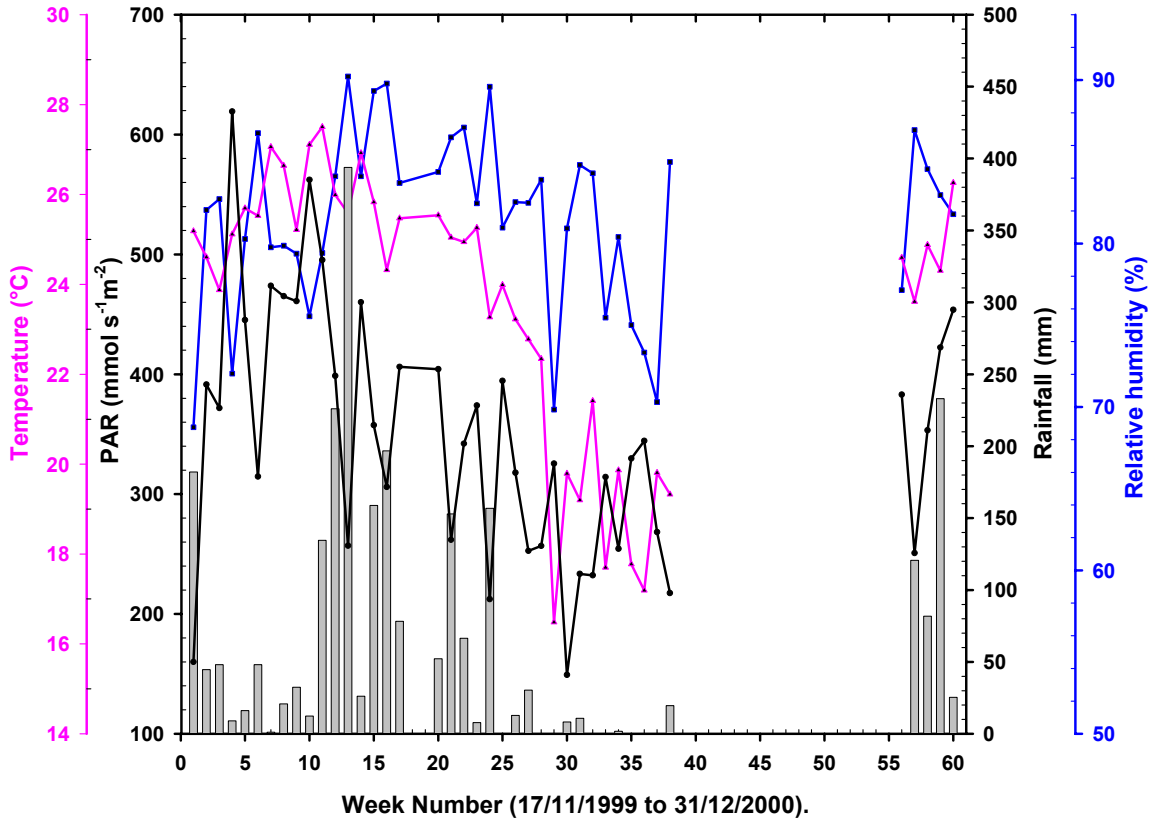

Figure 12: Mean weekly PAR, relative humidity and rainfall and weekly rainfall from 17 November 1999.

The annual variation for temperature, humidity, and PAR are obvious with passage from the summer solstice (week 6) through winter to the next summer solstice (week 59).

In earlier discussion, a contrast was made between aspects of sucker data collected in the plant crop of the large field trial conducted in this project and data collected in earlier research on suckering in the context of FATs in the BSES Meringa program. Comparative data were assembled for regional rainfall in the two growing seasons for which detailed data were presented - June 1998 - September 1999, for the 1999 2R FAT, and June 1999 - September 2000, for this trial (Figure 13). There are no major differences in the general pattern evident in the two seasons. There are differences on a monthly basis, e.g., November, February, and April rainfall for the 1999-2000 growing season exceeded that received for these months in the 1998-1999 growing season. Conversely, rainfall received in December, January, March, and September for the 1998-1999 growing season exceeded that received for these months in the 1999-2000 growing season. However, these data, by themselves, do not define differences between seasons that reasonably could explain differences in observed sucker development.

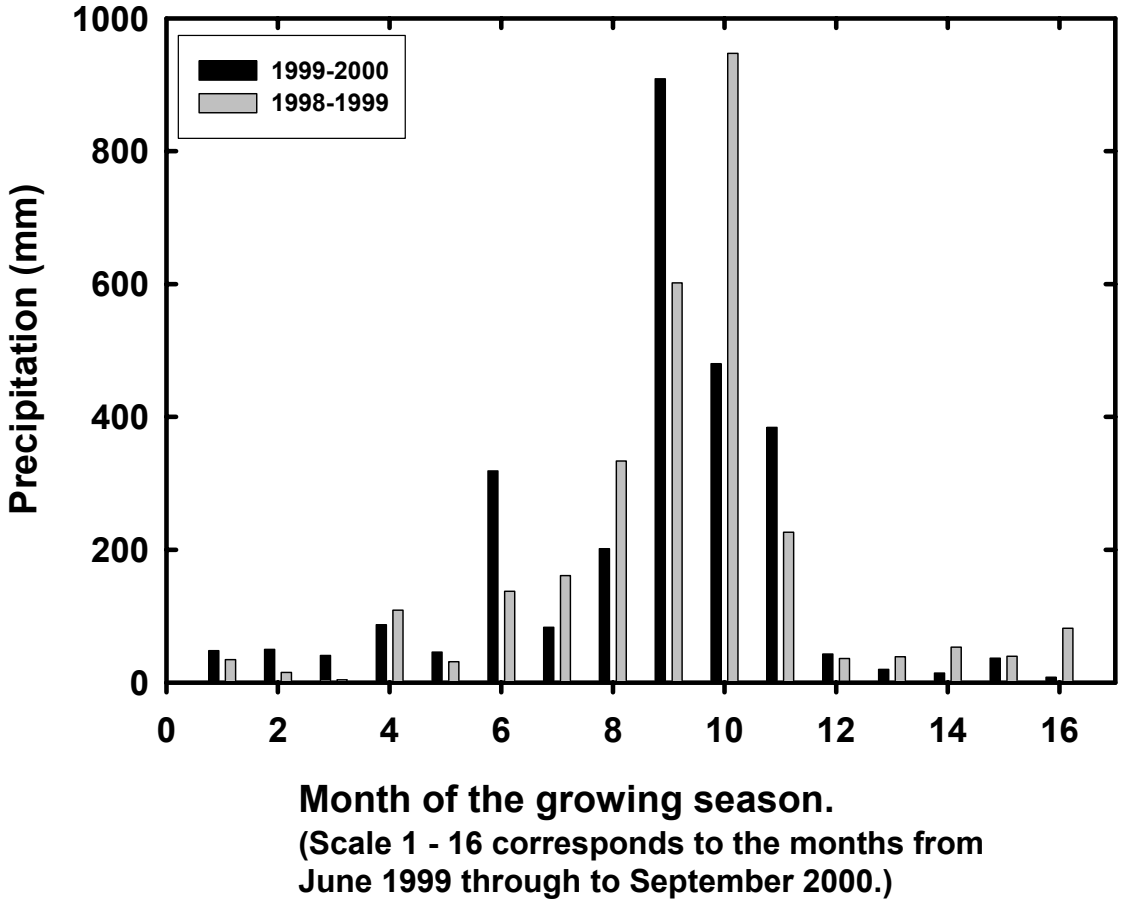

Figure 13: Comparison between monthly rainfall in 1999-2000 and 1998-99 growing seasons.

Water balance details ('A-pan' pan evaporation (and gain), applied irrigation, and recorded precipitation) for the post-monsoonal irrigation regime are detailed in Figure 14. This regimen was applied for 10 weeks beginning 19 June. The soil moisture regime was saturated in weeks 1 and 2 to ensure attainment of field capacity. This had been determined at about 18% by determining soil moisture on a series of core samples from the trial site three days after saturating rain early in the trial's history. Soil moisture was maintained using a three-day moving mean of [precipitation + irrigation]/evaporation = 1.0. As monitoring of this using TDR was suspect, gravimetric soil moisture was determined on several occasions. The regimen was again saturated in week 7 of the regimen, as maintenance of the moisture regimen appeared less than satisfactory. This regimen was maintained until 2 weeks before harvest. Results presented earlier clearly show the post-monsoonal maintenance of soil moisture to approximate field capacity had a profound effect on nearly all measured traits, despite being less than precisely maintained.

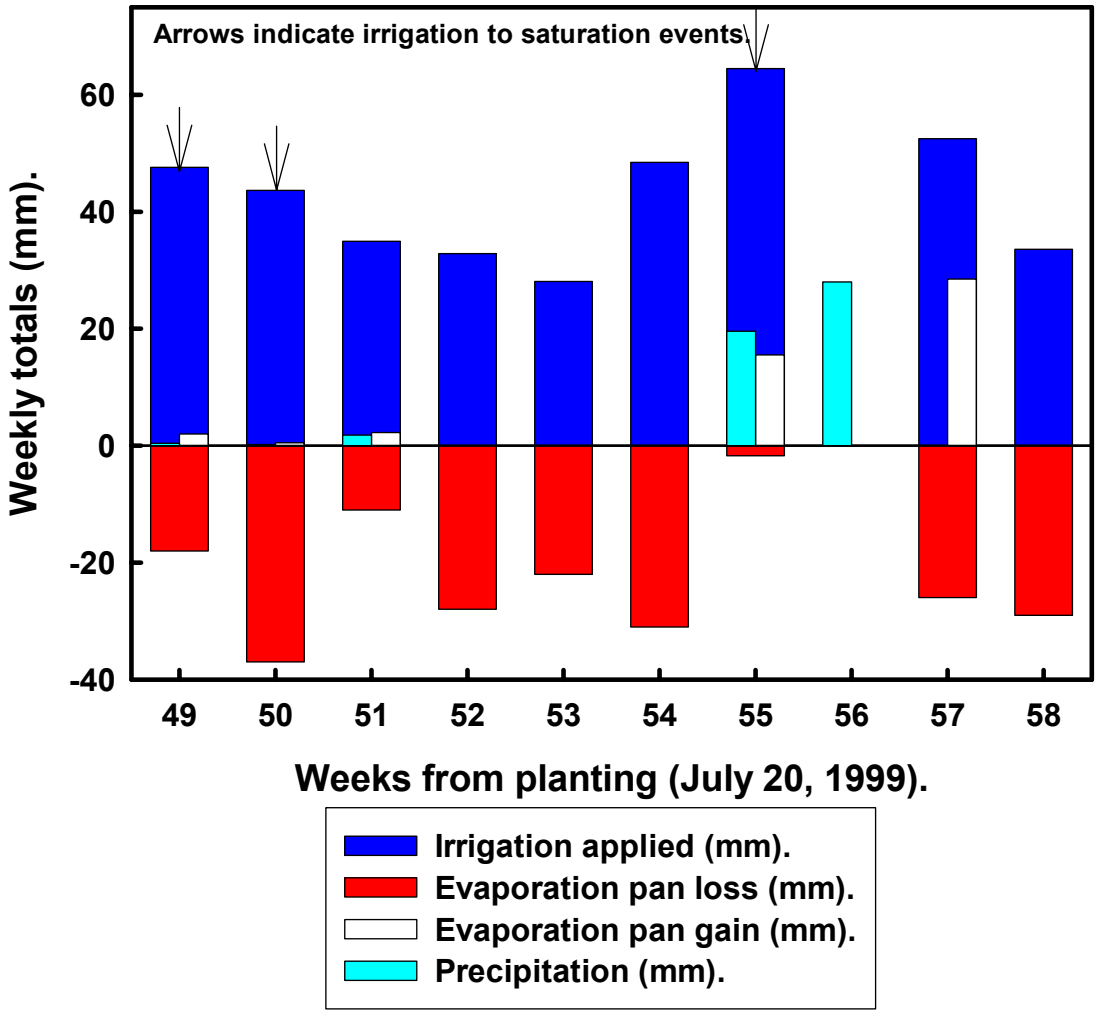

Figure 14: Irrigation management to maintain 'field capacity' in post-monsoonal environment from 19 June 2000.

3.7.2.8 Soil nitrogen

Soil nitrate concentrations in the 140 + 70 kg N/ha plots were significantly higher for both the 0-25 cm and 25.1-50 cm depths (Figure 15). There was no significant difference in soil nitrate-N concentration for the 0 kg N/ha treatment and 140 kg N/ha treatment. Samples taken on 4 July 2000 also showed a significant increase in soil nitrate-N concentration for both depths in the 140 + 70 kg N/ha plots. These results indicate that at least some of the additional N applied to plots in May was available to the crop, and was not leached or lost prior to the plant being able to utilize it, i.e., a treatment effect was generated by a late application of N.

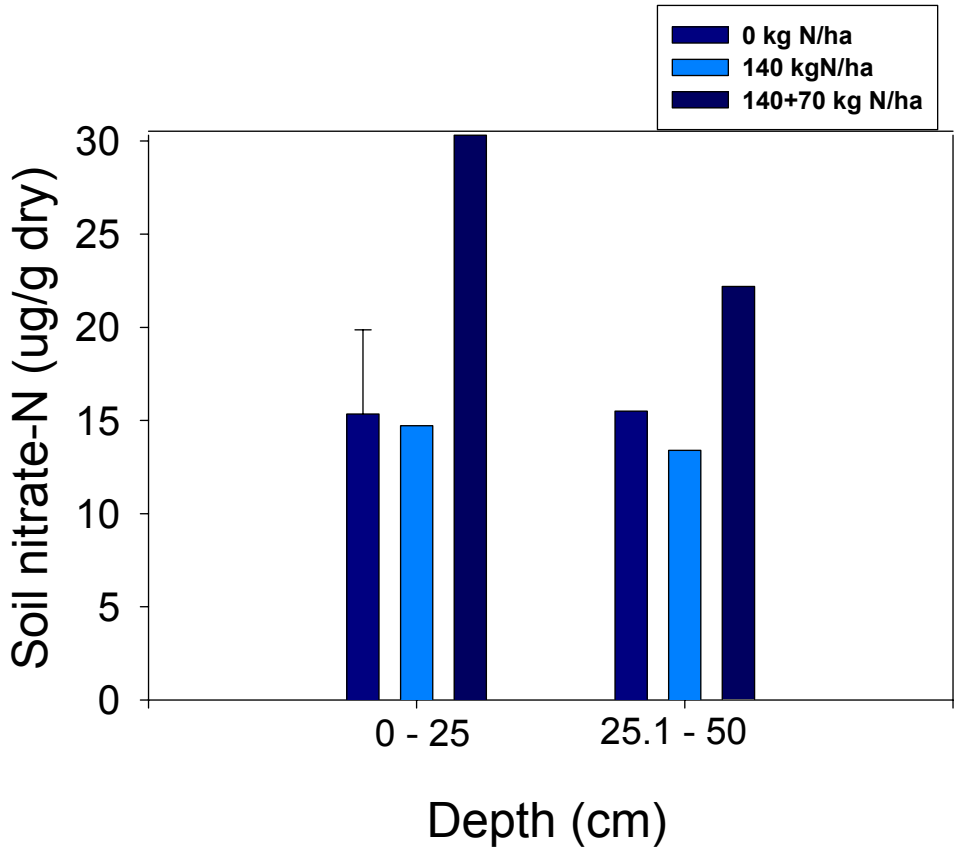

Figure 15: Soil nitrate concentrations following late nitrogen application. Bar represents LSD.

3.7.2.9 Light levels

There were significant differences due to stool space were found in the red/far-red ratio of light on 28 March 2000 (Figure 16). The overall effect of increased spacing resulted in an increase in the R/FR ratio of light beneath the canopy. However, no significant differences were found on the 25 May. Despite this, differences may still have been present in the period between the two samplings. Analysis of sucker number per stalk shows a significant effect of spacing at 292 days after planting. This date is after significant differences in R/FR ratio. The R/FR ratio may, therefore, be a factor partly driving suckering in this period.

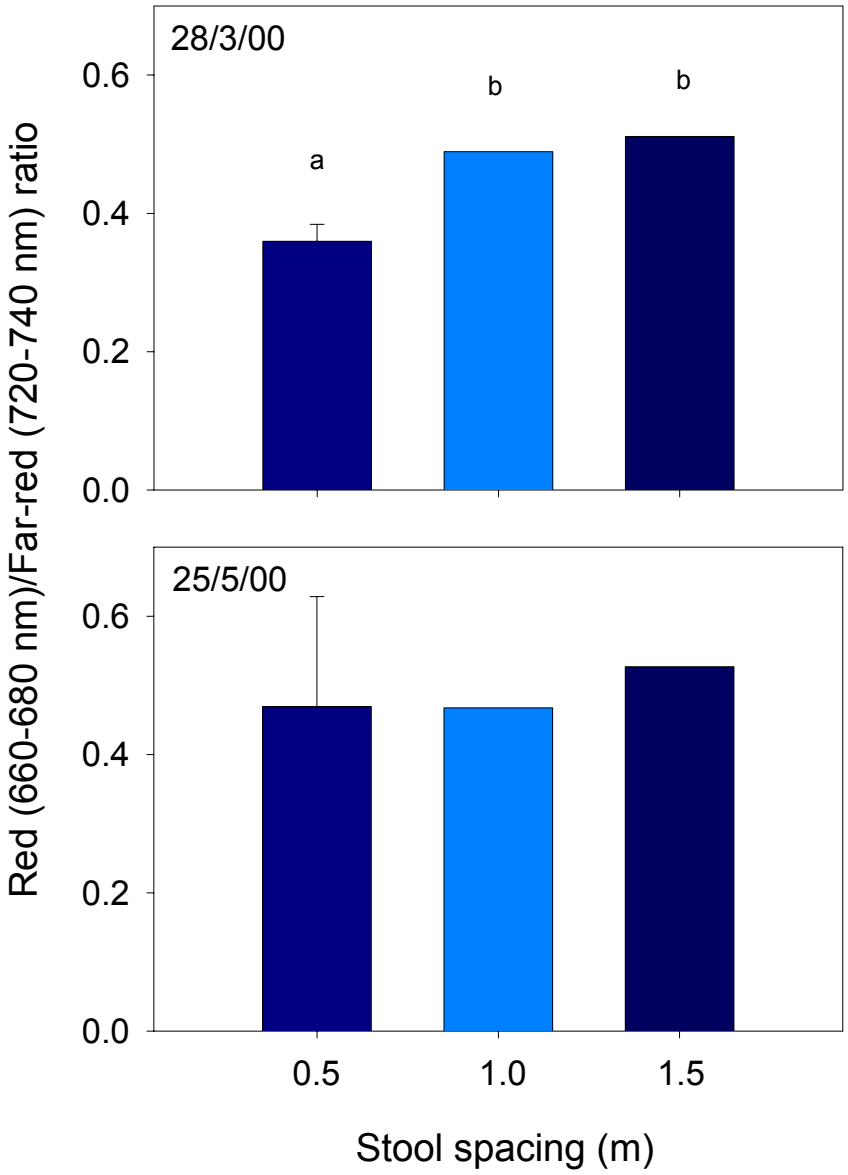

Figure 16: Red/far-red ratio of light beneath the canopy on 28 March and 25 May 2000. Sunlight ± 1.3. Bars represent LSD.

There was a significant increase in PAR due to increased stool spacing, and the height at which the measurement was taken (Figure 17). Significant differences also were found between environments, with the rain-fed environment having a higher average PAR than the irrigated environment. Significant differences in sucker number per stalk due to stool spacing, 292 days after planting and subsequently, may in part, have been due to the increase in light quantity.

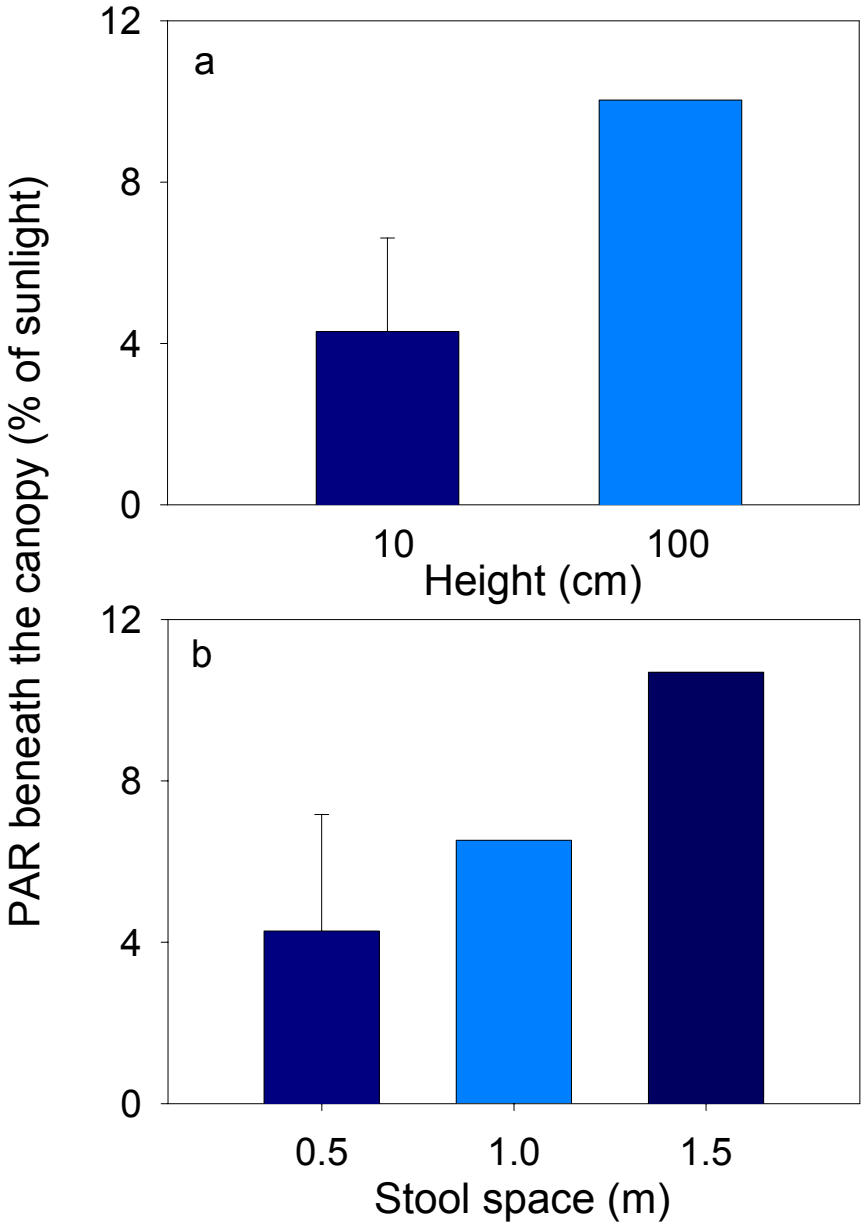

Figure 17: **PAR beneath the canopy as a percentage of sunlight: (a) difference in PAR due to height above ground; (b) difference in PAR due to stool spacing. Bars represent LSD.**

3.7.3 First-ratoon results

3.7.3.1 Mature stalks and sucker culms

Analyses of variance for these data are presented in Table 37. Coefficients of variation (C.V.%) values for mature stalk counts were acceptable (9.3-11.4%; Table 37). All main effects (environments – E, clones – C, nitrogen rates – NR, and spacings – S) for the four analyses were highly significant except for S for the last analysis. A range of interaction terms was significant across these sample dates, with E by C being significant, or highly

significant, for the last three sample dates. The dynamics for mature stalk population numbers are depicted in Figure 18. The mean across all treatments declined over the measurement period, from 77.5 mature stalks per core plot at 183 DAR, to 69.3 at 386 DAR.

However, C.V.% values from the analyses for sucker culm numbers were substantially higher, reflecting the variable nature of the various treatments, across replicates and other main factors. These C.V.% values ranged from 211.0 at 183 DAR, to 21.6 at 386 DAR. The dynamic of changes in sucker culm numbers as the season progressed are depicted in Figure 18. These were spectacular, rising from almost zero (0.649) per core plot at 183 DAR (Table 37) to 52 sucker culms per plot at 386 (DAR). This number of suckers at 386 DAR was 75% of the average number of mature stalks present in the core plot at that time. There was little consistency in the significance pattern of either the main effects, or the interactions among these (Table 37). Clones were highly significant across all sample times, whereas spacings were significant only at the third sample time (289 DAR). The environments differed significantly (highly) only at the 183 and 386 DAR counts. The significance pattern within sample times is more interesting. At 386 DAR, all main effects except S were highly significant. First order interactions E by C, and E by NR were highly significant, and C by NR, NR by S, as was the second order interaction E by C by NR were all significant. The number of significant effects, either main or interaction, increased from the first to the fourth sample time.

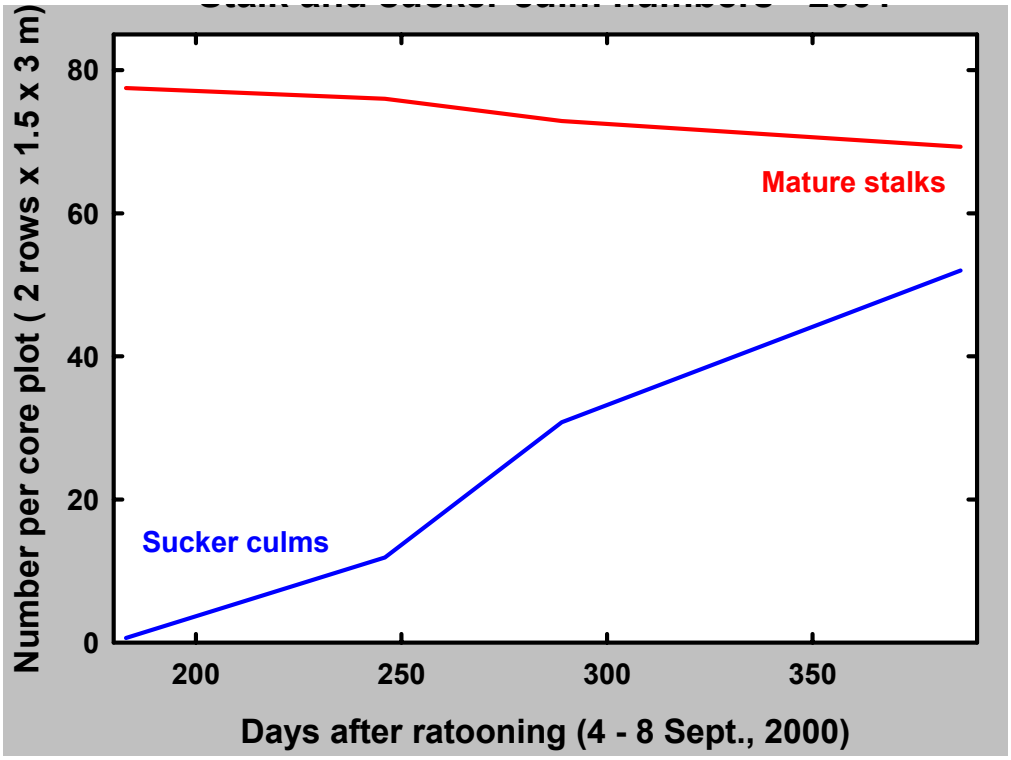

Figure 18: Mature stalk and sucker culm numbers during the first ratoon

Table 37: Summary statistics and significant mean squares from analyses of variance of mature stalk and sucker culm numbers collected on four occasions in the first-ratoon crop.

Count	Statistic[2]	Trait[1]				
		# MS	# Su	# Su/MS	SQRT (# Su)	SQRT (# Su/MS)
5-9 March, 2001 (183 DAR)	$\bar{x}$	77.5	0.649	0.009	0.354	0.041
	C.V.%	10.4	211.0	233.2	158.8	161.7
	MS – E	2,271.0**	68.3**	0.014**	19.2**	0.266**
	MS – C	2,906.9**	50.5**	0.010**	11.4**	0.151**
	MS – E by C	-	44.4**	0.009**	9.1**	0.123**
	MS – NR	7,681.6**	-	-	-	-
	MS – S	822.6**	-	-	-	-
	MS – Error	64.4	1.9	0.000	0.315	0.004
9-10 May, 2001 (246 DAR)	$\bar{x}$	76.0	11.9	0.156	3.212	0.368
	C.V.%	9.3	48.4	50.5	25.2	25.8
	MS – E	3,085.0**	-	0.214*	-	0.449*
	MS – C	4,949.4**	3,270.0**	0.445**	71.5**	0.701**
	MS – E by C	547.3**	462.9**	0.119**	5.3**	0.100**
	MS – NR	5,864.8**	644.3**	0.041**	18.7**	0.110**
	MS – E by NR	-	307.7**	0.070**	10.8**	0.159**
	MS – S	510.5**	-	-	-	-
	MS – E by S	169.8*	-	-	-	-
	MS – Error	49.9	33.3	0.006	0.654	0.009
21-22 June, 2001 (289 DAR)	$\bar{x}$	72.9	30.8	0.408	5.312	0.618
	C.V.%	10.0	29.3	29.4	14.8	14.8
	MS – E	791.0*	-	-	5.2	-
	MS – C	5,640.4**	13,374.3**	1.461**	109.9**	0.868**
	MS – E by C	474.1**	-	0.119**	3.1*	0.100**
	MS – NR	4,681.1**	8,437.2**	0.859**	77.9**	0.596**
	MS – E by NR	-	2,145.5**	0.377**	19.3**	0.256**
	MS – S	362.6**	669.1**	0.073**	4.7**	0.044**
	MS – NR by S	-	229.7*	-	-	-
	MS – Error	53.0	81.7	0.014	0.616	0.008
24-28 September, 2001 (386 DAR)	$\bar{x}$	69.3	52.0	0.727	6.9	0.830
	C.V.%	11.4	21.6	22.4	11.2	11.5
	MS – E	1,317.2**	55,980.2**	8.5**	269.8**	3.0**
	MS – C	5,968.2**	34,757.2**	3.6**	173.7**	1.3**
	MS – E by C	395.2*	2,767.5**	-	2.6*	-
	MS – NR	2,992.8**	7,797. 9**	0.715**	35.4**	0.214**
	MS – E by NR	-	3,309.1**	0.439**	11.4**	0.122**
	MS – C by NR	-	496.3*	0.084*	3.0**	0.029*
	MS – E by C by NR	-	520.7*	-	2.1*	-
	MS – S	241.3*	-	-	-	-
	MS – C by S	-	-	-	2.0*	-
	MS – NR by S	-	767.4**	0.091*	3.3**	0.032**
	MS – Error	62.0	125.7	0.026	0.605	0.009

[1]MS = mature stalk; Su = sucker; # Su/MS = number of sucker culms per mature stalk; SQRT = square root transformation of indicated variable.

[2] $\bar{x}$ = mean value; C.V.% = coefficient of variation = $100.\sqrt{\sigma_E^2}/\bar{x}$; MS – E = mean square for environments; MS – C = mean square for cultivars; MS – E by C = mean squares for environments by cultivars interaction; MS – NR = mean square for nitrogen rates; MS – E by NR = mean square for environments by nitrogen rates interaction; MS – C by NR = mean square for cultivars by nitrogen rates interaction; MS – E by C by NR = mean square for environments by cultivars by nitrogen rates interaction; MS – S mean square for

spacings; MS – E by S = mean square for environments by spacings interaction; MS – C by S = mean square for cultivars by nitrogen rates interaction; MS – NR by S = mean square for nitrogen rates by spacings interaction, and MS – Error = mean square for error = σ_E^2.
*Significant at P < 0.05; **Significant at P < 0.01.

Analysis of the trait # Su/MS revealed an additional significant main effect (E) for 246 DAR, an additional interaction (E by C) for 289 DAR, and one fewer interaction (E by C) for 386 DAR (Table 37). Values for the C.V.% were marginally higher for all samplings. We conclude that, analysis of sucker culm numbers on a 'per mature stalk basis', rather than as a direct measure, offered little advantage.

Use of the square-root transformation, for # Su and # Su/MS, also appears to offer little advantage. The C.V.% values are reduced, and, while this is not surprising, this is not a critical measure of the efficacy of the application of the transformation. There were only two addition significant effects revealed by use of the transformation, this being for 'E by C' for # Su at 289 DAR, and 'C by S' for # Su at 386 DAR. However, the significance for 'NR by S' for # Su at 289 DAR was lost.

We observed a 'new' phenomenon in this crop. There was a class of stalk that was initiated as a sucker but transformed into what appeared to be a mature stalk as the crop age progressed. These were characterized by retention of the thickened, smaller triangular leaves at the base of the stalk. This was a feature in common with a sucker culm, but the culm did not retain the larger diameter characteristic of a sucker but rather transformed into a 'normal' mature stalk. This was indistinguishable from the population of mature stalks in phenotype except for the 'relic' sucker culm leaves at the base. These culms were classified as 'transformed stalks' (TS). These only became evident between the 183 DAR and 246 DAR censuses. Results of the analysis of the trait # TS are given for counts conducted at 246, 289, and 386 DAR (Table 38). There can be no strict classification as to whether these transformed stalks are in fact suckers, or mature stalks, and hence dual analyses to cover both classifications – # (M + T)S versus # (Su + TS) and # Su/(M + T)S versus # (Su + TS)/MS were conducted (Table 38).

At no time did the # TS rise to a substantial number, the mean for all counts being less than 1.0 per core plot (Table 38). The C.V.% values for all were very high, 179-327% (Table 38). In all counts the main effects of 'E' and 'C', and their interaction (E by C) were highly significant. Again, use of the square root transformation on these data reduce the C.V.% values and introduced a number of additional significant interaction terms not present in the AOVs of the raw date, e.g., 'E by NR' for 289 DAR, and 'E by S' and 'E by C by S' for 386 DAR (Table 38).

Comparison of the results of the AOV of # MS versus # (M + T)S and the # Su versus # (Su + T)S revealed mainly minor shifts in significance levels for some of the terms in the AOV for the three censuses, except that the significance for the main effects 'NR' and 'S' at 386 DAR were lost. Such minor changes are not surprising given that the addition of the # TS to the plot data, either as # MS of as # Su, really is not substantial in a numerically sense.

Table 38: Summary statistics and significant mean squares from analyses of variance of data for mature stalk, transformed stalk, and sucker culm numbers collected on three occasions from the first-ratoon crop.

Count	Statistic[2]	Trait[1]					
		# TS	# (M + T)S	# (Su + TS)	# Su /(M + T)S	# (Su + TS)/MS	SQRT # TS
9-10 May, 2001 (246 DAR[3])	$\bar{x}$	0.516	76.5	12.4	0.153	0.163	0.315
	C.V.%	193.0	9.17	49.7	48.88	53.2	145.1
	MS – E	41.9**	2,407.5**	-	0.212*	0.340*	14.3**
	MS – C	39.1**	5,868.4**	4,024.3**	0.406**	0.571**	12.9**
	MS – E by C	41.0**	288.7*	779.4**	0.100**	0.190**	14.0**
	MS – NR	-	5,691.2**	591.2**	0.044**	0.035*	-
	MS – E by NR	-	-	348.5**	0.065**	0.084**	-
	MS – S	-	507.8**	-	-	-	-
	MS – E by S	-	159.2*	-	-	-	-
	MS – Error	0.992	49.2	38.2	0.006	0.007	0.209
21-22 June, 2001 (289 DAR)	$\bar{x}$	0.946	73.9	31.7	0.401	0.421	0.526
	C.V.%	178.5	10.1	30.2	28.7	30.4	116.9
	MS – E	38.4**	481.0*	-	-	-	6.9*
	MS – C	136.1**	7,528.6**	16,208.4**	1.265**	1.856**	38.4**
	MS – E by C	38.2**	243.2*	-	0.091**	0.191**	6.4**
	MS – NR	-	4,653.9**	8,336.5**	0.870**	0.820**	-
	MS – E by NR	-	-	2,310.3**	0.355**	0.418**	1.371*
	MS – E by C by NR	-	-	-	-	0.050*	-
	MS – S	-	364.2**	642.8**	0.075**	0.069*	-
	MS – Error	2.9	55.8	91.6	0.013	0.016	0.378
24-28 September, 2001 (386 DAR)	$\bar{x}$	0.645	70.0	52.6	0.721	0.736	0.291
	C.V.%	326.8	11.6	21.6	22.3	22.3	196.2
	MS – E	60.2*	814.3*	52,369.8**	8.9**	7.9**	10.2**
	MS – C	74.8**	7,379.7**	38,057.9**	3.3**	4.0**	15.3**
	MS – E by C	60.2**	-	2,011.6**	0.102*	-	10.2**
	MS – NR	-	2,768.2**	7,456. 0**	0.737**	0.664**	-
	MS – E by NR	-	-	3,516.1**	0.422**	0.488**	-
	MS – C by NR	-	208.1*	528.4*	-	0.099*	-
	MS – E by C by NR	-	-	493.5*	-	-	-
	MS – S	-	308.4*	-	-	-	-
	MS – E by S	-	248.0*	-	-	-	1.032*
	MS – E by C by S	-	-	-	-	-	1.032*
	MS – NR by S	-	-	815.5**	0.086*	0.096**	-
	MS – Error	4.4	66.3	128.7	0.026	0.027	0.326

[1]MS = mature stalk; TS = transformed stalk; Su = sucker; # Su/MS = number of sucker culms per mature stalk; SQRT = square root transformation of indicated variable.

[2] $\bar{x}$ = mean value; C.V.% = coefficient of variation = $100.\sqrt{\sigma_E^2}/\bar{x}$; MS – E = mean square for environments; MS – C = mean square for cultivars; MS – E by C = mean squares for environments by cultivars interaction; MS – NR = mean square for nitrogen rates; MS – E by NR = mean square for environments by nitrogen rates interaction; MS – C by NR = mean square for cultivars by nitrogen rates interaction; MS – E by C by NR = mean square for environments by cultivars by nitrogen rates interaction; MS – S mean square for spacings; MS – E by S = mean square for environments by spacings interaction; MS – E by C by S = mean square for environments by cultivars by nitrogen rates interaction; MS – NR by S = mean square for nitrogen rates by spacings interaction, and MS – Error = mean square for error = σ_E^2.

*Significant at P < 0.05; **Significant at P < 0.01.

Table 39: Summary statistics and significant mean squares from analyses of variance of data for mature stalk, transformed stalk, and sucker culm numbers collected on three occasions from the first-ratoon crop.

Count	Statistic[2]	Trait[1]		
		SQRT (# (Su + TS))	SQRT (# Su/(M + T)S)	SQRT (# (Su + TS)/MS)
9-10 May, 2001 (246 DAR)	$\bar{x}$	3.3	0.366	0.375
	C.V.%	25.5	25.5	26.4
	MS – E	26.0*	0.415*	0.564*
	MS – C	82.9**	0.660**	0.836**
	MS – E by C	8.9**	0.085**	0.156**
	MS – NR	17.7**	0.115**	0.099**
	MS – E by NR	11.6**	0.153**	0.174**
	MS – Error	0.693	0.009	0.010
21-22 June, 2001 (289 DAR)	$\bar{x}$	5.389	0.614	0.627
	C.V.%	15.1	14.5	15.2
	MS – C	129.0**	0.768**	1.064**
	MS – E by C	5.3**	0.082**	0.145**
	MS – NR	75.8**	0.604**	0.567**
	MS – E by NR	20.7**	0.244**	0.277**
	MS – S	4.6**	0.045**	0.042*
	ME – Error	0.663	0.008	0.009
24-28 September, 2001 (386 DAR)	$\bar{x}$	7.0	0.827	0.836
	C.V.%	11.2	11.5	11.4
	MS – E	251.3**	3.2**	2.8**
	MS – C	190.6**	1.2**	1.4**
	MS – NR	33.3**	0.222**	0.196**
	MS – E by NR	12.6**	0.115**	0.139**
	MS – C by NR	3.5**	-	0.037*
	MS – NR by S	3.4**	0.031**	0.034**
	MS – Error	0.607	0.009	0.009

[1]MS = mature stalk; TS = transformed stalk; Su = sucker; # Su/MS = number of sucker culms per mature stalk; SQRT = square root transformation of indicated variable.

[2] $\bar{x}$ = mean value; C.V.% = coefficient of variation = $100.\sqrt{\sigma_E^2}/\bar{x}$; MS – E = mean square for environments; MS – C = mean square for cultivars; MS – E by C = mean squares for environments by cultivars interaction; MS – NR = mean square for nitrogen rates; MS – E by NR = mean square for environments by nitrogen rates interaction; MS – C by NR = mean square for cultivars by nitrogen rates interaction; MS – S mean square for spacings; MS – NR by S = mean square for nitrogen rates by spacings interaction, and MS – Error = mean square for error = σ_E^2.

*Significant at $P < 0.05$; **Significant at $P < 0.01$.

The other interesting contrasts are for the ratio # Su/MS (Table 38) versus # Su/(M + T)S and # (Su + TS)/MS (Table 38). For the first contrast, with addition of the # TS to the denominator of the ratio, the term 'E by C' for 386 DAR attained significance. The term 'C by NR' lost significance in the same analysis. In the second contrast, with the addition of the # TS to the numerator, there were a number of minor changes in significance, e.g., 'NR' for 246 DAR, and 'S' for 289 DAR were reduced to being significant, while that for 'NR by S' increased for significant to highly significant. Overall, the changes to analyses based on the transformed stalks being classified as either mature stalks or as suckers affected the analyses in only a minor way. More important, was the observation that culms initiated as suckers have the ability to 'transform' to mature stalks as the crop aged

and be relatively indistinguishable from the population of early differentiated mature stalks with the exception of the relic sucker leaves present at the base of the transformed stalk.

The effect of using the square-root transformation of the three measures (# (Su + TS), # Su/(M + T)S, and # (Su + TS)/MS can be examined by contrasting the summary statistics from the analyses for the raw data (Table 38) and the transformed data (Table 39). Again, one can conclude that the effects are relatively minor. In general, the C.V.% values are about halved by use of the transformation. For # (Su + TS), the main effect for 'E' for 246 DAR attained significance, as did 'E by C' for 289 DAR for transformed data, and the 'C by NR' term for 386 DAR became highly significant. Transformation resulted in loss of significance for 'E by C' and 'E by C by NR' doe 386 DAR. In the analysis of transformed data for # Su/(M + T)S, the only changes were for data for 386 DAR, with the 'NR by S' term increasing to highly significant, and the term 'E by C' becoming nonsignificant. For the final trait, # (Su + TS)/MS, the main effect of 'NR' for 246 DAR increased to highly significant, and the term 'E by C by NR' became insignificant. Again, without being able to rigorously assess the impact of the square-root transformation on the analysis of these three traits, one can conclude that relatively minor changes resulted, and use of analyses of untransformed data would not result in distorted conclusions regarding the import of the main effects and interactions among them.

The discussion of means will be confined to pre-harvest data (383 DAR) for the raw data of number of mature stalks, number of sucker culms, number of transformed stalks, and number of sucker culms per mature stalks. The irrigated environment produced a greater number of mature stalks (72.0 versus 66.6), a greater number of suckers (69.9 versus 34.3), a lower number of transformed stalks (0.01 versus 1.2), and a greater number of sucker culms per mature stalk (0.94 versus 0.51) than the rain-fed environment (Table 40). Q152 exceeded Q138 for all these traits. In particular, number of transformed stalks was a strongly expressed clonal trait, with Q152 producing all of these. The pattern for # Su/MS was the same as that observed for # Su (Table 40).

The interaction of E by C provides an interesting pattern (Table 40). For mature stalks, Q152 showed a larger response in the irrigated environment (79.3/64.8 = 122.4%) than did Q138 (70.9/62.3 = 113.8). However, this is a response to irrigation preceding the ratoon crop. The stalk populations were well determined prior to the post-monsoonal irrigation in the ratoon crop, in May. This is graphically illustrated in Figure 19. The ratoon crop in the irrigated environment certainly ratooned more rapidly and more vigorously than that in the rain-fed environment. This observed response is considered a relic effect of the irrigation that was applied in the plant crop. A more marked response is seen for the number of sucker culms, but with Q152 (87.4/51.8 = 168.7%) showing a lower response to irrigation than that seen for Q138 (44.3/24.4 = 181.6%). As seen in the graph of sucker culm dynamics (Figure 19), this is a true response to post-monsoon irrigation, which occurred from the end of May, or from about 240 DAR. These interactions for mature stalks and sucker culms are well illustrated in Figure 19. The response of # Su/MS again reflected that observed for the number of sucker culms (Table 40).

Table 40: Mean values and least significant differences for the numbers of mature stalks (MS), sucker culms (Su), transformed stalks (TS), and number of suckers per mature stalk in the first ratoon at 383 days.

Effect	Contrast[1]	# MS	# Su	# TS	# Su/MS
Environments	Irrigation	72.0	69.6	0.067	0.944
	Rain-fed	66.6	34.3	1.223	0.509
	$lsd_{(0.05)}$	3.0	6.0	0.7	0.071
Cultivars	Q138	63.6	38.1	0.0	0.586
	Q152	75.1	65.9	1.29	0.867
	$lsd_{(0.05)}$	2.3	3.3	0.6	0.047
Environments by cultivars	Irrig. by Q138	64.8	51.8	0.0	0.784
	Irrig. by Q152	79.3	87.4	0.133	1.103
	RF by Q138	62.3	24.4	0.0	0.388
	RF by Q152	70.9	44.3	2.446	0.631
	$lsd_{(0.05)}$	3.3	4.6	0.9	0.058
Nitrogen rates (kg)	0	61.2	40.2	-	0.633
	210	74.0	52.7	-	0.700
	(140 + 70)	72.8	63.0	-	0.847
	$lsd_{(0.05)}$	2.8	4.0	-	0.082
Environments by nitrogen rates	Irrig. by 0	-	49.5	-	0.755
	Irrig. by 210	-	72.6	-	0.943
	Irrig by (140 + 70)	-	86.7	-	1.134
	RF by 0	-	30.8	-	0.511
	RF by 210	-	32.9	-	0.457
	RF by (140 + 70)	-	39.3	-	0.560
	$lsd_{(0.05)}$	-	5.7	-	0.082
Cultivars by nitrogen rates	Q138 by 0	-	25.1	-	-
	Q138 by 210	-	42.1	-	-
	Q138 by (140+70)	-	47.0	-	-
	Q152 by 0	-	55.3	-	-
	Q152 by 210	-	63.4	-	-
	Q152 by (140 + 70)	-	78.9	-	-
	$lsd_{(0.05)}$	-	5.7	-	-
Environments by cultivars by nitrogen rates	Irrig. by Q138 by 0	-	29.7	-	-
	Irrig. by Q138 by 210	-	61.3	-	-
	Irrig. by Q138 by (140 +70)	-	64.3	-	-
	Irrig. by Q152 by 0	-	69.4	-	-
	Irrig. by Q152 by 210	-	83.9	-	-
	Irrig. by Q152 by (140+70)	-	109.0	-	-
	RF by Q138 by 0	-	20.5	-	-
	RF by Q138 by 210	-	22.9	-	-
	RF by Q138 by (140 + 70)	-	29.7	-	-
	RF by Q152 by 0	-	41.2	-	-
	RF by Q152 by 210	-	42.8	-	-
	RF by Q152 by (140 + 70)	-	48.9	-	-
	$lsd_{(0.05)}$	-	8.0	-	-
Spacings (m)	0.5	68.9	-	-	-
	1.0	71.5	-	-	-
	1.5	67.5	-	-	-
	$lsd_{(0.05)}$	2.8	-	-	-

Effect	Contrast[1]	# MS	# Su	# TS	# Su/MS
Nitrogen rates by spacings	0 by 0.5	-	41.5	-	0.633
	0 by 1.0	-	39.3	-	0.616
	0 by 1.5	-	39.8	-	0.651
	210 by 0.5	-	56.3	-	0.750
	210 by 1.0	-	49.3	-	0.645
	210 by 1.5	-	52.7	-	0.705
	(140 + 70) by 0.5	-	58.9	-	0.829
	(140 + 70) by 1.0	-	72.9	-	0.935
	(140 + 70) by 1.5	-	57.1	-	0.776
	$lsd_{(0.05)}$	-	7.0	-	0.101

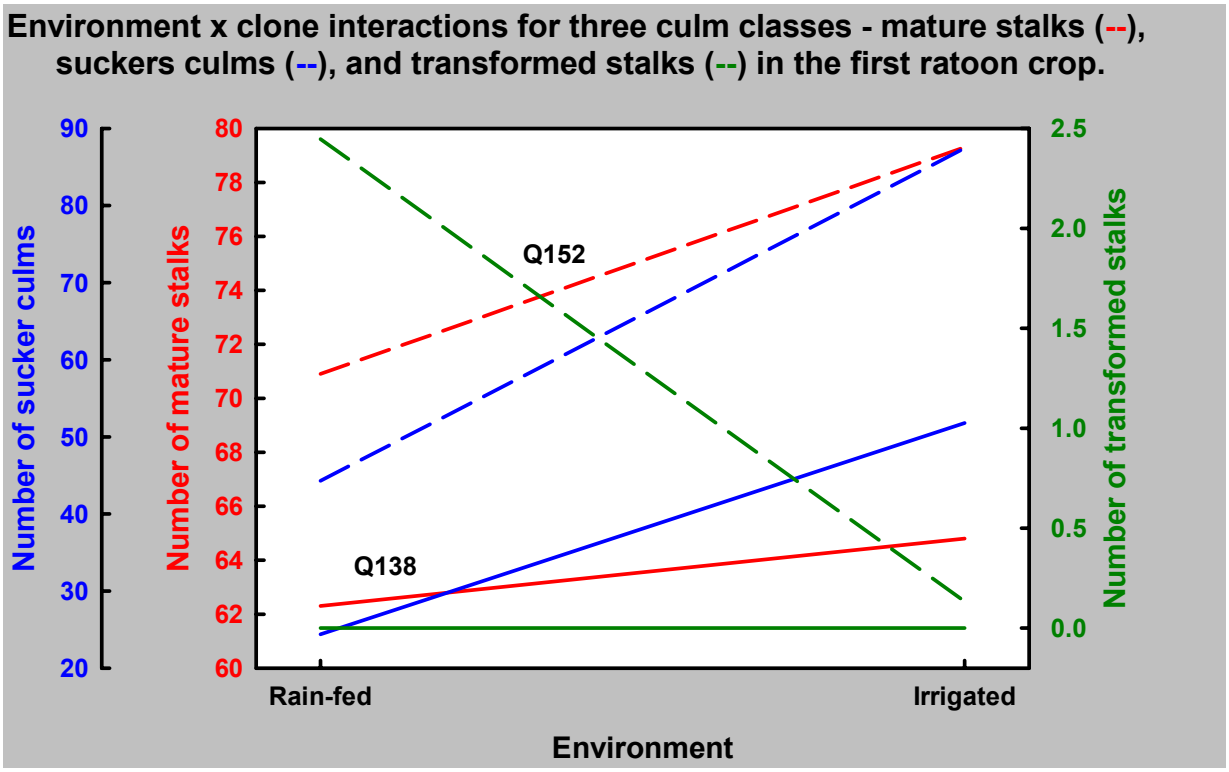

Figure 19: **Interaction of cultivars Q138 (solid lines) and Q152 (dashed lines) with rain-fed and post-monsoonal irrigated environments for three culm classes, mature stalks, sucker culms, and transformed stalks, in the first ratoon.**

As indicated earlier, the ability to produce transformed stalks was a strongly differentiated trait in the two cultivars used in this experiment. Q138 produced no transformed stalks in either environment (Table 40). Q152 produced almost 2.5 transformed stalks per core plot in the rain-fed environment but almost none (< 0.2 per core plot) in the irrigated environment (Table 40, and Figure 20). This demonstrates an interesting response. In the irrigated environment, where sucker culm initiation was favoured, sucker culms maintained their identity and there appeared to be minimal developmental plasticity for these to transform into mature stalks. In the 'stressed' rain-fed environment, this developmental rigidity was not enforced. The 'leakage' in the system is relatively low, at 11.4%, with an average of 0.982 transformed culms per core plot from 7.66 suckers

present, at the count at 246 DAR. This is when the phenomenon was first noted. While the rain-fed environment was not as conducive to sucker culm initiation, sucker culms present in this environment also were not as well maintained with a percentage 'escaping' by transforming to what were essentially mature stalks phenotypically.

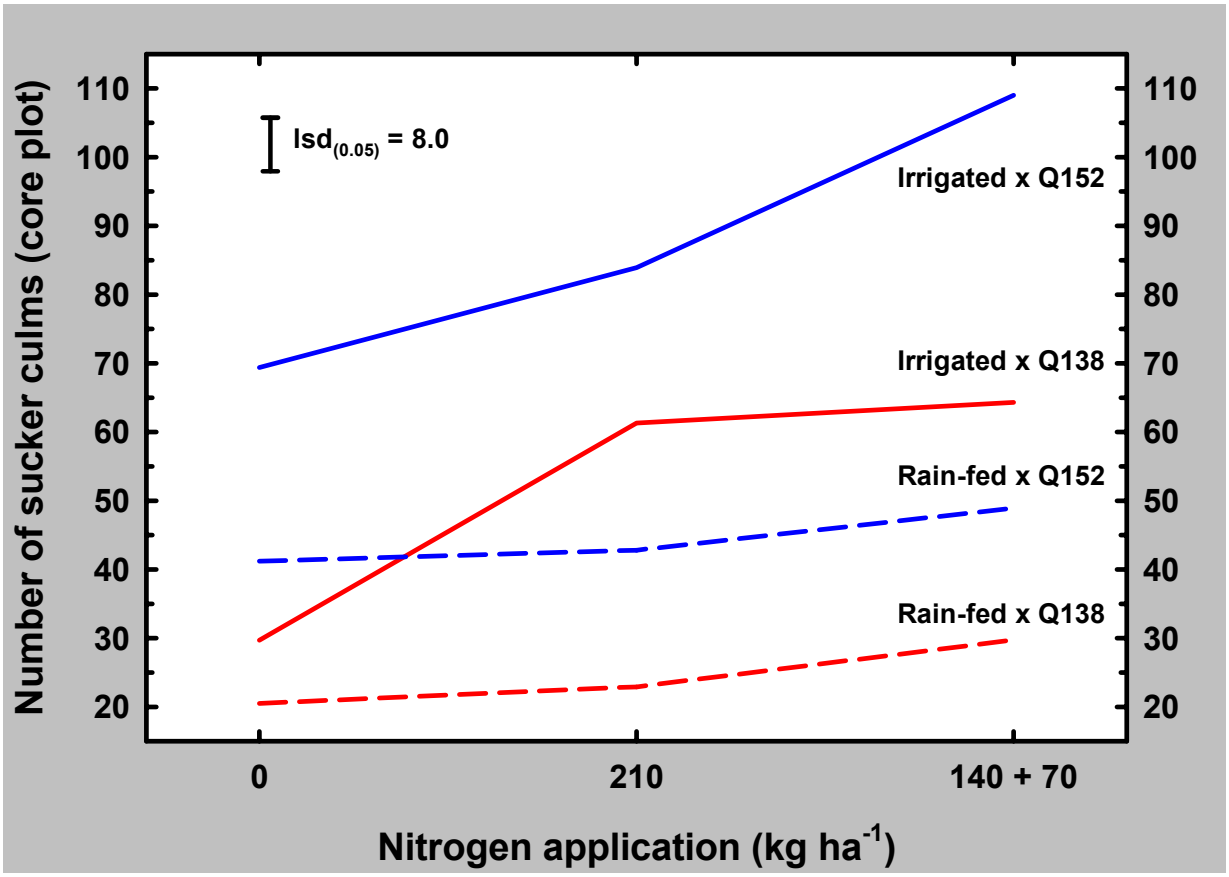

Figure 20: **Interactions for number of sucker culms per core plot in the first ratoon 383 days after ratooning for cultivars Q138 and Q152 and three nitrogen rates (zero, single application in October, and split applications in October and May) in two environments (post-monsoonal irrigation and rain-fed**).

The single and split NR applications did not differ in terms of number of mature stalks, but both were significantly greater than the zero nitrogen application (Table 40). The picture for sucker culms was substantially different. The single application of nitrogen (210 kg ha^{-1}) resulted in a significantly greater number of suckers than zero nitrogen (52.7 versus 40.2). The split application (140 + 70 kg N ha^{-1}) produced a significant greater number of suckers than did the single application (63.0 versus 52.7: Table 40.). Presumably, this resulted for the availability of nitrogen later in the crop period, i.e., post 18-19 May 2001.

This availability is accentuated by interaction with the moisture regimes, as the E by N interactions reveal (Table 40). The single N application in the rain-fed environment produced no significant increase in sucker culm numbers. The split application produced

significantly more sucker culms than did the other two treatments (39.3 versus 32.9 and 30.8; Table 40). However, with post-monsoon irrigation there were large differences in sucker culm numbers between the single application and zero (76.2 versus 49.5), and the split application and the single application (86.7 versus 72.6; Table 40). The response pattern for the number of sucker culms per mature stalk (# Su/MS) is similar to that observed for number of sucker culms (Table 40).

The C by NR interactions showed that there was no difference between the single and split applications for Q138 for number of suckers, but both were significantly different from the zero rate (Table 40). The response pattern for Q152 differed in that there was a significant difference between the single application and the zero application (55.3 versus 47.0) and a significant difference between the split application and the single application (78.9 versus 55.3).

The response pattern for C by NR interactions in the irrigated environments essentially mirrored those over environments, as discussed above. The response patterns in the rain-fed environment differed markedly. There were no significant difference between the single and zero applications or between the split and single applications for Q138. However, there was a significant difference between the split and zero applications (29.7 versus 20.5). There were no significant differences among nitrogen applications for Q152 in the rain-fed environment (Table 40).

Mature stalk number was greatest in core plots with a stool spacing of 1.0 m (71.5, Table 40). This was significantly greater that mature stalk numbers at 0.5 m (68.9) and at 1.5 m (67.5). At zero nitrogen treatment, there were no significant differences among stool spacings for sucker culm numbers (Table 40). The 0.5 stool spacing gave the highest number of suckers for the single nitrogen application (56.3) and this was significantly greater than the 1.0 spacing (49.3) and no different from the number produced at the 1.5 m spacing (52.7). Sucker culm numbers were greatest for the 1.0 m stool spacing in the split application, and this was significantly greater than sucker numbers produced at either the 0.5 m spacing (58.9) or the 1.5 m spacing (57.1; Table 40). Extra light penetration does not necessarily produce increased sucker number, and the response appears very dependent on nitrogen status. At low, or zero nitrogen spacing produced no significant differences. At the single, post-harvest application, the greatest response in terms of sucker number resulted at the close spacing (0.5), but for the split application (October and May), the greatest response resulted at the intermediate spacing (1.0 m). Again, when sucker culm number was expressed as a function of mature stalk numbers (# Su/MS), the response pattern mirrored that for sucker culm number in terms of significant differences.

3.7.3.2 Yield data

Analysis of the five harvest yield traits, tonnes cane per hectare (TCH), tonnes sucker culms per hectare (TSuH), tonnes sucker culms and cane per hectare (T(C + Su)H), percent sucker culms (%Su), 100 sucker weight (100 Su wt), and stalk weight (Table 41), resulted in two classes in terms of C.V.% - those acceptable by normal criterion (11.8-12.7%) and those normally consider too high (22.9-26.7). The latter were associated with sucker culms measures, TSuH, %Su, and 100 Su wt. The trial averaged 85.3 TCH and 97.7 T(C +Su)H, or 11.7% of culm biomass as sucker culms. Weight of 100 sucker culms averaged 21.9 kg, or 19.9% of the average 100 MS weight (Table 41).

Table 41: Summary statistics and significant mean squares from analyses of variance of six traits[1] measured at harvest of the first-ratoon crop.

Statistic[2]	Trait					
	TCH	TSuH	T(C + Su)H	% Su	100 Su wt (kg)	Stalk wt (kg)
$\bar{x}$	85.3	12.4	97.7	11.7	21.9	1.1
C.V.%	12.2	26.7	11.8	22.9	28.7	12.7
MS – E	3,492.0**	8,592.9**	23,040.6**	4,910.2**	4,239.9**	-
MS – C	2,822.2**	350.7**	1,183.2**	487.6**	11,634.3**	0.480**
MS – E by C	3,010.7**	96.9**	2,027.1**	170.2**	366.6**	0.251**
MS – NR	10,301.1**	1,721.3**	18,831.5**	565.4**	706.9**	0.242**
MS – E by NR	-	1,600.0**	1,547.3**	853.3**	1,390.2**	-
MS – C by NR	342.2*	117.7**	771.6**	40.3**	380.2**	-
MS – S	-	34.2*	-	31.7*	349.9**	0.065*
MS – NR by S	-	-	-	-	199.1**	-
MS – Error	108.0	11.0	133.5	7.2	39.5	0.020

[1]TCH = tonnes of cane per hectare; TSuH = tonnes of suckers per hectare; T(C + Su)H = tonnes of cane and suckers per hectare; % Su = 100(TSuH/(T(C + Su)H; 100 Su wt = kilograms per 100 suckers, and Stalk wt = weight per mature stalks, in kg.

[2] $\bar{x}$ = mean value; C.V.% = coefficient of variation = $100.\sqrt{(\sigma_s^2 + s\sigma_e^2)}/\bar{x}$; MS – E = mean square for environments; MS – C = mean square for cultivars; MS – E by C = mean square for environments by cultivars interaction; MS – NR = mean square for nitrogen rates; MS – E by NR = mean square for environments by nitrogen rates interaction; MS – C by NR = mean square for cultivar by nitrogen rate interaction; MS – S = mean square for spacings; MS – NR by S = mean square for nitrogen rates by spacings interaction, and MS – Error = mean square for error.

*Significant at $P < 0.05$; **Significant at $P < 0.01$.

There was a general surfeit of highly significant main effects and interactions. The 'E' effect was highly significant for all traits except Stalk wt. The main effects of 'C' and 'NR' were highly significant for all traits. The main effect of 'S' was highly significant for 100 Su wt, and significant for TSuH, %Su, and Stalk wt. In terms of interactions 'E by C' was highly significant for all traits (Table 41). The terms 'E by NR' and 'C by NR' were highly significant for all three suckering measures (TSuH, %Su, and 100 Su wt) as well as T(C + Su)H. The term 'C by NR' was significant for TCH only. Interestingly, the term 'NR by S' was highly significant for 100 Su wt only (Table 41).

The post-monsoonal irrigated environment exceeded the rain-fed for all traits for which there was significance - higher TCH (89.7 versus 80.9), TSuH (19.3 versus 5.5), T(C + Su)H (109.0 versus 86.4), %Su (17.0 versus 6.5), and 100 Su wt (26.7 versus 17.0; Table 42). Obviously, there is a clear message that post-monsoonal moisture is stimulatory for sucker initiation and development, as yield, proportion of crop, and size all were affected.

Q138 produced fewer TCH than Q152 (81.3 versus 89.2 t), more TSuH (13.8 versus 11.0 t), and fewer T(C + Su)H (95.1 versus 100.2 t; Table 42). Q138 exceed Q152 for the measures %Su (13.4 versus 10.1), 100 Su wt (29.9 versus 13.8), and stalk wt (1.158 versus 1.055). Suckers from Q138 were over double the weight of those from Q152 (29.9 versus 13.8) and although sucker numbers for Q138 were 57.8% of those produced by Q152 (Table 40), the size differential resulted in the sucker production of Q138 significantly exceeding that of Q152 (Table 42). Relative to the mean cultivar stalk weight, the sucker weigh of Q138 was almost double that of Q152 (25.8 versus 13.0%).

Q152 produced greater TCH than Q138 in the irrigated environment (97.7 versus 81.6), but the cultivars did not differ under rain-fed conditions (Table 42). Sucker culm production for Q138 exceeded that for Q152 in the irrigated (21.4 versus 17.2) and rain-fed (6.1 versus 4.8) environments. Total culm production (T(C + Su)H) was greatest for Q152 in the irrigated environment (114.9 versus 103.1). Q138 exceeded Q152 for %Su and 100 Su wt in both environments. There was a difference between cultivars for stalk weight only in the rain-fed environment, with Q138 having the heaviest stalk (1.178 versus 1.0; Table 42).

Both nitrogen applications, single and split, were significantly different from the zero nitrogen application for TCH (93.6 and 92.0 versus 70.2) but did not differ from each other. There was a consistent pattern of the split nitrogen application exceeding the single application, and the single application exceeding zero nitrogen for the traits of TSuH (17.9 versus 12.1 versus 7.2), T(C +Su)H (109.9 versus 105.8 versus 77.4), and %Su (15.2 versus 10.7 versus 9.3; Table 42). For '100 Su wt', there was no difference between the zero and single applications, but the split application was significantly greater than either one (25.8 versus 20.2 and 19.6). Again, this demonstrated the impact of the late nitrogen application in stimulating sucker development. In contrast, for mature stalk weight, there was not difference between nitrogen applications (split and single) but both were significantly greater than the zero application (Table 42).

The E by N interactions for TSuH showed the single application was significantly greater than the zero application in the irrigated environment (20.2 versus 8.4), and that the split application (29.3) was in turn significantly greater than the single application (Table 42). The pattern in the rain-fed environment was completely different with the single application (4.1) being significantly less that both the zero application (5.9) and the split application (6.5). The latter did not differ from the zero application (Table 42). For T(C + Su)H, in both environments, there was no difference between the single and split nitrogen applications but both were significantly greater than the respective zero application. As expected for %Su and 100 Su wt, the response pattern reflected that as seen for TSuH with the irrigated environment demonstrating quite a different pattern to that seen in the rain-fed environment.

The single and split applications did not differ significantly for TCH for either cultivar but produced significantly more than the zero application. Both cultivars displayed similar response patterns with nitrogen rates, with the single rate exceeding the zero application for TSuH and the split application being significantly greater than the single application. For total culm biomass (T(C+Su)H), there was a mixed response pattern with all nitrogen treatments being significantly different for Q138, with the split application the best. However, for Q152, the single and split applications did not differ, but both were significantly greater that the zero application. For %Su, another response pattern emerged. For Q138 all treatments differed significantly with the single and split applications being greater than the zero treatment, with the split treatment being greatest.

Table 42: Mean values and least significant differences for six harvest traits[1] determined in the first ratoon at 392 days after ratooning.

Effect	Contrast	TCH	TSuH	T(C + Su)H	%Su	100 Su wt (kg)	Stalk wt (kg)
Environments	Irrigation	89.7	19.3	109.0	17.0	26.7	-
	Rain-fed	80.9	5.5	86.4	6.5	17.0	-
	$lsd_{(0.05)}$	4.2	2.0	4.0	1.8	2.5	-
Cultivars	Q138	81.3	13.8	95.1	13.4	29.9	1.158
	Q152	89.2	11.0	100.2	10.1	13.8	1.055
	$lsd_{(0.05)}$	3.0	1.0	3.4	0.8	1.8	0.041
Environments by cultivars	Irrig. by Q138	81.6	21.4	103.1	19.6	36.2	1.138
	Irrig. by Q152	97.7	17.2	114.9	14.3	17.3	1.110
	RF by Q138	81.0	6.1	87.2	7.2	23.6	1.178
	RF by Q152	80.8	4.8	85.6	5.8	10.4	1.000
	$lsd_{(0.05)}$	4.3	1.4	4.8	1.1	2.6	0.058
Nitrogen rates (kg)	0	70.2	7.2	77.4	9.3	19.6	1.033
	210	93.6	12.1	105.8	10.7	20.2	1.141
	(140 + 70)	92.0	17.9	109.9	15.2	25.8	1.145
	$lsd_{(0.05)}$	3.7	1.2	4.1	1.0	2.3	0.050
Environments by nitrogen rates	Irrig. by 0	-	8.4	82.8	10.4	19.0	-
	Irrig. by 210	-	20.2	120.0	16.9	26.7	-
	Irrig by (140 + 70)	-	29.3	124.1	23.6	34.5	-
	RF by 0	-	5.9	71.9	8.3	20.1	-
	RF by 210	-	4.1	91.5	4.5	13.7	-
	RF by (140 + 70)	-	6.5	95.7	6.8	17.2	-
	$lsd_{(0.05)}$	-	1.7	5.8	1.4	3.2	-
Cultivars by nitrogen rates	Q138 by 0	63.5	7.4	70.9	10.4	27.3	-
	Q138 by 210	90.8	13.1	103.9	12.0	25.9	-
	Q138 by (140+70)	89.7	20.8	110.5	17.8	36.5	-
	Q152 by 0	76.9	6.9	83.8	8.3	11.9	-
	Q152 by 210	96.5	11.1	107.6	9.4	14.5	-
	Q152 by (140 + 70)	94.4	14.9	109.3	12.6	15.1	-
	$lsd_{(0.05)}$	5.3	1.7	5.8	1.4	3.2	-
Spacings (m)	0.5	-	11.5	-	10.9	20.0	1.121
	1.0	-	12.9	-	12.1	21.0	1.068
	1.5	-	12.8	-	12.3	24.6	1.129
	$lsd_{(0.05)}$	-	1.2	-	1.0	2.3	0.050
Nitrogen rates by spacings	0 by 0.5	-	-	-	-	17.7	-
	0 by 1.0	-	-	-	-	17.7	-
	0 by 1.5	-	-	-	-	23.3	-
	210 by 0.5	-	-	-	-	16.3	-
	210 by 1.0	-	-	-	-	21.7	-
	210 by 1.5	-	-	-	-	22.6	-
	(140 + 70) by 0.5	-	-	-	-	26.1	-
	(140 + 70) by 1.0	-	-	-	-	23.6	-
	(140 + 70) by 1.5	-	-	-	-	27.8	-
	$lsd_{(0.05)}$	-	-	-	-	3.2	-

[1]TSuH = tonnes of suckers per hectare; TCH = tonnes of cane per hectare; T(C + Su)H = Tonnes cane and suckers per hectare; % Su = 100*(TSuH/(T(C + Su)H; 100 Su wt (kg)= kilograms per 100 suckers; Stalk wt (kg) = average weigh per stalk (mature + transformed).

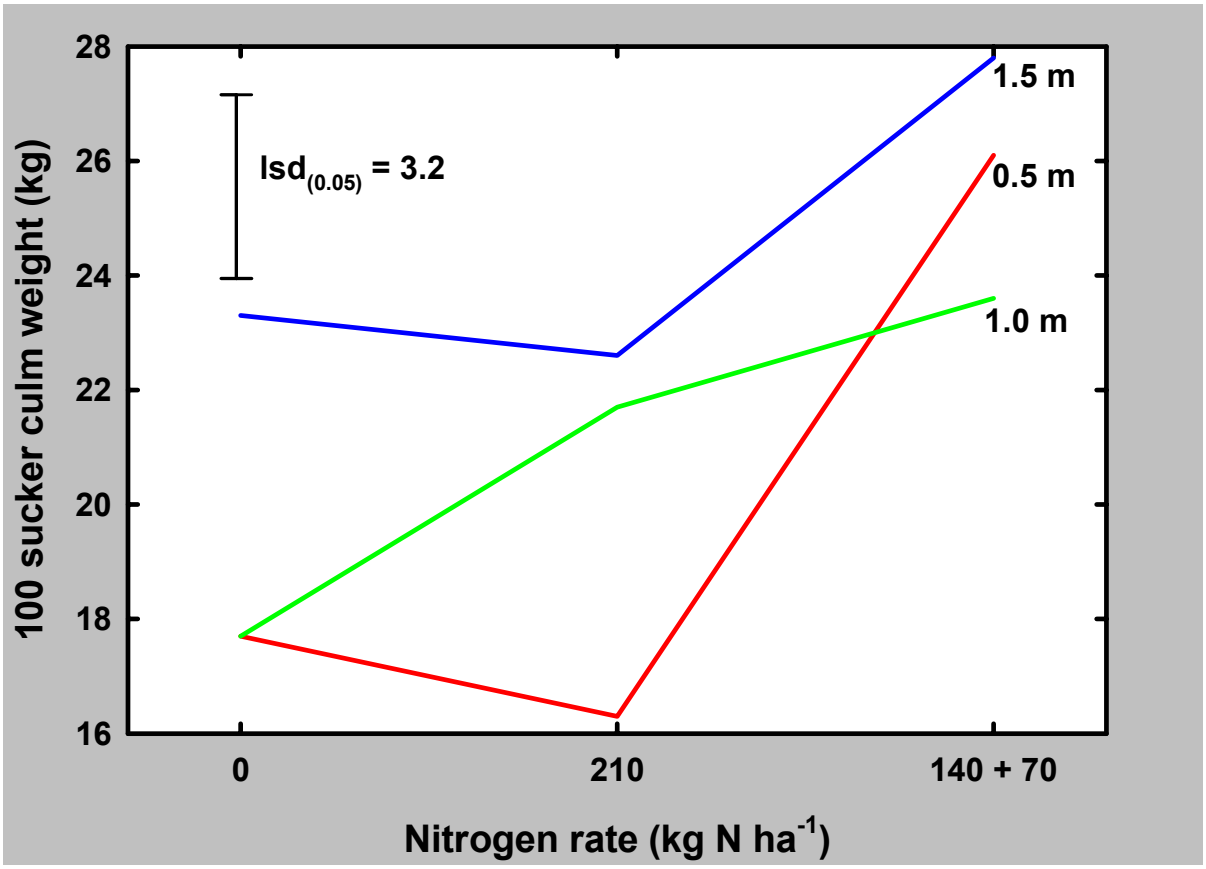

Figure 21: **Effect of the interactions among three nitrogen rates and three within-row stool spacings, in rows at 1.5 m, on sucker culm size (kilograms per 100 sucker culms) in the first-ratoon crop.**

However, for Q152, the zero and single applications did not differ while the split application was significantly greater (Table 42). For Q138, the single application had the lowest value for the 100 Su wt (25.9), with this being exceed significantly by the zero application (27.3) and this in turn by the split application (36.5). For Q152, there was no difference between the single and split nitrogen application treatments (15.1 and 14.5) but both were significantly higher than the zero application response (11.0).

Spacings was a significant main effect for only four traits – TSuH, %Su, 100 Su wt, and stalk weight. There was no difference between the 1.0 and 1.5 m spacings for TSuH (12.9 and 12.8), but both were significantly greater than the 0.5 m spacing. Increased space (light) did increase sucker culm yield over and above the closest spacing. This pattern also was reflected in the %Su data (Table 42). For 100 Su wt, the response was reversed, there being no difference between the 0.5 and 1.0 m spacing (20.0 and 21.0), but sucker culm weight at 1.5 m was significantly greater than either (24.6). The 100 Su wt was the only trait for which there were significant interactions for spacings, and this was with nitrogen (Table 42). The interactions for this trait are interesting. At zero nitrogen, there was no difference between the 100 Su wt at 0.5 and 1.0 m (17.7 kg) but the 1.5 m stool spacing produced significantly larger sucker culms (23.3 kg). For the single application of 210 kg ha^{-1} there was no significant difference between the 1.0 and 1.5 m stool spacing (21.7 versus 22.6 kg), but both were significantly higher than the 0.5 m spacing (16.3 kg).

The split application produced a 100 Su wt at 0.5 m of 26.1 kg. This was intermediate to that at the 1.0 (23.6) and 1.5 m (27.8) spacings but only the latter two were significantly different (Table 42). The NR by S interactions are depicted graphically (Figure 21).

3.7.3.3 Quality components

The analyses of variance of the five quality components determined on mature stalks (Table 43) can be contrasted with those presented for culm counts (Tables 37 and 39) and harvest yield traits (Table 41) for their relative simplicity. The analyses for these traits present an excellent picture of low error determinations, as judged by C.V.% values. These ranged from 1.2% for moisture to 5.4% for fibre. Only three of the four main effects showed significance for some of these traits – stool spacing being the factor that was absent. Environments differed highly significantly for all traits except fibre (Table 43). Cultivars differed significantly only for CCS. Nitrogen rate was highly significant for all five traits. There were only five significant interactions. These were confined to three traits, and all involved NR – brix (C by NR, significant; NR by S, significant), fibre (E by NR, significant; C by NR, highly significant), and moisture (C by NR, highly significant; Table 43).

Table 43: Summary statistics and significant mean squares from analyses of variance of five quality components of mature stalks measured at harvest of the first-ratoon crop.

Statistic[1]	Trait				
	Brix (g kg^{-1})	CCS (g kg^{-1})	Fibre (g kg^{-1})	Moisture (g kg^{-1})	Pol reading (°Z)
$\bar{x}$	217.3	168.6	136.5	672.9	88.5
C.V.%	3.2	4.9	5.4	1.2	4.3
MS – E	25,985.3**	18,773.8**	-	19,532.7**	5,153.8**
MS – C	-	311.5*	-	-	-
MS – NR	468.7**	635.1**	965.1**	936.4**	184.6**
MS – E by NR	-	-	183.3*	-	-
MS – C by NR	228.0*	-	414.0**	922.1**	-
MS – NR by S	129.5*	-	-	-	-
MS – Error	49.1	69.2	53.8	67.7	14.6

[1] $\bar{x}$ = mean value; C.V.% = coefficient of variation = $100.\sqrt{(\sigma_s^2 + s\sigma_e^2)}/\bar{x}$; MS – E = mean square for environments; MS – C = mean square for cultivars; MS – NR = mean square for nitrogen rates; MS – E by NR = mean square for environments by nitrogen rates interaction; MS – C by NR = mean square for cultivars by nitrogen rates interaction; MS – NR by S = mean square for nitrogen rate by spacings interaction, and MS – Error = mean square for error.
*Significant at $P < 0.05$; **Significant at $P < 0.01$.

The picture for the analyses of quality components of sucker culms (Table 44) is somewhat more complex. The main effects of E, C, and NR were highly significant for all five traits with one exception – NR for CCS was only significant. In contrast to the analyses of mature-stalk quality components the interaction E by C was highly significant for all traits except fibre. The C.V.% values were marginally higher for components such

as fibre and moisture, moderately higher for brix, but substantially higher for CCS and pol. reading. The only other significant interactions, all involving NR again, were E by NR for fibre – highly significant – and C by NR for brix, CCS, and pol. reading – all significant (Table 44).

Table 44: Summary statistics and significant mean squares from analyses of variance of five quality components of sucker culms measured at harvest of the first-ratoon crop.

Statistic[1]	Trait				
	Brix (g kg^{-1})	CCS (g kg^{-1})	Fibre (g kg^{-1})	Moisture (g kg^{-1})	Pol reading (°Z)
$\bar{x}$	116.2	50.4	115.6	783.1	33.3
C.V.%	11.5	27.6	6.7	2.0	19.3
MS – E	188,667.3**	150,509.0**	63,595.3**	362,854.5**	35,726.8**
MS – C	8,651.4**	7,436.8**	4,355.1**	17,772.2**	1,816.3**
MS – NR	12,271.5**	12,111.3**	-	10,103.4**	3,122.4**
MS – E by NR	1,638.8**	622.6*	339.7**	2,505.3**	201.9**
MS – C by NR	-	-	1,215.2**	-	-
MS – NR by S	604.0*	597.2*	-	-	137.4*
MS – Error	179.7	193.6	59.3	243.1	41.2

[1] $\bar{x}$ = mean value; C.V.% = coefficient of variation $=100.\sqrt{(\sigma_s^2 + s\sigma_e^2)}/\bar{x}$; MS – E = mean square for environments; MS – C = mean square for cultivars; MS – NR = mean square for nitrogen rates; MS – E by NR = mean square for environments by nitrogen rates interaction; MS – C by NR = mean square for cultivars by nitrogen rates interaction; MS – NR by S = mean square for nitrogen rate by spacings interaction, and MS – Error = mean square for error.
*Significant at $P < 0.05$; **Significant at $P < 0.01$.

The mean values for quality components of mature stalks (Table 43) and sucker culms (Table 44) are in marked contrast, e.g., brix (217.3 versus 116.2 g kg^{-1}), CCS (168.6 versus 50.4 g kg^{-1}), fibre (136.5 versus 115.6 g kg^{-1}), moisture (672.9 versus 783.1 g kg^{-1}), and pol reading (88.5 versus 33.3°Z). These are as expected, and reflect earlier collected data on the differential between these two crop fractions and the impact sucker culms, as extraneous matter, can have on harvested whole crop quality.

Analyses for the weighed mean quality component for culm biomass (T(C + Su)H; Table 45) really present an intermediate picture to those presented for mature stalks (Table 43) and sucker culms (Table 44). There were highly significant main effects for E, C, and NR for all components except for C for fibre. The interaction E by NR was highly significant for all traits except fibre, for which it was significant. The interaction of C by NR was highly significant for just fibre and moisture. Again, as for mature stalks NR by S was significant, and this was the only appearance of S in any of the significant terms, either main effects or interactions (Table 45). As expected, the C.V.% values for the weighted mean component values were close to those presented for mature stalk values (Table 43).

Table 45: Summary statistics and significant mean squares from analyses of variance of five quality components of mature stalks and sucker culms, on a weighted plot basis, measured at harvest of the first-ratoon crop.

Statistic[1]	Trait				
	Brix (g kg^{-1})	CCS (g kg^{-1})	Fibre (g kg^{-1})	Moisture (g kg^{-1})	Pol reading (°Z)
$\bar{x}$	204.6	153.9	133.0	687.7	81.6
C.V.%	3.8	5.9	5.1	1.3	5.2
MS – E	67,858.2**	60,949.4**	3,149.2**	72,142.7**	15,091.2**
MS – C	1,593.5**	2,248.7**	-	2,023.9**	380.6**
MS – NR	1,994.0**	2,735.4**	1,457.2**	3,727.9**	688.2**
MS – E by NR	1,097.5**	947.2**	159.1*	1,266.1**	231.7**
MS – C by NR	-	-	376.0**	661.9**	-
MS – NR by S	163.5*	-	-	-	-
MS – Error	60.4	83.4	45.0	84.7	17.9

[1] $\bar{x}$ = mean value; C.V.% = coefficient of variation $=_{100.\sqrt{(\sigma_s^2 + s\sigma_e^2)}/\bar{x}}$; MS – E = mean square for environments; MS – C = mean square for cultivars; MS – NR = mean square for nitrogen rates; MS – E by NR = mean square for environments by nitrogen rates interaction; MS – C by NR = mean square for cultivars by nitrogen rates interaction; MS – NR by S = mean square for nitrogen rate by spacings interaction, and MS – Error = mean square for error.
*Significant at $P < 0.05$; **Significant at $P < 0.01$.

Mean data for quality components for mature stalks, sucker culms, and a plot composition weighted value of these (Table 46) for main effects and all significant interactions, although presented, are too extensive to consider here in detail. The discussion will focus on main effects. The rain-fed environment recorded higher mature stalk brix (229.3 versus 205.3 g kg^{-1}), higher CCS (178.8 versus 158.3 g kg^{-1}), and higher pol reading (93.8 versus 83.1°Z) but lower moisture (662.5 versus 683.4 g kg^{-1}), as expected. The only significant cultivar effect was for CCS, with Q152 having a higher value than Q138 (169.9 versus 167.2 g kg^{-1}; Table 46). There is a relatively consistent pattern regarding NR. Brix, CCS, moisture, and pol reading all showed no difference between the single application and the zero application. For all these traits, the split application produced lower values for brix, CCS, and pol. reading, and a higher value for moisture (Table 46). The pattern for sucker culm quality components reflected that observed for mature stalks, but the values of course are at a somewhat different levels. Q138 had higher values than Q152 for all components except moisture where the position was reversed.

Table 46: Mean values and least significant differences for significant main effects and interactions for five quality components of three crop fractions determined at harvest of the first-ratoon crop.

Component	Effect	Contrast	Brix (g kg^{-1})	CCS (g kg^{-1})	Fibre (g kg^{-1})	Moisture (g kg^{-1})	Pol reading (g kg^{-1})
Mature stalks	Environments	Irrigation	205.3	158.3	-	683.4	83.1
		Rain-fed	229.3	178.8	-	662.5	93.8
		$lsd_{(0.05)}$	2.1	2.2	-	2.6	1.0
	Cultivars	Q138	-	167.2	-	-	-
		Q152	-	169.9	-	-	-
		$lsd_{(0.05)}$	-	2.4	-	-	-
	Nitrogen rates (kg)	0	218.2	169.2	141.0	669.8	89.1
		210	219.6	171.4	135.5	671.7	89.8
		(140 + 70)	214.2	165.0	133.2	677.4	86.5
		$lsd_{(0.05)}$	2.5	3.0	2.6	2.9	1.4
	Environments by nitrogen rates	Irrig. by 0	-	-	138.4	-	-
		Irrig. by 210	-	-	136.4	-	-
		Irrig by (140 + 70)	-	-	131.9	-	-
		RF by 0	-	-	143.5	-	-
		RF by 210	-	-	134.6	-	-
		RF by (140 + 70)	-	-	134.4	-	-
		$lsd_{(0.05)}$	-	-	3.7	-	-
	Cultivars by nitrogen rates	Q138 by 0	215.1	-	139.0	674.9	-
		Q138 by 210	219.2	-	138.7	669.7	-
		Q138 by (140+70)	214.9	-	134.6	675.9	-
		Q152 by 0	221.2	-	142.9	664.7	-
		Q152 by 210	220.0	-	132.2	673.6	-
		Q152 by (140 + 70)	213.5	-	131.8	678.8	-
		$lsd_{(0.05)}$	3.5	-	3.7	4.2	-
	Nitrogen rate by spacings	0 by 0.5	215.0	-	-	-	-
		0 by 1.0	219.6	-	-	-	-
		0 by 1.5	219.9	-	-	-	-
		210 by 0.5	220.0	-	-		-
		210 by 1.0	218.3	-	-	-	-
		210 by 1.5	218.5	-	-	-	-
		(140 + 70) by 0.5	212.7	-	-	-	-
		(140 + 70) by 1.0	215.8	-	-	-	-
		(140 + 70) by 1.5	214.1	-	-	-	-
		$lsd_{(0.05)}$	4.3	-	-	-	-
Sucker culms	Environments	Irrigation	83.8	21.5	96.8	828.0	19.2
		Rain-fed	148.5	79.3	134.4	738.2	47.4
		$lsd_{(0.05)}$	5.7	6.2	2.8	6.5	3.0
	Cultivars	Q138	109.2	43.9	110.7	793.0	30.2
		Q152	123.1	56.8	120.5	773.1	36.5
		$lsd_{(0.05)}$	3.9	4.1	2.3	4.6	1.9

Component	Effect	Contrast	Brix (g kg^{-1})	CCS (g kg^{-1})	Fibre (g kg^{-1})	Moisture (g kg^{-1})	Pol reading (g kg^{-1})
	Environments by cultivars	Irrig. by Q138	85.1	23.2	-	830.4	20.2
		Irrig. by Q152	82.5	19.7	-	825.5	18.3
		RF by Q138	133.3	64.7	-	755.6	40.1
		RF by Q152	163.7	93.9	-	720.7	54.8
		$lsd_{(0.05)}$	5.5	5.8	-	6.4	2.7
	Nitrogen rates (kg)	0	110.4	48.0	113.9	789.8	31.8
		210	120.6	54.0	118.3	776.9	35.3
		(140 + 70)	117.5	49.1	114.6	782.5	32.9
		$lsd_{(0.05)}$	4.8	5.0	2.8	5.6	2.3
	Environments by nitrogen rates	Irrig. by 0	-	-	100.3	-	-
		Irrig. by 210	-	-	96.6	-	-
		Irrig by (140 + 70)	-	-	93.5	-	-
		RF by 0	-	-	127.5	-	-
		RF by 210	-	-	140.0	-	-
		RF by (140 + 70)	-	-	135.7	-	-
		$lsd_{(0.05)}$	-	-	3.9	-	-
	Cultivars by nitrogen rates	Q138 by 0	105.6	44.4	-	-	29.9
		Q138 by 210	110.0	44.2	-	-	30.5
		Q138 by (140+70)	112.0	43.3	-	-	30.1
		Q152 by 0	115.2	51.6	-	-	33.6
		Q152 by 210	131.2	63.9	-	-	40.2
		Q152 by (140 + 70)	122.9	54.9	-	-	35.7
		$lsd_{(0.05)}$	6.8	7.0	-	-	3.2
Mature stalks + sucker culms	Environments	Irrigation	185.2	135.5	128.8	707.7	72.5
		Rain-fed	224.0	172.3	137.1	667.6	90.8
		$lsd_{(0.05)}$	4.0	4.4	2.5	4.6	2.0
	Cultivars	Q138	201.6	150.4	-	691.0	80.2
		Q152	207.6	157.5	-	684.3	83.1
		$lsd_{(0.05)}$	2.3	2.7	-	2.7	1.2
	Nitrogen rates (kg)	0	208.1	158.0	138.3	681.1	83.8
		210	207.7	157.7	132.1	685.4	83.4
		(140 + 70)	197.9	146.1	128.5	696.4	77.7
		$lsd_{(0.05)}$	2.8	3.3	2.4	3.3	1.5
	Environments by nitrogen rates	Irrig. by 0	193.2	143.7	134.3	697.0	76.6
		Irrig. by 210	187.8	139.1	129.5	704.6	74.3
		Irrig by (140 + 70)	174.5	123.9	122.6	721.4	66.6
		RF by 0	223.1	172.3	142.3	665.3	91.0
		RF by 210	227.5	176.2	134.8	666.2	92.5
		RF by (140 + 70)	221.4	168.4	134.4	671.5	88.9
		$lsd_{(0.05)}$	3.9	4.6	3.4	4.7	2.1

Component	Effect	Contrast	Brix (g kg^{-1})	CCS (g kg^{-1})	Fibre (g kg^{-1})	Moisture (g kg^{-1})	Pol reading (g kg^{-1})
	Cultivars by nitrogen rates	Q138 by 0	-	-	135.4	688.2	-
		Q138 by 210	-	-	134.3	686.0	-
		Q138 by (140+70)	-	-	128.4	698.9	-
		Q152 by 0	-	-	141.1	674.1	-
		Q152 by 210	-	-	129.9	684.9	-
		Q152 by (140 + 70)	-	-	128.6	693.9	-
		$lsd_{(0.05)}$	-	-	3.4	4.7	-
	Nitrogen rates by spacings	0 by 0.5	205.8	-	-	-	-
		0 by 1.0	209.8	-	-	-	-
		0 by 1.5	208.8	-	-	-	-
		210 by 0.5	211.5	-	-	-	-
		210 by 1.0	205.6	-	-	-	-
		210 by 1.5	205.9	-	-	-	-
		(140 + 70) by 0.5	196.9	-	-	-	-
		(140 + 70) by 1.0	198.7	-	-	-	-
		(140 + 70) by 1.5	198.2	-	-	-	-
		$lsd_{(0.05)}$	4.8	-	-	-	-

The brix for sucker culms in the single nitrogen application (120.6 g kg^{-1}) did not differ from the split application and it was significantly higher than the zero application (110.4 g kg^{-1}). The pattern for CCS was that the single application yielded the highest sucker culm value (54.0 g kg^{-1}) and this was significantly greater than the zero (48.0 g kg^{-1}) and split applications (49.1 g kg^{-1}). Fibre and pol reading displayed similar response patterns with the single application resulting in a value significantly greater than either the zero or split applications. The consistency here is that the single (early) nitrogen application resulted in the highest value for all four components and with the exception of brix. The split application resulted in component values not different from the zero application value. For moisture, the single application resulted in the lowest value (776.9 g kg^{-1}) that was significantly different from the split application. In turn, this was significantly lower than the zero application. The weighted component values reflect those of the contributing component values. The rain-fed environment yielded the higher values for all except moisture, for which it returned the lower value. Excluding fibre, Q152 had the higher value for all except moisture, for which it had the lower. The split nitrogen rate resulted in a significantly lowest value for brix, CCS, and pol reading, and these components had values for the zero and single applications that were not significantly different from each other (Table 46). All NR treatments for fibre were significantly different, with the zero treatment having the highest fibre (138.3) greater than the 132.1 and 128.5 g kg^{-1} recorded for the single and split treatments, respectively, which were significantly different.

3.7.3.4 Sugar yields

Sugar yield data were derived from the respective harvest trait data (Table 42) and the relevant quality component data (Table 46). Table 47 presents analyses of variance for three measures of sugar yield: ex mature stalks, ex suckers culms, and ex total culm biomass – mature stalks + sucker culms, as well as an analysis of the proportion of total sugar production arising from the mature stalks. On average, 97% of the sugar yield was produced from mature stalks. The coefficients of variation ranged from 1.7% for the mature stalk proportion to 54.3% for the sucker culm sugar yield. The main effect of cultivars was highly significant for mature stalk sugar yield and the total culm sugar yield, and significant for mature stalk proportion of sugar yield. The main effect of nitrogen rate was highly significant for all four measures, while that for spacing was significant only for sucker culm sugar yield. The E by C term was highly significant for all four traits. The remaining significant interactions all involved NR – E by NR was highly significant for sucker culm sugar yield and mature stalk proportion of sugar yield while C by NR was significant for mature stalk and sucker culm sugar yield and highly significant for total culm sugar yield.

Table 47: Summary statistics and significant mean squares from analyses of variance of three measures of sugar yield for three crop fractions (MS = mature stalk, Su = sucker culms, and mature stalk and sucker culms (MS + Su), and the proportion of total sugar yield contributed by mature stalks, measured at harvest of the first-ratoon crop.

Statistic[1]	Sugar yield (t ha^{-1})			MS/Total (%)
	ex MS	ex Su	ex (MS + Su)	
$\bar{x}$	14.3	0.431	14.8	97.0
C.V.%	13.3	54.3	12.9	1.7
MS – C	96.6**	-	88.6**	18.8*
MS – E by C	86.9**	0.557**	73.6**	41.1**
MS – NR	291.0**	0.952**	313.2**	24.7**
MS – E by NR	-	1.257**	-	69.3**
MS – C by NR	15.4*	0.224*	18.8**	-
MS – S	-	0.174*	-	-
MS – Error	3.6	0.055	3.6	2.8

[1] $\bar{x}$ = mean value; C.V.% = coefficient of variation $=100.\sqrt{(\sigma_s^2 + s\sigma_e^2)}/\bar{x}$; MS – C = mean square for cultivars; MS – E by C = mean square for environments by cultivars interaction; MS – NR = mean square for nitrogen rates; MS – E by NR = mean square for environments by nitrogen rates interaction; MS – C by NR = mean square for cultivars by nitrogen rates interaction, and MS – Error = mean square for error.
*Significant at $P < 0.05$; **Significant at $P < 0.01$.

Q152 produced a higher mature stalk sugar yield (15.1 t) than Q138 (13.6 t), a higher total culm sugar yield (15.5 versus 14.1), and a higher proportion of total sugar yield from mature stalks (97.3 versus 96.7%). There was a differential response for cultivars for mature stalk sugar production only in the irrigated environment, Q152 producing substantially more sugar than Q138 from mature stalks (15.7 versus 12.8 t). Sugar yield from sucker culms displayed a classic interaction response for E by C. In the rainfed environment Q152 produced a significantly higher sucker culm sugar yield (0.453 versus 0.404) while in the irrigated environment Q138 produced a significantly higher sucker culm sugar yield (0.521 versus 0.347; Table 48). The mature stalk pattern also was

displayed for total culm sugar yield and proportion of total sugar production arising from mature stalks. There were no difference between cultivars in the rain-fed environment but Q152 was significantly better in the irrigated environment.

Table 48: Mean values and least significant differences for significant main effects and interactions for sugar yield data for three crop fractions (MS = mature stalk, Su = sucker culms, and mature stalk and sucker culms (MS + Su), and proportion of total sugar yield (tonnes) coming from mature stalks (TS_{MS}/Total TS) determined at harvest of the first-ratoon crop.

Effect	Contrast	Sugar yield (t ha^{-1})			
		ex MS	ex Su	Ex (MS + Su)	100*TSH_{MS}/ Total TSH
Cultivars	Q138	13.6	-	14.1	96.7
	Q152	15.1	-	15.5	97.3
	$lsd_{(0.05)}$	0.6	-	0.6	0.5
Environments by cultivars	Irrig. by Q138	12.8	0.521	13.3	96.3
	Irrig. by Q152	15.7	0.347	16.0	97.9
	RF by Q138	14.4	0.404	14.8	97.1
	RF by Q152	14.5	0.453	14.9	96.8
	$lsd_{(0.05)}$	0.8	0.097	0.8	0.7
Nitrogen rates (kg)	0	11.9	0.318	12.2	97.3
	210	16.0	0.408	16.4	97.4
	(140 + 70)	15.2	0.567	15.7	96.3
	$lsd_{(0.05)}$	0.7	0.084	0.7	0.6
Environments by nitrogen rates	Irrig. by 0	-	0.155	-	98.6
	Irrig. by 210	-	0.481	-	97.0
	Irrig by (140 + 70)	-	0.666	-	95.6
	RF by 0	-	0.482	-	96.1
	RF by 210	-	0.335	-	97.8
	RF by (140 + 70)	-	0.468	-	97.0
	$lsd_{(0.05)}$	-	0.118	-	0.9
Cultivars by nitrogen rates	Q138 by 0	10.5	0.297	10.8	-
	Q138 by 210	15.5	0.425	15.9	-
	Q138 by (140+70)	14.8	0.665	15.5	-
	Q152 by 0	13.2	0.340	13.5	-
	Q152 by 210	16.5	0.392	16.9	-
	Q152 by (140 + 70)	15.5	0.469	16.0	-
	$lsd_{(0.05)}$	1.0	0.118	1.0	-
Spacings (m)	0.5	-	0.377	-	-
	1.0	-	0.433	-	-
	1.5	-	0.484	-	-
	$lsd_{(0.05)}$	-	0.084	-	-

The single nitrogen application resulted in the highest mature stalk sugar yield (16.0 t), and this was significantly higher than the split application (15.2 t), which was in turn was significantly greater than the zero nitrogen application (11.9 t). In contrast, sugar yield from sucker culms was highest with the split application (0.567 t), and this was significantly greater than the single application (0.408 t). This, in turn, was significantly greater than the zero application (0.318 t). Again, the late nitrogen application had an

impact on a sucker culm trait, in this case sugar production. This arose from a greatly increased sucker culm yield (Table 26) but a reduced CCS (Table 46). Total culm sugar yield was highest from the single nitrogen application (16.4 t). This was just significantly higher than the split application (15.7 t). The latter was significantly greater than the zero application. The proportion of total sugar production arising from mature stalks was greatest for the zero and single nitrogen application, which were not significantly different, but both were significantly greater than the split application.

Sucker culm sugar yield was lowest for the single nitrogen application in the rainfed environment (0.335 t), and this was significantly less that that from the zero and split application, which did not differ. In the irrigated environment, sucker culm sugar yields from all treatments differed, with the split application (0.666 t) exceeding that from the single application (0.481 t) and the zero application (0.155 t). In contrast, the proportion of sugar yield produced by mature stalks in the irrigated environment was the reverse of the sucker culm pattern. The proportion was highest for the zero application (98.6%), followed by the single application (97.0%) and then the split application (95.6%). In the rain-fed environment the nitrogen applications, single and split, did not differ but both were significantly higher than the zero application.

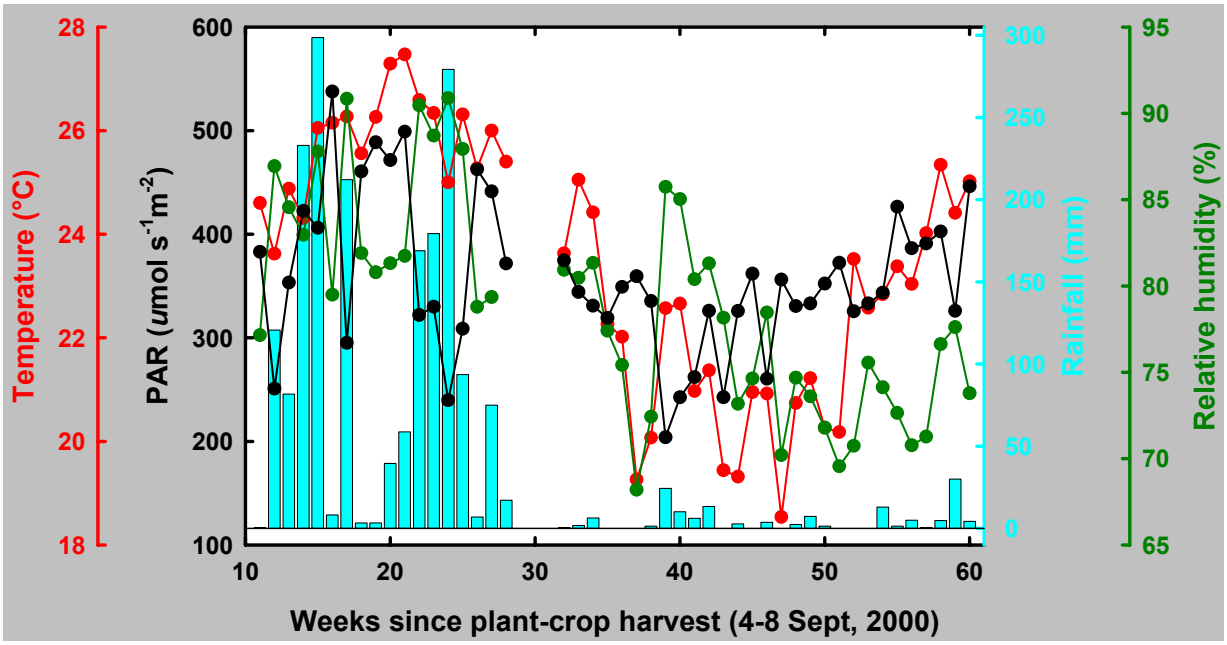

Figure 22: **Mean weekly photosynthetically active radiation (PAR), relative humidity, and temperature, and a bar chart presentation of weekly rainfall for the trial site for the first-ratoon crop from 22 November 2000, 11 weeks after the plant crop harvest.**

3.7.3.5 Environmental data

Meteorological data for photosynthetically active radiation (PAR), relative humidity, temperature (average) and rainfall (total), on a weekly basis, are depicted (Figure 22.). This graph commences in the 11th week after ratooning, from 22 November 2000. Data were not collected from weeks 1-10, and weeks 29-31. These discontinuities occurred because of technical difficulties with the data logger. The temperature and humidity data presented in Figure 22 were the average generated from data collected from two independent sensors averaged to a single set.

The obvious feature of this summary is the two marked wet episodes with peaks occurring at weeks 15 and 26 after ratooning. This indicated there were excellent rains late in 2000, commencing 11 weeks after harvest of the plant crop. Rainfall for the first two quarters of 2001 at the trial site was 1,137.8 mm (year weeks 1-13, or trial weeks 18-30) and 64.4 mm (year weeks 14-26, or trial week 31-43), respectively. Mean temperature peaked in week 21 and was lowest in week 47. The PAR values essentially parallel the temperature profile, with severe dips in their average value coinciding with rainfall episodes, e.g., weeks 11, 14, 16, 24, and 39. The responses obtained in the trial itself are difficult if not impossible to reconcile with the meteorological data collected and presented here, and these can really only be considered indicative of the general conditions in which the trial was conducted.

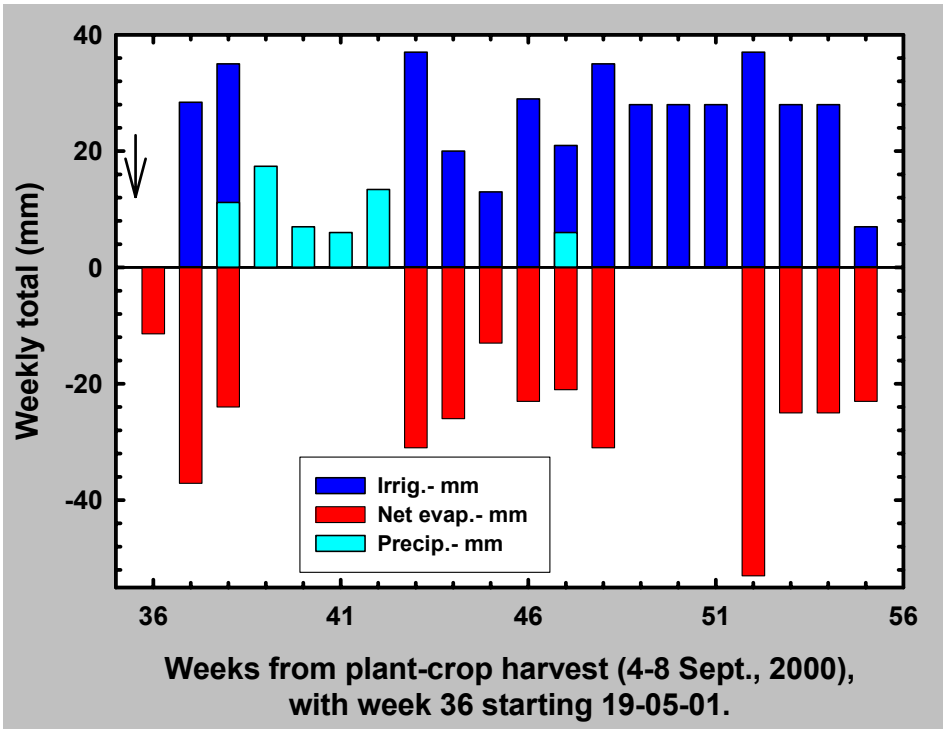

Figure 23: Summary of post-monsoonal applied irrigation, A-pan evaporation, and precipitation relevant to the irrigated environment in the first-ratoon crop of the field experiment. The environment was saturated to field capacity on 16 May (arrow), preparatory to commencement of the irrigation regime.

The post-monsoonal irrigation, which commenced with saturation to field capacity on 16 May, was maintained with difficulty. The irrigation system was surface placed trickle tube. Despite a rigorous rat-control campaign in the plant crop, persistent damage occurred to the trickle line system and a constant patrol and repair program was found necessary to maintain an element of element of efficacy for the system. The situation was far worse in the ratoon crop, and maintenance of the system became a demanding chore. Evaporation, irrigation and rainfall data for the post-monsoonal irrigation regime (Figure 23) show there was a near constant need, except for the receipt of rain in weeks 39-43, for irrigation. This was scheduled on a 3-day moving mean ratio [(precipitation + irrigation)/evaporation], with the latter being taken from a standard A-pan evaporimeters. In all, rain was recorded in 6 weeks of the 20 weeks for which the irrigation regime was maintained.

The efficacy of the irrigation treatment was monitored using time-domain reflectrometry. Readings were taken at 20 random paired sites within the irrigated environments. The sites were paired in the sense that a set of probes was located in the row and another set of probes immediately in the centre of the interspace at right angles to row in which the with-in row sample site was located. A further 20 within-row random sites were sampled in the rain-fed environment. Means and their standard deviations for these measurements collected on three occasions during the irrigation phase in the first-ratoon crop are presented in Table 49. Two high standard deviations were recorded for the combined irrigated data on 6 September, but this is not surprising given the differential between the within row and interspace values. Other high standard deviations were recorded for the combined irrigation data on 25 September, and again this is understandable, and the rain-fed environment on 25 September. The mean moisture for this rain-fed environment measurement was higher than the irrigated environment, which was unexpected, and resulted from misdirected irrigation spray from an adjacent recently ratooned block. As well, application of irrigation to the post-monsoonal irrigated block has ceased on 25 September. The lowest standard deviation was recorded for the rain-fed determination made on 06 September (Table 49).

Table 49: Details of environments and probe placements, with mean TDR moisture estimates (g kg^{-1}), and their variance.

Date	Environment	Probe placement	n	$\bar{x}$	σ
4-6 July 2001	Irrigated	Inter-space	20	280.8	36.51
		Row	20	276.9	40.88
		Combined	40	278.8	38.39
	Rainfed	Row	20	193.5	35.23
6 September 2001	Irrigated	Inter-space	20	297.2	38.82
		Row	20	204.1	35.73
		Combined	40	250.3	59.84
	Rainfed	Row	20	148.2	16.38
25 September 2001	Irrigated	Inter-space	20	233.7	86.54
		Row	20	179.7	38.71
		Combined	40	206.7	71.59
	Rainfed	Row	20	271.2	57.66

There was no difference between the within row and interspace measurements in the irrigated environment in July, but this difference was highly significant in the 6 September measurement and significant in the 25 September measurement (Table 50). In each case, the inter-row measurement was lowest, and this calls into question the efficacy of using drip irrigation line, that placed in the row, as a means of providing a uniformly irrigated profile from interspace to interspace. The contrasts between the irrigated and rain-fed measurements were highly significant, with the irrigated environment having the highest mean moisture for the first two measurements. This was reversed for the late determination because of the wayward irrigation, as explained above. In general, the differential between the irrigated and rain-fed environments was as desired (Table 50).

Table 50: Statistical tests for two contrasts of TDR-determined moisture (g kg^{-1}) collected on three occasions during the first-ratoon crop.

Date	Contrast	$s_{\bar{d}}$	$\bar{d}$	t'
4-6 July 2001	Irrigated: Interspace vs row	12.3	3.9	0.3
	Irrigated vs rainfed	10.1	85.4	8.4**
6 September 2001	Irrigated: Interspace vs row	11.8	93.2	7.9**
	Irrigated vs rainfed	10.2	102.1	10.0**
25 September 2001	Irrigated: Interspace vs row	21.2	54.0	2.5*
	Irrigated vs rainfed	17.2	- 64.5	-3.8**

Table 51: Soil nitrate-N and ammonium-N 249, 302 and 370 days after ratooning. Means followed by different letters indicate a significant difference (P < 0.05).

Effect	Soil nitrate-N (mg g^{-1} dry weight)			Soil ammonium-N (mg g^{-1} dry weight)		
	249 DAR	302 DAR	370 DAR	249 DAR	302 DAR	370 DAR
Nitrogen (kg N ha^{-1})						
0	12.04	5.81	9.52	12.84	3.14	6.13
210	13.95	6.73	9.07	12.72	2.84	5.56
140 + 70	15.07	8.04	10.03	11.02	3.11	6.82
	ns	ns	ns	ns	ns	ns
Stool space (m)						
0.5	13.85	6.44	8.86	13.41	3.19	6.62
1.0	13.30	7.51	8.43	11.98	3.22	5.91
1.5	13.92	6.63	11.39	11.20	2.68	5.97
	ns	ns	ns	ns	ns	ns
Depth (cm)						
0-25	13.69	7.08	10.14	12.19	3.24	7.08
25.1-50		6.64	8.93		2.82	5.25
		ns	ns		ns	ns

ns = F test not significant (p > 0.05)

3.7.3.6 Soil nitrogen

Analysis of soil ammonium-N and nitrate-N from samples taken 249, 302, and 370 DAR showed no effect due to nitrogen rate, stool spacing or depth (Table 51). The samples taken 302 and 370 DAR were after the additional 70 kg N ha^{-1} applied in May. A significant difference due to nitrogen treatments was expected. The differences between sampling times cannot be explained and the data within a sample period only should be compared. There may have been differences in N losses on storage of the soils between the different sample times.

3.7.3.7 Light levels

The red/far-red ratio of light was measured beneath the canopy on four occasions (Table 52). There was no effect of cultivar and stool spacing on the red/far-red ratio of light. The rain-fed environment had a significantly higher red/far-red ratio of light than the irrigated environment on all four sample dates.

Table 52: Red/far-red ratio of light beneath the crop canopy taken 199, 247, 302 and 372 days after ratooning. Means followed by different letters indicate a significant difference ($p < 0.05$).

Effect	Red (660-680 nm)/Far-red (720-740 nm) ratio of light			
	199 DAR	247 DAR	302 DAR	372 DAR
Stool space (m)				
0.5	0.44	0.43	0.57	0.69
1.0	0.48	0.44	0.55	0.78
1.5	0.48	0.44	0.53	0.79
	ns	ns	ns	ns
Cultivar				
Q138	0.50	0.46	0.53	0.78
Q152	0.43	0.41	0.57	0.73
	ns	ns	ns	ns
Moisture				
Irrigated	0.35a	0.33a	0.42a	0.70a
Rain-fed	0.58b	0.54b	0.69b	0.81b

ns = F test not significant ($p > 0.05$)

Measurements of PAR were taken on three occasions (Table 53). There was a significant effect of environment, stool spacing, and the height above ground at which the measurement was taken on the percentage of available PAR beneath the crop canopy. A significant difference also was found between cultivars at 247 DAR. There was a significant E by C interaction 247 DAR. Q152 had a higher percentage of available PAR in the rain-fed environment than in the irrigated environment.

There was no difference between environments for cultivar Q138. A significant C by S interaction was found 372 DAR. This was due to Q138 having the greatest amount of available PAR in the 1.0 m spacing and similar amounts in the 0.5 and 1.5 m spacings, whereas Q152 had a significantly greater amount of available PAR in the 1.0 and 1.5 m spacings than in the 0.5 m spacing.

Table 53: Photosynthetic active radiation (PAR, as % of sunlight) beneath the canopy of a sugarcane crop grown at three stool spacings 199, 247 and 372 days after ratooning. Means followed by different letters indicate a significant difference (P < 0.05).

Effect	199 DAR	247 DAR	372 DAR
Height above ground (cm)			
10	7.8a	3.5a	11.4a
100	10.3b	6.0b	21.7b
Stool space (m)			
0.5	7.1a	3.8a	13.2a
1.0	8.6b	3.9a	18.4b
1.5	11.6c	6.6b	17.8b
Moisture			
Irrigated	5.4a	3.1a	12.6a
Rain-fed	12.7b	6.5b	20.6b
Cultivar			
Q138	8.9	2.8a	17.3
Q152	9.2	6.8b	15.8
	ns		ns
Cultivar by moisture			
Q138 by irrigated	4.8	2.6a	15.0
Q138 by rain-fed	13.1	3.0a	19.6
Q152 by irrigated	6.1	3.6a	10.2
Q152 by rain-fed	12.3	10.0b	21.7
	ns		ns
Cultivar by space (m)			
Q138 by 0.5	5.9	1.9	12.0c
Q138 by 1.0	9.1	3.0	24.9a
Q138 by 1.5	11.8	3.4	15.0bc
Q152 by 0.5	8.2	5.6	14.6c
Q152 by 1.0	8.0	4.9	12.0b
Q152 by 1.5	11.4	9.8	20.6ab
	ns	ns	

ns = F test not significant (p > 0.05)

3.7.3.8 Sugars

There were significant effects of both environment and stalk type and a stalk type by environment interaction for all three sugars (Table 54). There was also a main effect of nitrogen for glucose and fructose content. Suckers have been widely reported to have lower sucrose content than mature stalks and have a lower purity juice (higher hexose to sucrose ratio), which is the basis of why they are a problem in commercial crops. The effect of environment on suckers was much bigger than on mature stalks (Figure 24.). The suckers emerged earlier in the rainfed than irrigated environment, 1.5 compared to 0 suckers per plot, 185 days after ratooning. There were more suckers in the 249 DAR count in the irrigated compared to rainfed environments but at the later counts there were more suckers in the irrigated environment. Consequently, in the rainfed environment the suckers were on average older and therefore had a longer time to accumulate sucrose than the suckers in the irrigated environment. The mature stalks in the rainfed environment had probably dried off reducing growth diverting more sucrose to storage rather than growth also reflected in lower glucose and fructose content.

Table 54: **Glucose, fructose and sucrose measured in juice from Q152 mature stalks and suckers in the first-ratoon crop. Means with different letters in the same effect and sugar are significantly different as judged by a LSD P < 0.05.**

Effect	Sugar %(w/v)		
	Glucose	Fructose	Sucrose
Stalk type			
Mature stalks	0.22a	0.27a	23.6a
Suckers	1.21b	1.08b	7.9b
Environment			
Irrigated	0.91a	0.80a	13.0a
Rainfed	0.40b	0.46b	20.3b
Nitrogen			
0	0.57a	0.54a	16.6
210	0.79b	0.76b	16.1
Stalk by environment			
Mature stalk			
Irrigated	0.23b	0.24a	22.4a
Rain-fed	0.17a	0.28a	25.3b
Suckers			
Irrigated	1.59d	1.37c	3.6c
Rain-fed	0.73c	0.72b	13.2d

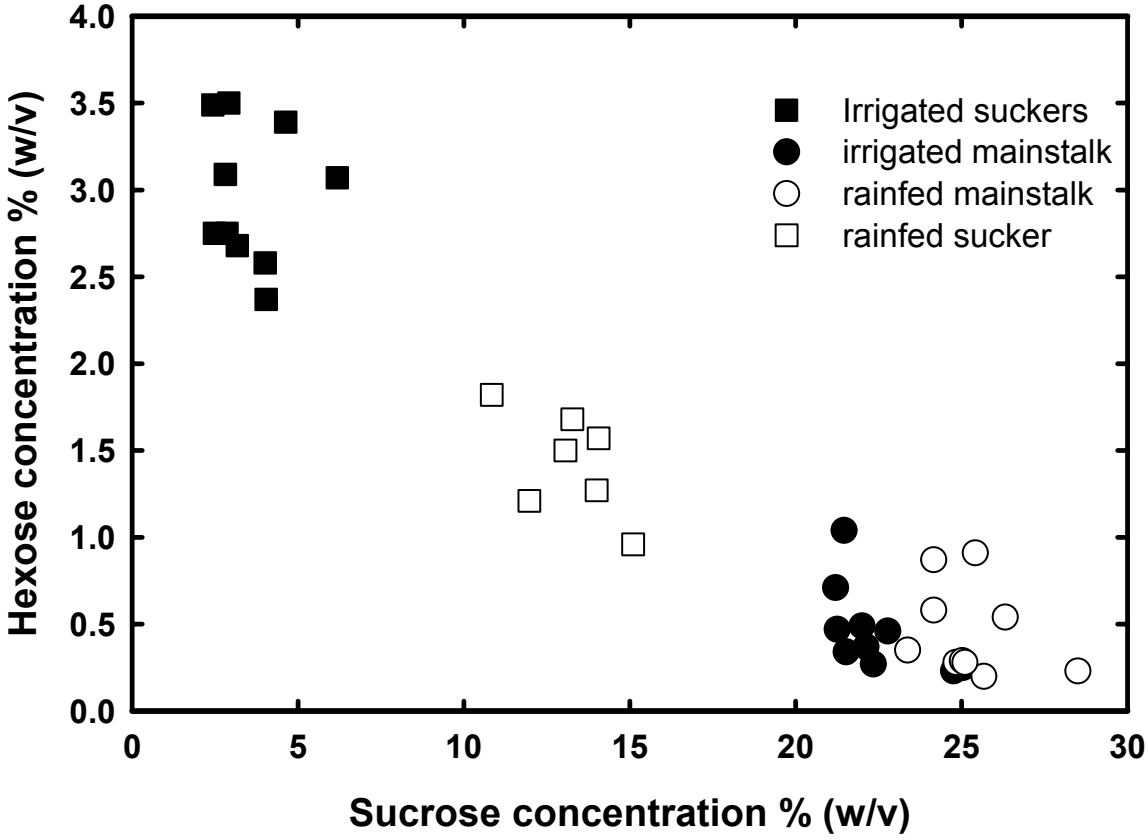

Figure 24: **Hexose versus sucrose concentration for suckers and mature stalks from irrigated and rain-fed sections of the first-ratoon crop.**

3.7.4 General discussion on main experiment

The experiment was a major success in that there was tremendous production of suckers in both the plant and first-ratoon crops (Figure 25). The number of suckers at harvest was fewer in the plant than the first-ratoon crop (36 versus 53 per core plot). Development of sucker culm number also was fast in the ratoon crop relative to the plant crop (Figure 25). For example, in the plant crop, 320 day elapsed before there were 10 sucker culms per core plot, whereas in the ratoon crop only 235 day passed from ratooning before this sucker culm count was reached. The main effects imposed in the plant crop were successful in stimulating the number of sucker culms, relative to numbers recorded in earlier research undertaken in 1999, a year of high suckering propensity. The numbers observed in the plant crop were in contrast to the general observations in the region in 2000. However, the delayed onset in sucker development relative to other observations made in the same year suggested a key stimulatory component might have been missing from the suite of effects imposed in the plant crop. Relative to the dynamics observed in the ratoon crop, in which the same main effects were imposed as treatments, this hypothesis can be sustained. The radical differences in the sucker culm number development may be confounded with crop class, e.g., do the greater resources in a ratoon stool facilitate greater sucker culm numbers and faster development relative to a stool developing from a plant sett? Alternately, year-to-year variation may explain the observed differences, or this could be confounded with differences imposed by the crop class. The means presented in Figure 25 are averages over all main effects. Importantly, for the final count in both crops, there were significant differences between the environments (post-monsoonal irrigation versus rain-fed). These were 45.5 versus 26.7 and 69.6 versus 34.3, for the plant and ratoon crops, respectively.

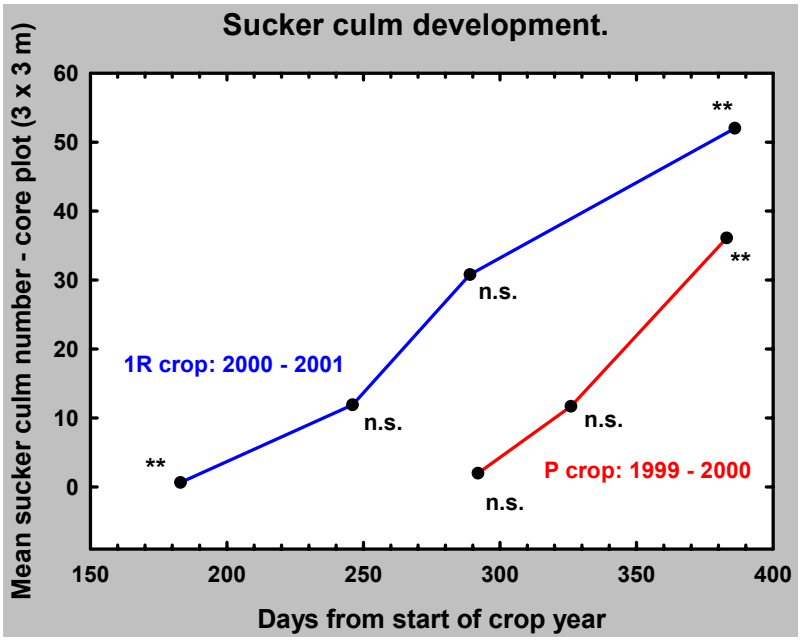

Figure 25: **Dynamics of the development of sucker culm numbers in the plant and first-ratoon crops of the main field experiment. The significance between the environments (post-monsoonal irrigation versus rain-fed) within each crop (P and 1R) is shown for each count.**

Table 55: Dissection of statistical significance for main and interaction effects for eight mature stalk traits and 10 sucker culm traits for four contrasts – main effects, P versus 1R crop; main effects, dissection by effect; environments by cultivars interactions, P versus 1R crop; proportion of significant interactions that contain the main effect of nitrogen.

AOV effect	Contrast	Mature stalk trait (8)			Sucker culm trait (10)		
		No.	No. possible	%	No.	No. possible	%
Main	P crop	20	32	62.5	35	40	87.5
	1R crop	19	32	59.4	32	40	80.0
Main	Environment	12	16	75.0	19	20	95.0
	Cultivar	10	16	62.5	19	20	95.0
	Nitrogen rate	14	16	87.5	20	20	100.0
	Spacing	3	16	18.8	9	20	45.0
Interaction (E by C)	P crop	1	8	12.5	9	10	90.0
	1R crop	3	8	37.5	9	10	90.0
Interaction	# significant – P crop	14	88	15.9	62	110	56.4
	# NR – P crop	7 (50.0%)[1]	56	12.5	39 (62.9%)[1]	70	55.7
	# significant – 1R crop	10	88	13.4	26	110	23.6
	# NR – 1R crop	7 (70.0%)[1]	56	12.5	17 (65.4%)[1]	70	24.3

[1]proportion of observed significant interactions that contained the main effect of 'nitrogen rate'.

The experiment also was a success in terms of the number of significant main and interaction effects visible in the summaries of the analyses of variance. This is a striking feature of this experiment. A means of assessing the impact of the experiment, in terms of the number and level of significant main and interaction effects obtained is to dissect these using simple criteria. Four such analyses are summarized in Table 55. The analysis focuses on eight mature-stalk traits and 10 sucker-culm traits of 24 traits analysed in both the plant and first-ratoon crop. The six excluded for this consideration are combination traits derive from mature stalk and sucker culm traits. The following conclusion can be made:

1. For main effects, there was little difference between the plant and ratoon crops for either set of traits. However, the sucker culm traits showed a higher proportion of significant main effects (Table 55).
2. Again, in terms of the possible number of times each main effect could be significant in each set, the proportion for which the sucker-culm traits was significant was higher than for the mature-stalk traits. Within both the mature-stalk traits and the sucker-culm traits, environments, cultivars, and nitrogen rate were significant for a much higher proportion than was the spacings effect (Table 55).
3. For the environments by cultivars interaction, a higher proportion of these was significant in the first-ratoon crop for the mature-stalk traits, but the sucker culm traits far exceeded the mature stalk traits for the proportion of significance for this interaction in each crops.
4. In significant interactions, of any nature, the plant and first-ratoon crops differed little in terms of the proportion of the possible number that was significant in both sets of traits. There was, again, a higher proportion significant for the sucker culm traits,

although in this instance the first-ratoon crop proportion was considerably less than the plant crop. This pattern was very similar when the significant interaction observed that involved the main effect of nitrogen rates is considered. However, for both trait classes, and both crops, interactions involving nitrogen rate dominated the number of significant interactions observed.

The experiment addressed the project objectives as follows.

Objective 1 To evaluate the role of light, nitrogen and moisture as stimuli initiating suckering.

The set of 18 traits considered in Table 55 was further reduced to include only CCS of the five quality components determined, i.e., brix, fibre, moisture and pol reading, for both mature stalks and suckers were not considered. Nine of the 10 traits considered were significant in both plant and ratoon crop (Tables 56 and 57). The irrigated environment produced significantly more sucker culms numbers in both the plant and ratoon crops (45.5 versus 26.7 and 69.6 versus 34.3, respectively.), Q152 produced a higher number of sucker culms than Q138 in each crop (38.1 versus 34.2 and 65.9 versus 38.1). The split nitrogen application applied in each crop produced the highest sucker culm number (46.4 and 63.0, on a core plot basis; Table 56). For mature stalks, Q152 produced more than Q138 in each crop (76.5 versus 70.6 and 75.1 versus 63.6, for the plant and ratoon crops, respectively). The single and split nitrogen application produced more stalks than the zero application in both crops. As Table 55 indicated, the main effect of spacings really was a general failure and the only instance where this effect was significant in both crop was for number of mature stalks (Table 56). In the plant crop, the 1.5 m spacing produced fewer mature stalks than either the 0.5 and 1.0 m spacings (67.7 versus 77.1 and 75.9). The latter two did not differ. The broader within-row spacing of 1.5 m produced significantly fewer stalks than either the 1.0 m in the first-ratoon crop. The 0.5 and 1.0 m spacings did not differ, nor did the 0.5 and the 1.5m.

Table 56: Means for number of sucker culms and mature stalks in plant and first ratoon crops for four main effects, which showed statistical significance in both crops.

Main effect	Treatment	# Su[1]		# MS[1]	
		Plant	First ratoon	Plant	First ratoon
Environments	Irrigated	45.5	69.6	-	-
	Rain-fed	26.7	34.3	-	-
Cultivars	Q138	34.2	38.1	70.6	63.6
	Q152	38.1	65.9	76.5	75.1
Nitrogen rates	Zero	27.4	40.2	72.0	61.2
	Single	34.5	52.7	73.1	74.0
	Split	46.4	63.0	75.5	72.8
Spacings	0.5 m	-	-	77.1	68.9
	1.0 m	-	-	75.9	71.5
	1.5 m	-	-	67.7	67.5

Table 57: Means for eight yield and quality component traits of sucker culms and mature stalks in plant and first-ratoon crops for three main effects, which showed statistical significance in both crops.

Trait	Crop	Environments		Cultivars		Nitrogen rates		
		Irrigated	Rainfed	Q138	Q152	Zero	Single	Split
TCH	P	105.9	99.1	97.8	107.2	99.5	103.0	105.0
(t ha^{-1})	1R	89.7	80.9	81.3	89.2	70.2	93.6	92.0
TSuH	P	7.0	2.6	5.9	3.8	2.9	4.8	6.8
(t ha^{-1})	1R	19.3	5.5	13.8	11.0	7.2	12.1	17.9
%Su	P	6.2	2.6	5.5	3.3	2.8	4.4	5.9
	1R	17.0	6.5	13.4	10.1	9.3	10.7	15.2
kg/100 Su	P	13.9	9.0	14.7	8.2	9.7	12.1	12.6
	1R	26.7	17.0	29.9	13.8	19.6	20.2	25.8
CCS – MS	P	127.8	143.1	133.7	137.2	140.1	135.5	130.7
(g kg^{-1})	1R	158.3	178.8	167.2	169.9	169.2	171.4	165.0
CCS- Su	P	-33.0	-13.2	-27.1	-19.1	-23.2	-21.4	-24.8
(g kg^{-1})	1R	21.5	79.3	43.9	56.8	48.0	54.0	49.1
Sugar yield – MS	P	-	-	13.0	14.7	-	-	-
(t ha^{-1})	1R	-	-	13.6	15.1	-	-	-
Sugar yield – Su	P	-	-	-	-	-0.07	-0.14	-0.22
(t ha^{-1})	1R	-	-	-	-	0.318	0.408	0.567

The failure of spacings to be an effective main effect for many of the sucker culm traits was unexpected. This factor was included as there was ample evidence to suggest that increased light availability in a maturing crop, e.g., when a crop sprawls or lodges, or as occurs of the periphery of fields, is a strong stimulus to sucker culm initiation and development. There is supporting evidence from the preliminary experiments in this project that light is a factor, e.g., a comparison of non-removal and removal of mature stalk trash in a developing crop resulted in significant sucker culm stimulation. However, the facts from the main experiment which successfully stimulated sucker development suggest that increased light, as facilitated by variable within-row stool spacing, plays a relatively minor role relative to the other main effects assessed – cultivars, mature crop moisture availability, and late availability nitrogen.

Clearly, post-monsoonal irrigation had a profound impact on the expression of many traits measured in the experiment, and this impact was consistent. Higher TCH, TSuH, %suckering, sucker size (weight), were all higher in the irrigated environment than in the rain-fed environment (Table 57). The reverse was true for mature stalk and sucker culm CCS, both of which were higher in the rain-red environment in the plant and ratoon crops (Table 57). Interestingly, the ratoon crop performance for mature stalks was 84.7 and 81.6%, respectively, of the plant crop yield in the irrigated and rain-fed environments. The irrigated environment performance was 107 and 110% of the rain-fed environment for the plant and ratoon crops, respectively.

Cultivar performance also was consistent over crops. Q138 produced higher values than Q152 for TSuH, % Su, and sucker culm weight, but the reverse was true for TCH, CCS of mature stalks and of sucker culms, and sugar yield from mature stalks.

The split nitrogen application also had a pronounced effect of the traits featured in Table 57, and again there was a high consistency in these responses. The split and single application were no different for TCH, and both were higher than the zero application. For the sucker culm traits TSuH, %Su, and sucker weight, the split application produced the highest mean, although for sucker weigh there was no difference between the split and single application but both were superior to the zero application. The split application results in the lowest CCS for mature stalks in both crops. For sucker culm CCS, the split application was no different from the zero application and both were inferior to the single application (Table 57). Finally, the split application produced the highest sucker culm sugar yield in both crops. This was despite its impact on culm CCS. The effect the split application had on sucker yield (TSuH) was the variable driving this superiority in sugar yield.

From these results one can conclude that the main effects of environment (post-monsoonal irrigation versus rain-fed), cultivars (Q138 versus Q152), and nitrogen rates (zero, single, and split) producing statistically significant in most of the traits examined, and that these effects were relatively consistent over crops. Spacing was relatively ineffective as a major effect in influencing sucker culm initiation and development of traits associated with this culm class.

Objective 2 To determine the effect of interactions among these factors and cultivars studied on sucker initiation.

Seven of the traits considered had significant environment by cultivar interaction over both crops (Table 58). Q152 had the highest mature stalk number in the irrigated environment in both crops and possessed the highest sucker culm number in the same environment. Sucker yield was highest for Q138 in the irrigated environment and this was achieved despite a deficiency in sucker culm number because of the significantly greater sucker weight. Q138 was clearly superior in the irrigated environment in terms of %Su, the proportion of total culm yield produced by sucker culms. Values for this were 7.5 and 19.6%, respectively, in the plant and ratoon crops. Some of the rare inconsistencies across environments occurred for CCS and sugar yield of the suckers. Q152 had the highest sucker culm CCS in the rain-fed environment in the plant and ratoon crops. The highest sugar yield from sucker culms resulted from Q152 in the irrigated environment, but Q138 was highest in the ratoon crop by virtue if the cultivars greater sucker culm yield under irrigated conditions. In many instances in the above discussion, the alternate cultivar also expressed the next highest level of a trait in the irrigated environment, and this confirms the suitability of post monsoonal irrigation to stimulating expression of many of these traits regardless of the genetics. Obviously, the impact of the post-monsoonal irrigation as a main factor was pronounced on expression of clonal traits, particularly those associated with suckering. The presence of moisture in the mature crop, as imposed by wet weather condition experience in the tropical region in many of the years in the past decade up to 2002 has a pronounced effect on expression of suckering propensity. This will be exacerbated by use of cultivars that will express this trait under wet, mature-crop conditions.

Table 58: Means for seven yield and quality component traits of sucker culms and mature stalks in plant and first ratoon crops for two interaction effects, environments by cultivars and environments by nitrogen rates, which showed statistical significance in both crops.

Trait	Crop	Environments	Cultivars		Nitrogen rates		
			Q138	Q152	Zero	Single	Split
# MS	P	Irrigated	70.2	78.7	-	-	-
		Rain-fed	71.0	74.3	-	-	-
	1R	Irrigated	64.8	79.3	-	-	-
		Rain-fed	62.3	70.9	-	-	-
# Su	P	Irrigated	41.8	49.2	34.4	42.5	59.6
		Rain-fed	26.5	26.9	20.5	26.4	33.3
	1R	Irrigated	51.8	87.4	49.5	72.6	86.7
		Rain-fed	24.4	44.3	30.8	32.9	39.3
TSuH ($t\ ha^{-1}$)	P	Irrigated	8.4	5.7	3.8	7.3	10.1
		Rain-fed	3.4	1.9	2.0	2.4	3.5
	1R	Irrigated	21.4	17.2	8.4	20.2	29.3
		Rain-fed	6.1	4.8	5.9	4.1	6.5
%Su	P	Irrigated	7.5	4.8	3.7	6.3	8.5
		Rain-fed	3.4	1.8	2.0	2.4	3.4
	1R	Irrigated	19.6	14.3	10.4	16.9	23.6
		Rain-fed	7.2	5.8	8.3	4.5	6.8
kg/100 Su	P	Irrigated	17.8	10.0	10.4	15.7	15.6
		Rain-fed	11.6	6.4	9.0	8.5	9.5
	1R	Irrigated	36.2	17.3	19.0	26.7	34.5
		Rain-fed	23.6	10.4	20.1	13.7	17.2
CCS – Su ($g\ kg^{-1}$)	P	Irrigated	-39.1	-27.0	-	-	-
		Rain-fed	-15.2	-11.3	-	-	-
	1R	Irrigated	23.2	19.7	-	-	-
		Rain-fed	64.7	93.9	-	-	-
Sugar yield – Su ($t\ ha^{-1}$)	P	Irrigated	-0.34	-0.16	-0.11	-0.25	-0.40
		Rain-fed	-0.05	-0.02	-0.03	-0.20	-0.05
	1R	Irrigated	0.521	0.347	0.155	0.481	0.666
		Rain-fed	0.404	0.453	0.482	0.335	0.468

The split nitrogen application in the irrigated environment produced the strongest expression for the sucker culm traits of number, yield, proportion of crop, and weight in terms of environments by nitrogen rates interactions (Table 58). This was consistent over crops. Only for sucker-culm weight did the single application produce an equivalent mean to the split application. Sugar yield was highest for the split application in the irrigated environment in both crops. This gives the clearest clue as to the driving variables for sucker culm development. The late nitrogen application combined with moisture in the mature crop stage successfully stimulates marked expression of many sucker culm traits against which selection is required.

There are two traits for which the interaction term cultivar by nitrogen rates was consistently significant over crops, and these were sucker culm CCS and sugar yield (Table 59). Such interaction are expected, and as they were not reflected in mature stalk CCS, they probably are unimportant. The split application and Q138 produced the lowest

CCS in both crops. For sugar yield from sucker culms, the Q152 and Q138 shared the honours for lowest CCS with the zero nitrogen application in the plant and ratoon crops, respectively.

Table 59: Means for two yield and quality component traits of sucker culms in plant and first-ratoon crops for the cultivars by nitrogen rates interaction, which showed statistical significance in both crops.

Trait	Crop	Cultivar	Nitrogen rates		
			Zero	Single	Split
CCS – Su ($g\ kg^{-1}$)	P	Q138	-26.3	-24.8	-30.3
		Q152	-20.1	-18.0	-19.3
	1R	Q138	44.4	44.2	43.3
		Q152	51.6	63.9	54.9
Sugar yield – Su ($t\ ha^{-1}$)	P	Q138	-0.10	-0.19	-0.30
		Q152	-0.05	-0.08	-0.14
	1R	Q138	0.297	0.425	0.665
		Q152	0.340	0.392	0.469

Objective 3 To provide specifications for the necessary environmental conditions to conduct screening of populations of clones for suckering propensity.

There is little doubt from these results that moisture persisting in the mature crop is essential for good expression of suckering propensity and the traits that can be measured on these, e.g., number, size, weight, proportion of crop, yield. This expression is clearly enhanced by the availability of nitrogen late in the crop development, e.g., May as was used in both crops in this experiment. Increased light penetration, as afforded by increased within-row stool spacing was not a prominent stimulatory variable. The reason for this is not understood, but is confused because of conflicting evidence from the preliminary experiments.

Objective 4 To develop research, crop management, or crop improvement strategies to address the problems caused by suckering.

- Ideotype selection as currently being practiced is essential if climatic change continues to impose wet conditions in the tropical region. However, this change may not persist, and one must ask are there negative implications associated with selection of low suckering propensity clones. We do not know the genetic association between suckering propensity and ratoonability. Is there a 'thin red line' between these, e.g., we can successfully select clones with low propensity for suckering, but what, if any are the implications for ratoon productivity and profitability?
- The extent of genotype by environment interaction for suckering propensity is unknown and this needs to be determined. This could be easily done in existing trials. This would enhance our understanding of the genetics of the trait, assessed across a broad range of environments. This also would provide guidance as to how information on suckering propensity could be used for the industry's benefit. For example if a managed suckering screen was implemented, the results would not necessarily result in the automatic discard of all high propensity clones. These may

well have applicability to drier environments, but this needs conformation by enhancing our understanding of the extent of G by E interactions for suckering propensity.

- Obviously, the impasse we are at regarding the role of light needs resolution. The observations strongly suggest that increased light penetration in a mature crop has serious implication in terms of stimulating suckering. In the main experiment, increased light penetration, as induced by increasing stool spacing, was disappointing.

4.0 OUTPUTS

This project produced clear-cut results that show that post-monsoonal irrigation is an environmental variable that facilitates the initiation and development of sucker culms, and the expression of important traits of these. These are further enhanced in almost all instances by late nitrogen applications. The genetics component of the suckering scenario is well appreciated from other work, and was confirmed here. This research highlights interactions of these with moisture and nitrogen nutrition.

Spacing is more problematic. In a preliminary trial, light penetration was important in initiating suckering. However, when tested in conjunction with other factors, it was relatively ineffective as a major effect in influencing sucker culm initiation and development of traits associated with this culm class.

The project enhances our knowledge of the importance of prudent nitrogen use as a means of limiting sucker culm development, and hence increasing extraneous matter. It importantly provides an understanding that allows implementation of a managed screen for sucker culm development. This will be useful in classifying clones in the northern program, but such information may not necessarily be used for selection.

5.0 EXPECTED OUTCOMES

The results from this project could have a major impact on the tropical sectors of the industry. In a practical sense, the use of recommended nitrogen rates, so that excess nitrogen is not available through into the mature crop phase, is important in managing sucker development. If excess nitrogen is available, and excess moisture becomes available in this period, suckering propensity as seen in the region for much of the past decade will again occur. Sensible nitrogen use also is required from an environmental viewpoint, and adherence to this would assist the avoidance of excessive sucker culm initiation and development. Given that we have shown that 10% suckering is equivalent to the loss of one unit of CCS, any reduction in suckering, and the automatic increase in CCS, will provide increased returns. With determinations of up to 50% of culm biomass being produced by sucker culms, the economic benefit is clear.

We now have the tools to develop a managed screen for suckering propensity, but implementation of this course of action without a clearer understanding of the genotype by environment interactions associated with expression of the trait and a clear

understanding of the genetic association between suckering propensity and ratoonability would be a folly.

Screening for suckering potential does not mean the immediate imposition of an additional selection trait. In some environments, this may be the case, but overall one would hope that such knowledge would be used as additional information in cultivar selection and management, with real benefits in increased CCS being realized with little if any additional cost.

6.0 FUTURE NEEDS AND RECOMMENDATIONS

- A clearer understanding of the role of genotype by environment interactions for suckering propensity should be obtained. Knowledge of the suckering propensity of clones at the pre-cultivar stage may allow their recommendation for specific environments suited to their sucker propensity rating, e.g., one unsuited to a moist environment because of high suckering propensity may well have a place in a drier environment. Such information is envisaged primarily as an addition tool for correct choice and management of cultivars in the commercial context.
- The other major concern is that the genetic relationship between suckering propensity and ratoonability is unknown. This needs clarification. At the start of this project, the importance of major environmental variables as tested in this project was unknown in terms of their impact on sucker culm initiation. This project has provided clarification of their importance. In a similar manner, we need to clarify the relationship between suckering propensity and ratoonability.
- The puzzle remains that light was a main factor of little consequence in the main experiment, but was important in preliminary experiments and is in every-day observations. This conundrum requires further study.

7.0 PUBLICATIONS ARISING FROM THE PROJECT

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8.0 ACKNOWLEDGMENTS

We thank the growers who allowed trials on their properties.

The preliminary experiment was part of the research by PhD scholar Barry Salter in partial fulfilment of a PhD degree at JCU with augmented funding from the CRC for Sustainable Sugar Production. Much of the description of the preliminary experiments has been taken from his thesis.

We thank Dr Peter Albertson CSIRO Tropical Agriculture for running the HPLC samples.

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APPENDIX 1 – Paper by Bonnett *et al.*

Suckers: What are they and what causes them?

By Graham Bonnett[1], Barry Salter[1,2,3], Alan Hurney[4], Nils Berding[5] and Robert Lawn[2,3]

Suckers are stalks produced by premature germination of buds on the stool. They have a relatively high water content and consequently are called 'water shoots' or 'bull shoots' in sugar industries in other parts of the world.

They are distinguished from other shoots by the way they look; they have what is called 'different morphology'. In our recent studies, we have shown that in the variety Q138 (at least) suckers have broader, shorter leaves, longer leaf sheaths and thicker internodes than either plant or ratoon stalks of a similar age (Figure 1). Similar measurements are currently being made in other varieties.

Once a sucker, always a sucker?

Another question we asked is whether the different appearance of suckers is transmitted to the next generation. Or does a sucker give rise to a sucker? Our results to date show that the morphology of shoots arising from suckers is reset during germination and that the appearance of suckers is not a permanent genetic change (Figure 2).

What benefit suckers are to wild sugarcane is not currently known. But in a commercial situation, suckers can be a problem, particularly in the wet tropics.

Graham Bonnett.

SUCKERS REDUCE PROFITS

Suckers contain low levels of sucrose because of their young age. They are harvested along with the main stalks. Sucker billets ending up in the harvested material lower the CCS of the harvested cane by dilution.

In addition, because suckers are shorter than the main stalks their tops are also more likely to end up in the bin — further reducing CCS. From a whole of industry perspective, suckers increase the amount of material harvested, transported and processed per tonne of sugar produced — consequently reducing profitability.

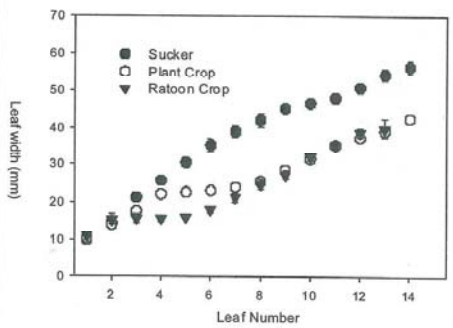
Another potential loss caused by suckers is the removal of sugar from the main stalk to fuel their growth. This has not previously been investigated

We sampled the sugar content of internodes on stalks with and without suckers attached. There was significantly less sucrose in the underground internodes (number 1 and 2), but not in the above ground internode (number 3) that we sampled (Figure 3). So there may not be a commercial loss of sucrose in internodes above ground.

But further samples were taken later in the season, including internodes higher up the stem in the varieties Q138 and Q152. These samples are yet to be analysed but should give a better indication of the likelihood of sugar loss from main stalks supporting suckers.

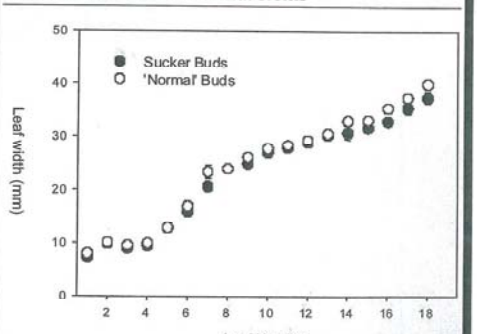
12 ▷

FIGURE 1: The width of leaves at each leaf position



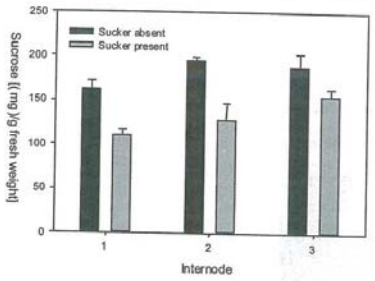
Position 1 is the first formed leaf, for suckers, ratooning stalks and germinating plant cane. Measurements were taken in Tully in crops of Q138 growing in the same locality at the same time. Sucker leaves are wider than the ratoons and plant crops at the same position on the stalk. (Unpublished data of B Salter)

FIGURE 2: Leaf widths for shoots developing from buds on suckers and normal stems



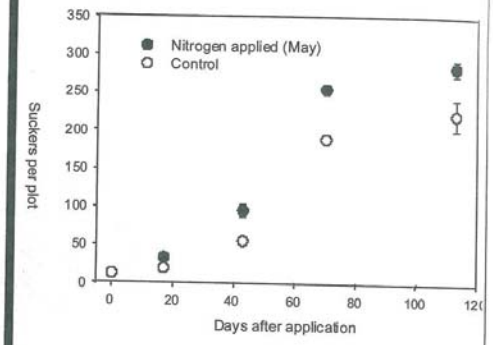
Buds were taken from the same position on both stalk types (that is, of the same age). There is no difference between the plants developed from buds on suckers or normal cane (unpublished data of B Salter)

FIGURE 3: Sucrose content of internode 1 and 2 above the point of attachment of a sucker (1,2) and the first internode above ground (3) for stalks with a sucker and from the equivalent internode positions from a stalk that had never produced a sucker (variety Q152)



Producing a sucker significantly reduced the amount of sugar in the internodes below the ground but the difference was not significant in the first internode above ground (unpublished data of B Salter).

FIGURE 4: Effect of applying 70 kg/ha of nitrogen using ammonium nitrate to a crop of Q152 in May



Sucker number increased in the crop with additional nitrogen applied. Plots were 4 rows of 5 m length (Figures 3 and 4: unpublished data of B Salter)

◁ 12...SUCKERS: WHAT AND WHY?

WHAT CAUSES SUCKERING?

So what causes suckering? There is no doubt that different varieties in the same environment have differing tendency to sucker. Recent analyses of a BSES final assessment trial showed that suckers contributed between three and 30 per cent of the harvestable weight. Unfortunately many of our currently used varieties have a reasonably high tendency to sucker.

Suckering also occurs because of environmental factors or stimuli. Once the environmental stimuli that initiate and promote suckering are understood, developing a artificial managed environment to screen varieties against suckering tendency will be possible.

Some of the environmental stimuli under investigation are light, moisture and nitrogen. In a major field trial recently set up in the Mulgrave mill district, Q138 and Q152 will be tested with three different plant densities (giving different light levels), two soil moisture levels and three nitrogen regimes.

In part, this experiment is testing the theory that changes in soil moisture and nitrogen status after many years of green cane trash blanketing are promoting suckering.

Availability of late nitrogen can increase suckering

As a preliminary experiment to help determine the nitrogen treatments in the main experiment, nitrogen was applied to a crop of Q152 in Tully in the autumn. This increased the number of suckers formed (Figure 4). So availability of nitrogen late in the season has the potential to increase suckering.

Although the work is in a preliminary stage and is based on a limited number of varieties, clues about what suckers are and what causes them are already being uncovered.

At the end of the project we hope to have quantified the relative effects of the main reasons for suckering.

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2 CRC for Sustainable Sugar Production, Townsville.
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Graham Bonnett discusses suckering with SRDC Executive Director Eoin Wallis and Babinda grower Alan Zappala. (Photo: SRDC)