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INFLUENCE OF HARVESTER BASECUTTERS ON RATOONING OF SUGARCANE

by

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SD05005

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SUMMARY

Current single-row mechanical sugarcane harvesters use twin rotary basecutters with multiple blades to produce an impact cut in the stalk at or near ground level. However, the cane stubble is often damaged during harvesting, which is considered to be caused by the basecutter. Many instances of poor ratooning have been attributed to either basecutter damage increasing the risk of infection by stalk diseases, or due to a reduction in the number of viable buds. While this matter was discussed regularly, there were no data that quantified the level of damage occurring in the field or the relationship between stubble damage and ratooning. In addition, if stubble damage was affecting ratooning, harvesting and cultural practices contributing to stubble damage needed to be identified.

This was addressed in this project by conducting surveys in harvested fields in the Tully Burdekin and Mackay districts to asses the level of damage that occurred during harvest. These surveys clearly indicated that the stubble was being damaged during harvest, with some 60-75% of stubble stalks suffering some form of damage. This effect was common across all three districts. It was of some concern that approximately 40% of stalks had been seriously damaged either with deep splits or a combination of shattering and deep splits. Other types of damage included shallow splits and snapping of the stalks.

This damage to the stubble was considered to have the potential to interfere with ratooning, either from physical damage, or because it could facilitate infection of the stubble by fungal diseases such as pineapple disease. The surveys showed that pineapple disease was common to all soils surveyed. This suggested that infection of the damaged stubble by this fungus had the potential to be a contributing factor to ratoon regrowth problems, as the fungus can adversely affect germination in plant crops. Although the surveys showed that snapping the stalks below ground was a common problem with 17% of the stalks affected, it was unclear if snapping would interfere with ratooning.

Basecutter simulation trials showed that splitting the stubble stalk significantly reduced ratoon-shoot numbers by about 40%. However, this was an indirect effect, because the split facilitated infection of the stalk by disease. It was the level of disease in the stubble that was found to inhibit ratooning. It was also found that infection of stubble stalks can occur in the absence of damage, but this was generally a lower level of infection. Therefore, stalks snapped below ground level can be infected by fungal disease, but the level of infection and effect on ratooning would be expected to be less than in a stalk that had a deep split. The types of fungi infecting the stubble were classified as indeterminate rots. Pineapple disease was not isolated from any stalks with natural infection, but only from stalks that had been inoculated with that fungus. Inoculations with red rot were unsuccessful.

Trials to determine the degree of stalk damage required to influence ratooning were inconclusive. This was because the results were influenced to a greater extent by external variables, such as high rainfall and suckers. These types of factors can override the effects of damage and disease on ratooning. The data do suggest that it is probably the depth rather than the type of damage that is important. The data also suggested that a stalk needs to be split for about 50% of its length to have any appreciable effect on ratooning.

Harvesting trials were also carried out to identify harvesting and cultural practices contributing to stubble damage. It was found that harvesting lodged cane on a face rather than one way in the direction of lodging increased stubble damage. There is a simple remedy to this problem, which is not adopted in many instances, because of the increase in operating cost and time. Damage increased at low harvesting speeds (3.8 km/h), but results were variable at higher speeds (7.9 km/h), when compared with the damage level at 6 km/h. This latter speed is considered too slow for large harvesting contracts, except in high yielding crops, and this aspect requires further study.

Increasing the cutting height above the ground increased damage in some cases but not others. Where damage increased, it was generally associated with an increase in the proportion of snapped stalks. Harvesting with worn basecutter blades also increased stubble damage. However, it was also found to contribute to a more serious problem. Because the cane is not cut properly and picked up by the harvester, operators compensate for this by lowering the cutting height to below ground level. Cutting below ground can reduce yields, because stubble is removed from the ground, leaving a gappy stand of cane. Yields were reduced by 34 t/ha in a trial in the Burdekin because of this practice.

Cutting below ground level is a common practice in the Burdekin area because of the high rows for furrow irrigation. These high rows do not suit the basecutter inline angle, and the usual consequence is to lower cutting height to below ground level. Mismatch between row height and profile and the basecutter inline angle is considered to be a major cause of stubble damage and contributing to potential yield losses. The benefits of getting this correct was demonstrated in a Burdekin trial, where low damage levels of 30% and 40% were obtained with new and worn blades, respectively, with no adverse effect on crop growth. This result was achieved because basecutter inline angle had been adjusted to suit the row height and cutting height was set above ground. The use of harvesters with the capacity to hydraulically adjust basecutter angle will help alleviate this problem. However, it will require a good extension program to get operators to accept the need for this equipment. It will also require an additional program to make farmers aware of the need to implement the most appropriate cultural practices to suit their harvesting system.

Varieties are considered to have a minor role in this problem. Rotting stubble, as noted in Q96 in the Burdekin, will make a variety more prone to yield loss if harvested below ground. Q138 tendered to shatter more than Q127, presumably because of its harder rind and higher fibre content. This can not be avoided, but may be reduced with the implementation of better harvesting systems. Slow ratooning will make a variety more prone to adverse effects from stubble diseases, but the risk can be reduced if appropriate harvesting systems are adopted.

The results of the project have been incorporated into the *Harvesting Best Practice Manual*. Growers and harvester operators have been informed of the results of these studies at farmer group or shed meetings and on a one-to-one basis.

1.0 BACKGROUND

The yield plateau that has beset the sugar industry since the mid 1970s has been linked circumstantially with mechanical harvesting. Research on extractor losses has provided a direct link between mechanical harvesting and yield loss, but research into other potential problem areas associated with harvesting has been limited. Improved harvester performance through improved cutting of cane, leading to longer more profitable ratoon cycles, could result in large economic returns.

Current single-row mechanical sugarcane harvesters use twin rotary basecutters with multiple blades to produce an impact cut in the stalk at or near ground level. However, the cane stool or stubble is often damaged during harvesting; this is thought to be caused by the basecutter. Many instances of poor ratooning have been attributed to basecutter damage either increasing the risk of infection by stalk diseases or reducing the number of viable buds.

While the fact that basecutters did damage the stool had been recognised, there has been limited information describing the type and severity of damage that was observed in the field. Kroes and Harris (1994) developed a classification system for modes of failure and severity of damage, based on observations of cutting using an experimental basecutter. They also discussed the mechanisms, including basecutter speed, feed rate, basecutter inline angle, knockdown roller angle, and blade type and wear, which caused the damage observed. This improved the level of understanding of basecutter damage. In addition, the development of a classification system would allow consistent damage description during research and investigations of damage and its consequences. In a later study, they concluded that the responsibility for stubble damage did not rest solely with the basecutter, but that knockdown of stalks prior to cutting was a significant factor in controlling damage to the stubble because of the bending stresses applied to the stalk (Kroes and Harris 1996).

Field observations of damaged stubble usually suggest that there has been some infection of the stalk tissue by pathogens and the symptoms normally observed are reddish discolouration and drying out of the stalk tissues. Inhibition of the germination of sugarcane buds by pineapple disease (*Ceratocystis paradoxa*) and black rot (*C. adisporum*) was reported by Kuo *et al.* (1969). They found that the production of ethyl acetate by these two pathogens was toxic to sugarcane buds in diseased tissues. Watanabe *et al.* (1974) isolated 1010 isolates of fungi from poor ratooning sugar cane in Taiwan. In inoculation experiments with 49 selected isolates, and single-eye cuttings, pineapple disease was the most pathogenic. This pathogen is often found in plant crops under Australian conditions. Another pathogen isolated and also common to Australian conditions was red rot (*Colletotrichum falcatum*).

While the potential for adverse effects on yield from basecutters is recognised, little is understood about the actual causes. Is the effect the result of various types of mechanical damage or due to increased opportunity for pathogens to invade tissue and inhibit ratooning? The objective of this project was to study these factors and determine their relative importance. This would provide information that would assist in improving basecutter performance.

2.0 OBJECTIVES

- Survey information about ratoon failures throughout the state, and investigate sites where basecutter damage appears to be an important factor.
- Investigate the effect on ratoon regrowth of underground breakage, shattering and other forms of stool damage.
- Investigate the interaction between various forms of stool damage and infection by red rot and pineapple disease, and their effect on ratooning.
- Determine the implications for harvester design and operation, cultural practices and further research into ratooning.

All of these objectives were realised as summarised below. The results of the project have been incorporated into the *Harvesting Best Practice Manual.* Growers and harvester operators have been informed of the results of these studies at farmer group or shed meetings and on a one-to-one basis.

Objective 1 - Survey information about ratoon failures throughout the state, and investigate sites where basecutter damage appears to be an important factor.

A SRDC review of the project recommended that this objective should be abandoned because of the difficulties of obtaining reports on ratoon failures. It was recommended that it should be changed to conducting surveys within several-cane growing districts to assess the extent of stubble damage incurred during the harvest operations. A similar survey had already been conducted in the Tully area as part of the project and the review panel considered ‘the quality of this information may be better than would be obtained from the survey as originally proposed’. They recommended that survey work similar to the one conducted in Tully be undertaken in other locations. It was also suggested an assessment of factors contributing to stool damage should be investigated, if possible. Investigation of ratoon failures would also be undertaken as the opportunity arose.

Surveys in harvested fields in the Tully Burdekin and Mackay districts clearly indicated that the stubble was being damaged during harvest, with some 60-75% of stubble stalks suffering some form of damage. This effect was common across all three districts. It was of some concern that approximately 40% of stalks had been seriously damaged either with deep splits or a combination of shattering and deep splits. Other types of damage included shallow splits and snapping of the stalks.

This damage to the stubble was considered to have the potential to interfere with ratooning, either from physical damage, or because it could facilitate infection of the stubble by fungal diseases such as pineapple disease. The surveys showed that pineapple disease was common to all soils surveyed. This suggested that infection of the damaged stubble by this fungus had the potential to be a contributing factor to ratoon regrowth problems, as it can adversely affect germination in plant crops. Although the surveys showed that snapping the stalks below ground was a common problem with 17% of the stalks affected, it was unclear if snapping would interfere with ratooning.

Objective 2 - Investigate the effect on ratoon regrowth of underground breakage, shattering and other forms of stool damage.
Objective 3- Investigate the interaction between various forms of stool damage and infection by red rot and pineapple disease, and their effect on ratooning.

Basecutter simulation trials showed that splitting the stubble stalk significantly reduced ratoon shoot numbers by about 40%. However, this was an indirect effect because the split facilitated infection of the stalk by disease. It was the level of disease in the stubble that was found to inhibit ratooning. It was also found that infection of stubble stalks can occur in the absence of damage, but this was generally a lower level of infection. Therefore, stalks snapped below ground level can be infected by fungal disease, but the level of infection and effect on ratooning would be expected to be less than in a stalk that had a deep split. The types of fungi infecting the stubble were classified as indeterminate rots. Pineapple disease was not isolated from any stalks with natural infection, but only from stalks that had been inoculated with that fungus. Inoculations with red rot were unsuccessful.

Trials to determine the degree of stalk damage required to influence ratooning were inconclusive. This was because the results were influenced to a greater extent by external variables like high rainfall and suckers. These types of factors can override the effects of damage and disease on ratooning. The data do suggest that it is probably the depth rather than the type of damage that is important. The data also suggested that a stalk needs to be split for about 50% of its length to have any appreciable effect on ratooning.

Objective 4 - Determine the implications for harvester design and operation, cultural practices and further research into ratooning.

Harvesting trials identified harvesting and cultural practices contributing to stubble damage. It was found that harvesting lodged cane on a face rather than one way in the direction of lodging increased stubble damage. There is a simple remedy to this problem, which is not adopted in many instances because of the increase in operating cost and time. Damage increased at low harvesting speeds (3.8 km/h), but results were variable at higher speeds (7.9 km/h), when compared with the damage level at 6 km/h. This latter speed is considered too slow for large harvesting contracts, except in high yielding crops, and this aspect requires further study.

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3.0 METHODOLOGY

3.1 Basecutter-damage surveys

It was originally proposed that ratooning problems be surveyed to determine if these were associated with basecutter damage during harvest. This was abandoned following a review of the project. This was modified to conducting surveys during the harvest season in selected mill districts to assess the extent of stubble damage incurred during the harvest process. Additional information was to be obtained, if possible, to attempt to identify causal factors. In addition, case studies into ratoon failures were to be assessed if the opportunity arose.

Surveys assessing the type and severity of damage to the stubble stalks that can be caused during harvest were carried out in the Tully, Burdekin and Mackay districts. The Tully survey was conducted during the 1995 harvest season as time permitted. The Burdekin and Mackay surveys were conducted in 1996 during September and October, respectively.

The severity and type of damage that the harvester basecutter can cause to the stubble were classified by Kroes and Harris (1994) and are shown in Figure 1. Basecutter damage had not been clearly described prior to that study. They described a range of damage, but made no attempt to define acceptability of each damage classification. Our project was concerned about the relationship between stubble damage and ratoon regrowth, so we modified this classification to above- and below-ground damage. The modified classification was based on the assumption that stubble damage above ground had a low probability of affecting ratooning. Therefore, the focus was on below ground damage because this had an increased probability of affecting ratooning. The classification was modified to fit the following categories:

1. No damage. – This was modified to include all minor damage classifications described in Figure 1 with the damage occurring above the soil surface. This included all the following categories: no damage, minor edge, major edge, minor split, and snap above soil surface.
2. Split. – This was defined as a single split in the stalk that only extended beyond the first node below the soil surface; approximate depth 40 mm.
3. Major split. – This was defined as a split that extended beyond at least two nodes below the soil surface; approximate depth > 40 mm.
4. Shatter surface. – This was defined as shattering or fibration of the stalk above the surface that extended beyond the first node below ground as per the split classification. It could contain multiple splits, but required a minimum of one 'split' to be included in this category.
5. Shatter at depth. – This was defined as shattering or fibration of stalk above the surface that extended beyond at least two nodes below the surface as per a major split classification. It could contain multiple major splits but required a minimum of at least one 'major split' to be included in this category.
6. Snap. – This was defined as a stalk snapped below ground although the snapped stalk may still remain *in situ* after harvest although severed from the remainder of the stalk below.

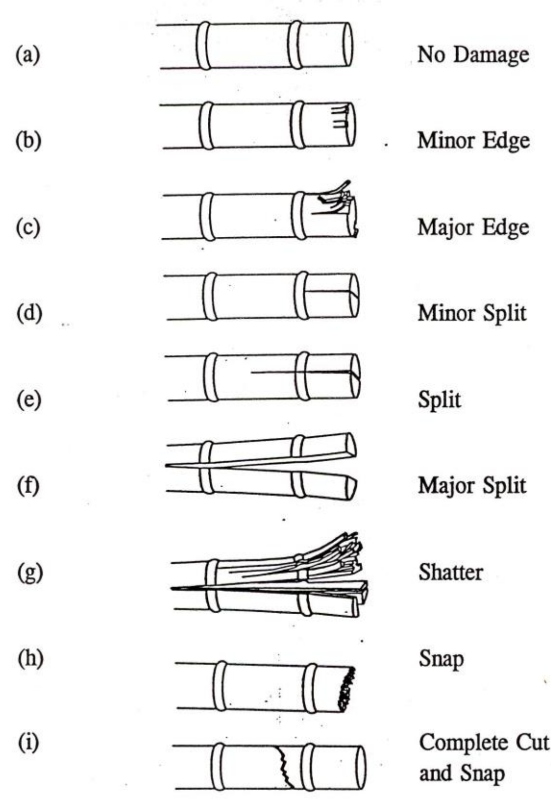


Figure 1 Classification of severity and type of damage to stubble stalks and two modes of failure associated with basecutter effects at harvest (Kroes and Harris 1994)

Assessments of stubble damage were carried out on 2-m sections of row selected at random within a field which was either in the process of being harvested or had been harvested recently. The trash and loose soil was removed from the length of row to be assessed with a plastic rake to avoid any additional damage. A 2-m measuring stick was placed on the row and the number of stubble stalks in each of the six categories listed above counted and recorded. The number of stalks in each category was expressed as a percentage of the total number of stalks within the 2-m section of row. The data were combined across sites within and between districts and analysed using a one-way analysis of variance. There was a total of 20, 12 and 14 fields surveyed in the Tully, Burdekin and Mackay areas, respectively, with a minimum of four assessments carried out on any individual field. The sites were selected at random, but each survey endeavoured to stratify the district to provide an assessment of harvester damage within the whole district.

In the Tully survey, there was no differentiation between shallow and deep shattered stalks with all observations being included in the one shattered category. Observations suggested this was probably not realistic. Depth of shattering was evaluated on stools excavated from recently harvested plant and first-ratoon Q127 and plant Q138 to determine if some adjustment to the classification system was required. Four stools were excavated from each field. Depths of major splits and snaps were also assessed. These data were used as the basis for including both shallow and deep shattered stalks categories in the Burdekin and Mackay surveys.

Additional information was obtained where possible in the Tully survey on factors that might contribute to or influence the extent and type of basecutter damage. These observations were opportunistic and restricted in number. This included factors such as the influence of harvesting with or against the direction of lodging in lodged crops. The normal harvest system in Tully is to harvest on a face, i.e. harvest adjacent rows from opposite ends of the field. This means that with crops lodged along the direction of the row, one row will be harvested with the direction of lodging, which results in the base of the stalk being the first section feeding into the harvester. However, the adjacent row will be harvested against the direction of lodging, and this means the top of the stalk is the first section feeding into the harvester. Stalk damage was assessed on adjacent rows with a minimum of four 2-m paired observations being undertaken at each of the three fields assessed.

A case study of poor ratooning was evaluated in a field of Q130 in the Tully district. Rows one and two of a field had ratooned very well compared with poor ratoon regrowth in the remainder of the field. Stalk damage and ratoon shoot numbers were assessed at three random transects across each of the paired rows 1-2, 4-5, 11-12, and 19-20; this provided three observations per row or six observations from each of the paired rows. Stalk damage and shoot number evaluations were carried out on 2-m sections within each row. Assessment was carried out 4 months after harvest.

Soil samples were also collected from each of the fields in the Tully, Ayr and Mackay districts that were surveyed for harvester damage. These samples were assayed for the presence of the pineapple disease fungus (*Ceratocystis paradoxa*), a major disease affecting germination of sugarcane stalks in plant crops. The soil was evaluated for the presence of pineapple disease by using a baiting technique. Cane setts were split longitudinally and placed in contact with the soil in a plastic bag and placed in an incubator. Infected tissued was plated onto PDA medium and cultured in an incubator for 10 days. The plates were assessed at the end of this period for the presence of pineapple disease.

3.2 Simulating stubble damage and disease effects on ratooning

This part of the research focussed on two main aspects of basecutter damage to ratoon stalk stubble. The first was to determine whether ratoon regrowth was adversely affected by mechanical damage to stubble stalks. The second was to investigate if infection of the stubble by diseases would adversely affect the ratooning process. This would also enable the interaction between stubble damage and stubble disease to be assessed. Two major stalk diseases of sugarcane in Queensland, pineapple disease and red rot, were selected for investigation. Both had also been isolated from poor ratooning fields in Taiwan (Watanabe *et al.* 1974).

Stubble stalks exhibiting basecutter damage usually contain a range of symptoms, which means it is virtually impossible to assess the importance of individual components because of confounding. To overcome this problem, we simulated mechanical damage to enable the effects of different symptoms to be assessed either individually or in combination. This would assist in determining the important issues to address in order to minimise stalk damage during the harvest process.

The initial experiments were kept simple to enable evaluation of the effectiveness of the damage simulation as an experimental technique. We also used the system to evaluate the method being used to inoculate pineapple and red rot disease.

3.2.1 1994 early season stubble-damage-by-disease trials

The first experiment (SPN94-1) was initiated on 21 July 1994 in first-ratoon Q127 in Block 34B on the farm at BSES Tully. This variety was selected because it was considered to exhibit erratic or unreliable ratooning. Two stalk-damage treatments and four disease-management treatments were combined in a factorial design with five replicates set out as a randomised complete block. Plot size was one row by 5 m in length.

The two stalk-damage treatments compared the effect on the ratooning process of an undamaged control with a single major split inserted vertically through the centre of the ratoon stubble stalk. A major split was defined as a split that passes through at least two nodes of the stalk (Kroes and Harris 1994). In these experiments, the objective was for the split to be a minimum of 75 mm in length. The eight treatments were:

1. Nil damage – nil fungicide (D_0F_0); control;
2. Nil damage – fungicide applied (D_0F_1);
3. Nil damage – red rot inoculation (D_0R);
4. Nil damage – pineapple disease inoculation (D_0P);
5. Damage (major split) – nil fungicide (D_1F_0);
6. Damage (major split) - fungicide applied (D_1F_1);
7. Damage (major split) - red rot inoculation (D1R);
8. Damage (major split) - pineapple disease inoculation (D1P).

The plant crop of the Q127 was harvested manually by cutting the stalks at no more than 25 mm from the soil surface with large pruning secateurs. The stalk was split by inserting a banana de-suckering blade vertically through the centreline or diameter of the ratoon stubble stalk. A depth gauge was mounted on the back of the blade to ensure it would not be inserted more than 75 mm into the stalk. This treatment was implemented within 2 h of harvest.

The four disease-management treatments were: untreated control; fungicide; pineapple disease; and red rot disease. The three latter treatments were applied to the cut surface of the stubble as a liquid drench from a watering can.

We applied 5 L of a 0.02% solution of the fungicide Tilt® to each plot of the fungicide treatment, and 3 L of a solution containing a suspension of 100 spores /mL to each pineapple-disease plot. The concentration of red rot was 3 spores/ mL and 2.2 L of solution was applied per plot. These three treatments were applied after 3.00 pm to avoid high temperatures and excessive drying out. In addition, the disease-treated stubble was covered for 24 h with paper towel after excess moisture had drained off the stubble to reduce the impact of temperature and radiation on spore viability.

An isolate of pineapple disease was obtained by baiting soil from BSES Tully with cane setts. This isolate were used to inoculate PDA medium, cultured for 10 d, and then harvested. The mycelium and spores were scraped off the petri dish and filtered through a 2-mm filter. The spore concentration was measured to enable preparation of spore suspensions containing 100 spores/ mL.

An isolate of red rot was cultured from a red mid-rib lesion in leaf tissue collected at BSES Tully. Cultures of this isolate were inoculated and prepared as per pineapple disease. The spores of both diseases were harvested on the day the trial was established.

The number of harvested stubble stalks per plot was recorded. Ratooning or ratoon regrowth was monitored by counting the number of ratoon shoots per plot on five occasions at 49, 60, 78, 88 and 116 d after treatment (DAT). Ratooning was compared on the ratio of number of ratoon shoots per harvested stubble stalk. The assessment of numbers of ratoon shoots was terminated when we considered that tillering had commenced.

Two stools were excavated from each plot 40 DAT and washed to remove all the soil from around the stubble stalks. The number of harvested stalks removed in these stools was recorded and used to adjust the number of stubble stalks per plot for any subsequent assessments of ratoon shoot numbers. The level of the soil surface was marked on each stool before excavation. This enabled both depth or length of the stubble stalk and split length to be measured relative to the soil surface. The length of split was also calculated as a percentage of the stubble stalk length.

Disease incidence and severity were assessed on each stalk of the excavated stools. This disease rating was carried out on the internode tissue about 10-20 mm below the first subsurface node, as this provided a consistent point of reference. Disease incidence was rated on a 1-3 scale, where 1 = healthy moist white tissue, 1.5 = dry yellow tissue, 2 = water-soaked, yellow tissue, and 3 = red to black tissue. Disease severity was rated on a

0-5 scale, where 0 = healthy and 5 = 100% of the internode surface affected. A disease rating for each stalk was calculated as:

Disease rating = disease incidence x disease severity;
with values ranging from 0 = healthy to 15 = badly diseased.

The number of buds per stalk was also recorded, as was the number of diseased buds with a diseases severity rating > 1 that enabled the proportion (%) of diseased buds per stalk to be calculated. The stool was divided into an upper and lower half based on the overall depth of the stool below the soil surface. These bud assessments were subdivided on this basis, as well as being evaluated on a whole-stubble-stalk basis.

Tissue samples were collected from the excavated stubble of each treatment for pathogen isolation. Damaged tissue excised from the stalks was placed on a PDA plate to isolate any organisms from these tissues. There were two plates per replicate and three pieces of tissue per plate. This was to determine what natural disease infection was occurring in the stalks and if inoculation with pineapple and red rot diseases had been successful.

We assessed bud morphology according to the following categories: pre-harvest shoots or suckers (PHS), emerged (EM), swollen (SW), sprouted (SPR), dormant (DOR), and dead or damaged (Dead) buds. The number of buds in each category was recorded and expressed as a percentage of the total number of buds per stubble stalk. This bud evaluation was also partitioned into upper and lower sections of the stool.

3.2.2 1994 late-season stubble-damage-by-disease trials

A second trial (SPN94-4) was established on 28 October 1994 in first-ratoon Q127 adjacent to the July trial site in Block 34B on BSES Tully. This was established to evaluate the same eight treatments under different environmental conditions. Experimental design, plot size and details were the same as the early season trial except for the following variations.

The same isolate of pineapple disease, which had been stored in cane setts, was used. The concentration was reduced to 90 spores /mL, but the suspension was still applied at 3 L per plot. A new isolate of red rot from reddened stalk tissue collected on Tully Experiment Station was used in this trial. We applied 3 L of a spore suspension containing 3 spores /mL to each plot.

The number of harvested stubble stalks per plot was recorded. Suckers started to emerge within 1 day of harvest in this experiment. The number of suckers or pre-harvest shoots (PHS) per plot was recorded 3 DAT and all future shoot counts were adjusted downwards to allow for the presence of these suckers in the shoot counts.

Numbers of ratoon shoots were recorded at 7, 13, 21, 42, and 66 DAT. Ratooning was again evaluated as the ratio of ratoon shoots per harvested stubble stalks.

Two stools were excavated from each plot 28 DAT. Disease evaluation and bud morphological assessments were conducted on these stools as in the July trial. In the stalk disease evaluation, the additional measurements of depth to the first node below the soil surface and the length of the stalk that was diseased were also recorded.

3.2.3 1995 stubble-damage-by-disease trials

Further trials were initiated to confirm the damage and disease results obtained in 1994. Two experiments were established in second-ratoon stubble in Block 34B at BSES Tully. The first trial was on Q127 (SPN95-2) and the second on Q138 (SPN95-3). A randomised complete-block design with five replicates and plot size of one row by 5 m was utilised in both experiments. Treatments were:

- Control;
- Fungicide applied;
- Pineapple disease inoculation;
- Shallow split (35 mm);
- Intermediate split (75 mm);
- Deep split (100 mm);
- Multiple split(75 mm);
- Deep split plus fungicide;
- Deep split plus pineapple disease inoculation.

These were similar to those used in the 1994 trials (Section 3.2.1), except the range of damage treatments were increased and red rot was omitted. The first-ratoon crop of each variety was harvested manually with a cane knife on 24 July 1995, and damage, fungicide and pineapple disease treatments were implemented on 25 July 1995. The method used to impose the damage treatments was as outlined for SPN94-1 in Section 3.2.1. The multiple-split treatment consisted of inserting two splits at right angles to each other vertically into the stalk to the desired depths. Fungicide and pineapple disease rates and application methods were as in trial SPN94-4 (Section 3.2.2).

The number of harvested stubble stalks per plot was recorded. Suckers were present at harvest in these experiments. The number of suckers per plot was recorded 3 DAT and all future shoot counts were adjusted downwards to allow for the presence of these suckers in the shoot counts. Numbers of ratoon shoots were recorded at 6, 13, 20, 27, 34, 48, 55 and 83 DAT. Ratooning was again evaluated as the ratio of ratoon shoots per harvested stubble stalks. Monitoring of populations of ratoon shoots was terminated when tillering commenced.

One stool per treatment was excavated 79 DAT from each treatment in both trials for evaluation. Measurements included length of the stubble stalk and split and disease rating and length of stalk diseased. The incidence of disease was rated on the internode tissue immediately below the root primordia band on each node of the stubble stalk. Disease rating was modified in these experiments, with disease incidence being rated on a 0-10 scale; with 0 being no disease present and 10 being 100% diseased. The individual ratings were summed over the stalk to give a total disease rating per stalk with the average stalk rating being determined for each stool. The length of diseased stalk was measured from the soil surface to the first node with zero disease rating.

3.2.4 1996 stubble-damage-by-disease trials

Two experiments were established in first-ratoon stubble in Block 3A at BSES Tully. The first trial was on Q127 (SPN96-1) and the second on Q138 (SPN96-2). A randomised complete-block design with five replicates and plot size of one row by 5 m was utilised in both experiments. Treatments were:

- Control;
- Shallow split (35 mm);
- Intermediate split (75 mm); deep split (115 mm);
- Multiple split (75 mm);
- Shatter; shatter plus intermediate split;
- Edge split (75 mm);
- Pineapple disease inoculation;
- Shatter plus pineapple disease.

The plant crop of each variety was harvested manually with secateurs on 2 July 1996, and damage and pineapple disease treatments were implemented on 3 July 1996. The method employed to impose the damage treatments has been outlined previously, except for the shatter treatment. The method used to achieve the shatter treatment was to cut the stalk vertically with a cane knife on a 2 x 2 grid. This effectively cut the stalk into nine sections. The objective for the shattering depth was approximately 25 mm below the soil surface.

The number of harvested stubble stalks and suckers per plot was recorded 7 DAT. Suckers were present at harvest in these experiments. Numbers of ratoon shoots were recorded at 14, 21, 36, 47, 58, 65, 75 and 112 DAT and evaluated as in the 1994 and 1995 trials. One stool per replicate was excavated from the control, shallow-, intermediate-, deep- and multiple-split treatments in each trial. Stalk and split lengths were recorded.

3.3 Simulating the degree of stubble damage to affect ratooning

The initial experiment in early 1994 was conducted to establish the methodology for basecutter damage simulation. These preliminary results indicated that major or deep splits in the stubble stalk adversely affected ratooning. Further experiments were undertaken to establish the type or extent of damage that was required to have an adverse effect on ratoon regrowth. These trials are detailed in the following sections.

3.3.1 1994 stubble-damage simulation trials

An experiment (SPN94-2) was established in Q138 first-ratoon stubble in Block 34B at BSES Tully. A second experiment (SPN94-3) was established in first-ratoon stubble of Q127 on the Hewitt farm in the Tully mill area. This latter site was about 0.5 km from the SPN94-2 trial. Each trial included the same five stalk-damage treatments set out in a randomised complete-block design with four replicates. Plot size was one row by 5 m in length. The five stalk-damage treatments were:

1. No damage;

2. No damage but stalk bent to an angle of 60^{o} before cutting;
3. Stalk split to 35 mm below the soil surface (shallow split);
4. Stalk split to 75 mm below the soil surface (intermediate split);
5. Stalk split to 115 mm below the soil surface (deep split).

Treatment two was included to simulate and determine the effect of harvester knockdown angle on damage to the stalk as it was cut, as well as its effect on ratooning. No extra damage was inflicted on this treatment.

Both experiments were established on 6 September 1994. Q138 andQ127 plant cane was harvested manually by cutting the stalks at no more than 25 mm from the soil surface with large pruning secateurs. The split-damage treatments were implemented within 2 h of harvest using the method described for SPN94-1. A depth gauge mounted on the back of the de-suckering blade was used to attain the split lengths of 35, 75 and 115 mm.

The number of harvested stubble stalks per plot was recorded. Suckers or pre-harvest shoots (PHS) tat had emerged were recorded 13 DAT in both trials and the numbers of ratoon shoots assessed at subsequent sampling times were reduced according to the PHS for each plot as detailed previously for SPN94-4. Numbers of ratoon shoots were recorded in both trials at 31, 45 and 71 DAT. Ratooning was again evaluated as the ratio of ratoon shoots per harvested stubble stalks.

Two stools were excavated from each plot 50 and 56 DAT in the Q138 and Q127 trials respectively. Numbers of stubble stalks were adjusted for each plot to take into account the loss of these stalks. Disease-evaluation and bud-morphological assessments were conducted on these stools using the methodology described for experiment SPN94-1.

3.3.2 1995 stubble-damage simulation trials

An experiment (SPN95-4) was established in Q127 second-ratoon stubble in Block 34B at BSES Tully. The trial included six stalk-damage treatments set out in a randomised complete-block design with five replicates. Plot size was one row by 5 m in length. The five stalk damage treatments were:

1. No damage;
2. Shallow split (35 mm) below the soil surface;
3. Intermediate split (75 mm) below the soil surface;
4. Deep split (115 mm) below the soil surface;
5. Multiple split (75 mm) below the soil surface;
6. Shatter.

The experiment was established on 13 September 1995. Q127 first ratoon was harvested manually with large pruning secateurs. The split-damage treatments were implemented on14 September 1995 using the method described for SPN94-1. The multiple-split treatment was implemented as in the 1995 trials (section 3.2.3). The method used to achieve the shatter treatment was to cut the stalk vertically with a cane knife on a 2 x 2 grid. This effectively cut the stalk into nine sections.

The number of harvested stubble stalks per plot was recorded. Suckers which had emerged were recorded 4 DAT and the numbers of ratoon shoots assessed at subsequent sampling times were reduced according to the PHS for each plot as detailed for SPN94-4. Numbers of ratoon shoots were recorded at 13, 19, 25 32 46 and 74 DAT. Ratooning was again evaluated as the ratio of ratoon shoots per harvested stubble stalks.

One stool was excavated from each of two replicates 77 DAT for stalk-damage and disease evaluation. The evaluation methods described in Section 3.2.3 for trials SPN95-2 and 3 were also used for this trial.

3.4 Harvester studies

The basecutter is only one of the components that can contribute to stubble damage. Harvesting and cultural practices, such as harvester speed, basecutter height above the soil surface, worn basecutter blades and row profile, may contribute to the damage problem. A number of harvesting studies were carried out during the course of this project to identify some harvesting and cultural practices contributing to stubble damage.

3.4.1 Harvesting speed and basecutter height

Two trials were established on 28 September 1994 to assess the effect of harvester speed on stubble damage. Discontinued burnt and green variety trials were used for the sites of the trials SPN94-5 and 94-6, respectively. These were in blocks 1A and 2A at BSES Tully and comprised three replicates of the six varieties Q107, Q113, Q117, Q120, Q124 and Q138. Harvester speed objective was 4 and 6 km/h with one row by 10 m being harvested at each speed in every plot. Stalk damage was assessed 26 d after harvest (DAH) on a 1.5 m section in each row. The assessments method was as described for the basecutter surveys in Section 3.1. Numbers of ratoon shoots were counted (one row x 10 m) at 47 DAH.

Two trials were also established in Block 34S at BSES Tully on 27 July 1995 to evaluate the effect of basecutter height and harvester speed on stubble damage. One trial (SPN95-5) was established in Q127 and the second trial (SPN95-6) in Q138 second ratoons. The objective basecutter height settings were 15 and 40 mm above ground level, with three harvester speeds of 4, 6 and 8 km/h. Plot size was one row by 50-60 m in length in a split-plot design with three replicates. Damage assessment was carried out 13 DAH using the method described above. Numbers of ratoon shoots were determined at 8, 15, 25, 32, 46, 53 and 83 DAH on the central 10 m section of row in each plot.

These trials were all harvested with an Austoft 7000 harvester with underslung basecutters. The basecutters were fitted with new blades in both the 1994 and 1995 trials and the trials were harvested in one direction only.

3.4.2 Worn blades and basecutter angle

Several trials were carried out to assess the effect of worn basecutter blades on stubble damage. A trial (SPC96-1) established on A. Gibson's farm in the Racecourse mill area by the Mackay Productivity Services was utilised as part of this program. This trial comprised non-replicated 10-row strips comparing the effects of new and worn blades on stubble damage. The lodged plant crop of Q124 was harvested green on 27 September 1996 with an Austoft 7000 with underslung basecutters. Stalk damage was assessed 5 DAH using the method described above. Shoot counts were carried out on eight 10-m sections of row in each strip 38, 66 and 101 DAH.

A replicated strip trial was established on A. Comos' farm in the Pioneer mill area at Ayr (SPA96-1). Second-ratoon Q96 was harvested on 24 September 1996 using two Cameco harvesters with basecutters mounted on legs. One harvester was fitted with new blades and the other harvester with worn blades. They were used to harvest alternate rows, with each pair of rows being replicated eight times. Harvester speed was calibrated to ensure they were operating at similar speeds, 7.5 km/h. The crop, which was lodged, was harvested burnt and only in one direction. Stalk damage was assessed at establishment of the trial, ratoon-shoot populations were monitored at 71 and 168 DAH, and cane yield was measured in the third-ratoon crop by weighing 50 m from each row in the same section of the block at harvest on 19 October 1997. A four-replicate trial was also established in a contiguous block of Q117. Damage assessment only was carried out in this trial, as this part of the block was subsequently ploughed out.

A third trial (SPA97-1) in this series was also established in the Pioneer mill are on C. Cacciola's farm on 6 August 1997. Two Cameco harvesters were again used in this trial fitted with new and worn blades as in SPA96-1. These were new machines and the angle of the leg basecutters was adjustable. There were seven replicates of the paired treatments. The lodged, plant Q117 was burnt and harvested in one direction. Harvesting speed was 4.4 and 4.6 km/h for the new and worn treatments respectively. Basecutter inline angle was set at about 14^{o} for both machines, which suited the row height at this site. Stalk damage was assessed at establishment using two 1.5-m subsamples per treatment. Ratoon shoot were counted out 43 and 258 DAH.

3.4.3 Manual verus mechanical harvest

A trial was established in Blocks 4A and 5A at BSES Tully during the period 7-10 July 1995 to compare the effects of manual with mechanical harvesting. The trial was a split-plot design with five replicates that had been planted for this purpose the previous year. Two varieties, Q127 and Q138, were the whole-plot treatments, with three harvesting treatments as the split plots. The three harvesting treatments were manual harvest, mechanical harvest with low basecutter setting, and mechanical harvest with high basecutter setting. The low basecutter height setting was intended to be at ground level and the high setting 40-50 mm above the ground. Plot size was four rows by 10 m and 35 m for the manual harvest and mechanical harvest plots, respectively. The manual harvest was cut with cane knives and the cane removed from the plot. The basecutter was raised when the harvester passed through these plots. New blades were installed on the basecutters and the cane was harvested in one direction with an Austoft 7000 with underslung basecutters.

Stubble damage was assessed 11 DAH on a 1.5-m section in each of the two centre rows of every plot. Stubble height was also measured on 10 random stubble pieces per plot at this time. The number of gaps greater than 0.5 m was assessed 112 DAH and used to calculate the proportion of the row length that had not ratooned in each plot. Ratooning was assessed by counting shoot numbers in 10 m of the two centre rows in each plot on a regular basis until February 1996. They were discontinued in March when lodging commenced. Stalk height was measured in January 1996 (179 DAH) on a random sample of 10 stalks per plot. Plot weights were obtained using the BSES weighing tipper at harvest on the 2 July 1996.

4.0 RESULTS AND DISCUSSION

4.1 Basecutter-damage surveys

4.1.1 Stubble damage

Damage to the stubble during harvest was surveyed in the Tully, Burdekin and Mackay districts. We considered that these districts provided a diverse range of crop sizes and harvesting conditions. Therefore, these surveys should have provided a realistic assessment of the type and degree of stubble damage that occur during the harvest process. This would also provide a clearer indication of the significance of stubble damage during harvest in the farming system. The focus in these surveys was on damage to the stalk that occurred below ground level, as this had a higher probability of adversely affecting ratooning. We assumed that damage to the stalk below ground could damage the buds from which the ratoon shoots develop. It could also facilitate infection by soil-borne diseases that might interfere with the ratooning process. By comparison, damage above ground would affect few buds and stalk infection would be slower and would be impeded to some degree at the first undamaged node below ground level.

The results from the basecutter damage surveys for the individual districts and the combined analysis across districts are shown in Table 1. These results showed there were significant differences among damage categories within particular districts. The proportion of stalks within different categories were fairly similar for the Burdekin and Mackay districts, but the level of damage in these districts was higher than recorded at Tully (Table 1). These differences appeared to be primarily associated with the split and shatter categories. The reasons for this are not clear, but we suggest that it may be associated with interpretation of the classification system. The system was still being developed when the Tully survey was carried out, which may have influenced results. In addition, the Burdekin and Mackay surveys were carried out by a different person to the one who conducted the Tully survey and the differences may result from interpretations associated with the depth of damage.

Irrespective of these differences, the results do indicate there may be cause for concern because of the extent of damage to the stubble as a result of the harvesting process. The results from the combined analysis across districts indicate that approximately 66% of the stubble stalks suffered some form of damage during harvest. This varied between districts ranging from 60% for Tully to 75 and 74% for the Burdekin and Mackay districts, respectively (Table 1).

Table 1 Proportion of stalks in different damage categories determined in surveys conducted in the Tully, Burdekin and Mackay districts to assess basecutter damage to the stubble

Damage category	Proportion of stubble stalks (%)			
	Tully	Burdekin	Mackay	Combined
No damage	40	25	26	34
Split	16	9	8	13
Major split	18	19	22	19
Shatter	8	32	30	18
Snap	18	15	14	17
lsd $_{(0.05)}$	3	7	6	3
Probability	< 0.01	< 0.01	< 0.01	< 0.01
Number of samples	170	64	69	303

However, not all the damage is associated with the basecutter. Stalks get snapped during harvest, because of the acute knockdown angle as a result of the basecutter being aligned behind the knockdown roller at the front of the harvester. As a consequence of this, there is less opportunity to actually cut erect stalks because they can be knocked over and snapped before the basecutter reaches the base of the stalk. Although snapping was included in the damage classification, it is unclear if it would have a major impact on ratoon regrowth. Infection of the stubble by disease may be limited because it is generally a clean break. Loss of buds may slow ratoon emergence because the shoots would develop from deeper and therefore emergence would be slower. Ratoon regrowth might be adversely affected if the stalk had been snapped near or at its base. This is more likely to occur if the stubble was located at a shallow depth below the soil surface. Shallow stubble can be a problem with some varieties because of their ratooning habit or where the crop has been planted at a shallow depth with any variety.

It is of some concern that about 37% of the stalks suffered serious damage (major splits and shattered) across the three districts (Table 1). The characteristics of major splits and shattering of stubble stalks are shown in Figure 2a. The stalks affected by a major split have not ratooned in this instance. The shattering and fibration at the top of the stubble together with the red discolouration and drying out of the tissue associated with disease infection of these damaged stalks are shown in Figure 2b. It can be seen how the spread of disease symptoms are restricted by the nodes on a stalk. This suggests that disease infection could be exacerbated with increasing length of splits in the stubble stalks.


(a)


(b)

Figure 2 Characteristics of major splits and shattering damage of stubble stalks during harvest. (a) Shattered and major splits of stalks; stalks with major splits have not ratooned. (b) Red discolouration and drying associated with disease infection of split stubble.

The classification system was still being developed during the Tully survey, with a single shatter category being used in that survey. However, field observations suggested that the damage classification would be improved if the shatter category was subdivided into shallow and deep categories, similar to the split and major split delineation. Measurements on damaged stubble in stools excavated at Tully indicated that the split in shattered stalks could extend to depths of 125 mm below the soil surface (Table 2). These data suggested there was merit in delineating between shallow and deep shattering, with an arbitrary depth of 40 mm being adopted. These data also indicated that the arbitrary depth of 40 mm was also quite acceptable for delineating between splits and major splits, as minimum depths for the latter were slightly in excess of this depth (Table 2). The data also indicated that stalks were not only snapped off near the surface, but could also be snapped at depths of 145 mm below the surface (Table 2).

Table 2 Variation in the depth a split can extend below the soil surface associated with different types of harvester damage to stubble

Variety	Crop class	Damage category	Depth of split below soil surface (mm)	
			Minimum	Maximum
Q127	P	Shatter	20	55
	1R		0	85
Q138	P		25	125
Q127	P	Major split	50	110
	1R		65	130
Q138	P		50	165
Q127	P	Snap	35	140
	1R		65	130
Q138	P		55	145

This modification to the classification system was adopted for the Burdekin and Mackay surveys. Amalgamation of the shallow- and deep-shatter categories for these two districts did allow direct comparison with data from the Tully survey. The depth of a split was difficult to judge, but a number of aids (steel ruler, spatula, automotive feeler gauges) were used to obtain some differentiation between shallow and deep splits in the stalk.

The survey data showed that the proportion of stalks in the stubble showing major splits and shattering damage was more pronounced in the Burdekin and Mackay districts, particularly the former (Table 1). The data from the surveys in these two districts showed that when the stalks were shattered, a higher proportion of the stalks were damaged at depth (Table 3). There were also a high proportion of stalks showing damage to depth as major splits. These would increase the potential for disease infection affecting ratoon regrowth, particularly under adverse growing conditions.

Table 3 Proportion of stalks in different damage categories determined in surveys conducted in the Burdekin and Mackay districts to assess basecutter damage to the stubble

Damage category	Proportion of stubble stalks (%)	
	Burdekin	Mackay
No damage	25	26
Split	9	8
Major split	19	22
Shatter surface	2	11
Shatter deep	30	19
Snap	15	14
lsd $_{(0.05)}$	6	5
Probability	< 0.01	< 0.01
Number of samples	64	69

The type of stubble damage can be influenced by a number of factors or combination of these factors. For example, the major splits appear to be related to basecutter and knockdown angles either individually or in combination (Kroes and Harris 1994). Major splits are also influenced by the combination of partial cuts to the stalk, knockdown angle and the forward speed of the harvester (Kroes and Harris 1996). Shattering appears to be influenced by harvester speed and also the combination of harvester forward speed and basecutter speed. Unfortunately, many of these variables are continually changing and, therefore, it becomes difficult to ‘optimise’ operating conditions to achieve an acceptable level of basecutter damage. It is also quite probable that many harvester operators are not aware of the influence of these factors or variables on stubble damage.

4.1.2 Stubble-damage case studies

Damage to the stubble at harvest can be influenced by crop condition. For example, factors such as lodging or, more appropriately, the methods used when harvesting lodged crops can influence the extent and type of damage to the stubble. The level of damage was examined in three case studies during the Tully survey. The normal harvest system in Tully is to harvest on a face, i.e. harvest adjacent rows from opposite ends of the field. This means that, with crops lodged along the direction of the row, one row will be harvested with the direction of lodging, which results in the base of the stalk being the first section feeding into the harvester. However, the adjacent row will be harvested against the direction of lodging, and this means the top of the stalk is the first section feeding into the harvester.

Assessment of stubble damage after harvest of lodged crops in three fields in Tully showed that harvesting crops with the direction of lodging along the row resulted in significantly less damaged stubble stalks (52%) than when the crop was harvested against the direction of lodging (18%) (Table 4). The main differences were in the proportion of stalks with major splits and those that had been snapped. The latter is not surprising as the harvester is trying to drag the stalk into the feed train for its full length before the basecutter reaches its base. This is likely to cause some stress failure.

Table 4 Influence of direction of harvesting crops lodged along the row on the proportion of stubble damage over three case study sites[1] in the Tully district

Damage category	Proportion of damaged stubble stalks (%)			
	Harvest with lodging	Harvest against lodging	lsd (0.05)	Probability
No damage	52	18	13	<0.01
Split	19	18	ns[2]	0.74
Major split	11	24	12	0.03
Shatter	6	7	ns	0.66
Snap	12	33	15	<0.01

[1]Number of samples = 28; [2]ns = not significant.

The damage incurred during this type of harvest in lodged crops can result in variable ratooning (Figure 3). This compares two rows of good ratoon growth with a row of poor ratoons at one of the sites, which correspond to harvesting with and against the direction of lodging, respectively. Harvesting against the direction of lodging has adversely affected ratoon regrowth. This type of result could be avoided by harvesting the entire crop with the direction of lodging. However, this strategy is not favoured by harvest contractors because of the extra time and travel required to harvest a field.

Figure 3 **Poor ratoon regrowth in centre row because of harvesting against the direction of lodging. Good ratooning in rows either side that were harvested with the direction of lodging.**

Figure 4 **Variable ratooning associated with basecutter damage. Good ratooning in rows 1 and 2 on edge of field associated with high incidence of suckers**

Variable ratoon regrowth in a field of Q130 harvested 4 months earlier was also evaluated in the Tully district. Ratooning was quite poor and variable in the majority of the field except for the first two rows (rows 1 and 2) on the eastern side of the field (Figure 4). Inspection of the ratoons and stubble stalks suggested that these two rows would have had a relatively high sucker population prior to harvest. This was confirmed in discussion with the grower. The crop was erect at harvest, which is a characteristic of this variety.

Damage evaluation of the stubble showed that there was less damage to the stubble in the two rows (1 and 2) that had a higher incidence of suckers than the rest of the field (Table 5). The higher level of stubble damage in the rest of the field was primarily the result of a 15% increase in the occurrence of major splits. This increased level of damage was reflected in a reduction in the number of ratoon shoots that had emerged (Table 5). This difference in ratooning was quite apparent in the ratoon growth illustrated in Figure 4. The type of damage which occurred at this site is illustrated in Figure 2, which was from samples excavated at this site.

Table 5 Influence of suckers on stubble damage during harvest and on ratoon shoot numbers in a Tully harvester damage case study

Character	**Proportion of stubble stalks (%)**		
	Suckers[1]	**No suckers[2]**	**Probability[3]**
No damage	28	17	0.10
Split	15	12	0.28
Major split	18	33	0.06
Shatter surface	14	11	0.46
Shatter deep	14	15	0.28
Snap	12	13	0.96
Ratoon shoots per meter	14.5	8.4	0.07

[1]Evaluation on rows 1 and 2.
[2]Evaluation on rows4-5, 11-12, and 19-20.
[3]Probability values attached to effect of suckers in the one-way ANOVA of stalk damage and ratoon shoots.

While the data are not conclusive, they do confirm other anecdotal observations. It also highlights a potential problem. The current selection policy against suckering in the crop-improvement program could lead to ratooning problem, unless major stalk damage at harvest can be minimised. These observations also indicate that the presence of suckers should always be taken into account when assessing factors influencing ratooning as they may mask damage symptoms.

4.1.3 Pineapple-disease assessment

Soil samples collected from fields included in the basecutter damage surveys were assayed for the presence of pineapple disease. Infection of cane setts by pineapple disease in plant crops is a common problem and can have an adverse effect on germination of the setts. This raised the question of whether this fungus might also have an adverse effect on ratoon germination if it gained access and infected the stubble tissue. Therefore, this survey would indicate the distribution of pineapple disease in soils within different districts. It would also indicate its potential to be a contributing factor to ratoon regrowth problems.

The results from the assays of soils from survey fields showed that the pineapple disease fungus was present at all sites. The assay was only intended to indicate the presence or absence of the fungus. This indicated that pineapple disease did have the potential to infect ratoon stubble on any of these soils and influence the ratooning process. However, it should be noted that pineapple-disease symptoms were not observed in any assessments of ratooning problem carried out during the surveys. The symptoms noted were the red discolouration of the tissue indicated in Figure 2. While tissue infected with pineapple disease can also show red discolouration, it also has a pineapple odour and is black in latter stages. These were not noted in the ratoon survey fields.

4.1.4 Summary

Surveys in harvested fields clearly indicated that ratoon stubble was being damaged during the harvest process. They also indicated that there was a range of damage that was incurred and the problem was common across districts. Assessments carried out on case studies as part of the surveys suggested that this damage may have been contributing to ratoon regrowth problems, because of inappropriate harvesting methods. However, they did not indicate what degree of damage was required to adversely affect the ratooning process.

The results showed that pineapple disease was common to all soils surveyed. This suggested that infection of the damaged stubble by this fungus had the potential to be a contributing factor to ratoon regrowth problems.

4.2 Simulating stubble damage and disease effects on ratooning

Field observations of stubble stalks after harvest had indicated that stalk splitting was a common type of damage. In addition, many of these split stalks had a discoloured or unhealthy appearance as though they were infected by disease. Experiments conducted in July and October 1994 examined the effect of simulated major stalk splitting, both singularly and in combination with stubble disease (pineapple and red rot diseases), in replicated microplot field trials. The experiments were repeated within the one year to assess treatment effects under different environmental conditions.

4.2.1 1994 stubble-damage-by-disease trials

4.2.1.1 Effect of stubble damage on ratooning

Simulated basecutter damage was applied to stubble of the slow-ratooning variety Q127. The stalks had been harvested manually with secateurs to try to minimise any damage to the stubble stalks. The simulation methodology was employed to enable single damage factors to be studied, although simple or single forms of damage are normally not encountered in mechanically harvested fields. Major (or deep) splits were selected for evaluation because they represented damage to a significant length of a stubble stalk. A major split was defined as a split that extended past a minimum of two nodes (Kroes and Harris 1994). However, maximum length was not defined as this could potentially extend for the total length of the stubble stalk. A minimum split length of 75 mm was set as the target in these experiments.

Ratoon regrowth was expressed as the ratio of the number of ratoon shoots per harvested stubble stalk, because it was considered this system related ratooning to the actual number of harvested stalks. This also enabled adjustments to be made realistically and accurately when stools were excavated for examination. Ratoon shoot population monitoring was terminated when tillering commenced, as we considered that the role of the stubble stalk as a primary influence on the ratooning process was probably finalised at that stage of the growth phase. These experiments were designed to determine what effect altering the condition or state of the stubble stalks had on ratooning.

Ratooning was slow in the July experiment (SPN94-1) and shoot counts were not commenced until 49 DAT. There was no evidence of suckers (pre-harvest shoots). Results from the July experiment clearly indicated that ratoon regrowth in the Q127 first-ratoon crop was inhibited by a major split in the stubble stalks (Figure 5, Table 6). The effect of this split was to significantly reduce ratoon-shoot numbers at all five assessment times from 49 to 116 DAT, when assessments were terminated. These results showed that ratooning was adversely affected due to the presence of major splits in the stubble, with ratoon shoot numbers being reduced, on average, by 37%. The reduction in ratoon-shoot population was consistent throughout the assessment period, ranging from 35 to 40%.

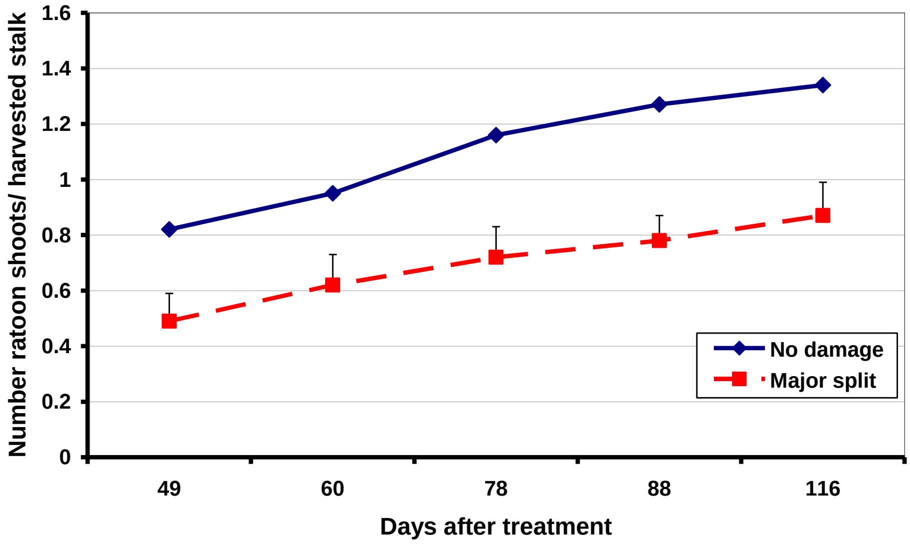


Figure 5 **Effect of a major split in stubble stalks on ratoon regrowth in Q127 harvested in July 1994 in basecutter-damage simulation trial SPN94-1. LSD$_{(0.05)}$ bars shown where applicable**

Table 6 **Effect of stalk damage and disease inoculation of stubble stalks on ratoon shoot emergence in Q127 harvested in July 1994 in basecutter-damage simulation trial SPN94-1**

Treatment	**Number of ratoon shoots per stubble stalk**				
	49 DAT[1]	**60 DAT**	**78 DAT**	**88 DAT**	**116 DAT**
Damage					
Nil	0.82	0.95	1.16	1.27	1.34
Major split	0.49	0.62	0.72	0.78	0.87
lsd $_{(0.05)}$	0.10	0.11	0.11	0.09	0.12
Probability	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Disease					
Nil	0.72	0.88	1.02	1.09	1.17
Fungicide	0.70	0.82	0.94	1.05	1.13
Red rot	0.67	0.83	1.01	1.07	1.11
Pineapple	0.54	0.64	0.79	0.89	1.03
lsd $_{(0.05)}$	ns	0.16	0.15	0.13	ns
Probability	0.07	0.03	0.01	0.02	0.47

[1] Days after treatments implemented on 21 July 1994 (SPN94-1).

Suckers started to emerge within 1 d of harvest in the October experiment (SPN94-4). The number of suckers per plot was recorded 3 d after treatment and all future shoot counts were adjusted downwards to allow for the presence of these suckers in the shoot counts. This was considered an acceptable strategy as the presence of the suckers and their speed of emergence was not considered to have any relationship to the experimental treatments.

Ratoon regrowth was assessed on five occasions between 7 and 66 DAT. Ratooning was quite rapid in the October experiment, with a rapid increase in ratoon shoot emergence from 21 DAT (Figure 6). However, shoot numbers were significantly higher in the undamaged stubble on four of the five assessment dates (Table 7). Results indicated that splits in stubble stalks inhibited ratoon regrowth by an average of 35% over this 66-d period. Although the damaged stalks have ratooned quite well, the data in Figure 6 suggest that, because of the slower shoot emergence from the damaged stalks, the difference between damaged and split ratoon shoot populations actually increased over the assessment period.

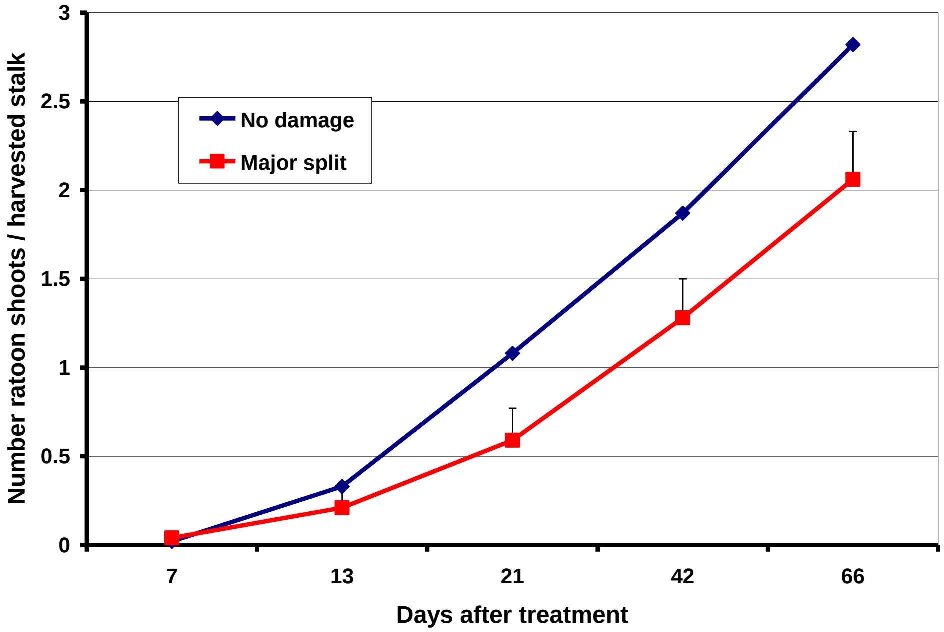


Figure 6 **Effect of a major split in stubble stalks on ratoon regrowth in Q127 harvested in October 1994 in basecutter-damage simulation trial SPN94-4. LSD$_{(0.05)}$ bars shown where applicable**

Table 7 **Effect of stalk damage and disease inoculation of stubble stalks on ratoon-shoot emergence in Q127 harvested in October 1994 in basecutter damage simulation trial SPN94-4**

Treatment	Number of ratoon shoots per stubble stalk				
	7 DAT[1]	**13 DAT**	**21 DAT**	**42 DAT**	**66 DAT**
Damage					
Nil	0.02	0.33	1.08	1.87	2.82
Major split	0.04	0.21	0.59	1.28	2.06
lsd $_{(0.05)}$	ns	0.10	0.18	0.22	0.27
Probability	0.20	0.02	<0.01	<0.01	<0.01
Disease					
Nil	0.01	0.27	0.83	1.66	2.46
Fungicide	0.02	0.22	0.82	1.52	2.51
Red rot	0.05	0.35	0.97	1.70	2.52
Pineapple	0.03	0.22	0.71	1.41	2.27
lsd $_{(0.05)}$	ns	ns	ns	ns	ns
Probability	0.08	0.21	0.22	0.22	0.52

[1] Days after treatments implemented on 28 October 1994 (SPN94-4).

The influence of the presence of suckers at ratooning on ratoon regrowth was examined using linear regression analysis to assess the relationship between sucker and ratoon shoot numbers on a plot basis. These data showed that the presence of suckers had a negative effect on ratoon shoot emergence (Table 8). While the relationship between the presence of suckers and ratooning was significant, the results indicate that it would not have had a major impact on the results in this trial. Sucker numbers in the trial averaged 0.25 suckers/stubble stalk (i.e. 1 sucker per 4 stubble stalks), which is not considered excessive. However, these results do indicate that suckers may have an impact on the ratooning process which could be very significant with a high incidence of suckers. The presence of suckers would mean that ratooning will occur irrespective of the condition of the stubble stalk. This is consistent with field observation reported earlier.

Table 8 **Linear regression relationship between the presence of suckers[a] and ratoon shoot emergence[b] on three assessment dates in Q127 harvested in October 1994 in basecutter damage simulation trial SPN94-4**

Assessment date (DAT)	b_o[c]	b_1	R^2	Prob[d]
21	1.14	-1.19	0.179	<0.01
42	1.88	-1.30	0.191	<0.01
66	2.81	-1.54	0.171	<0.01

[a] Sucker:stubble stalk ratio per plot.
[b] Ratoon shoot:stubble stalk ratio per plot.
[c] Regression coefficient.
[d] Probability level for significance of the regression.

The average depths of the splits in the stalks were 138 and 105 mm for the July and October experiments, respectively. Since the average stubble stalk length below the surface in the two trials was 210 mm, this means that an average ratoon stalk was split for approximately 66 and 50% of its length in the two experiments, respectively. This was substantially deeper than the minimum of 75 mm originally planned, although this was considered to be satisfactory particularly as it had achieved the desired result. Although the depth of the splitting implement can be controlled, it is not possible to prevent the split extending further down the stalk past the set depth.

The slower ratooning noted in the July experiment is considered to be associated with lower temperatures experienced during the early growth phase. The average monthly minimum and maximum temperature for August and September was 6° and 5° lower, respectively, than that experienced during November and December (Table 9, Figure 7). Differences in rainfall during these periods do not appear to be an issue, although the interaction with lower temperatures during August and September would have resulted in less favourable growing conditions (Table 9, Figure 8).

Table 9 Monthly ambient temperature and rainfall data recorded at BSES Tully for July-December during 1994, 1995 and 1996

Month	Temperature (°C)		Rainfall	
	Min	Max	mm	No. wet days
1994				
July	13.9	23.0	162.4	12
August	13.8	24.0	72.4	13
September	14.2	27.2	45.8	7
October	17.0	30.5	113.8	5
November	19.1	32.0	51.2	6
December	20.3	30.2	160.5	8
1995				
July	12.4	25.5	39.3	9
August	15.6	23.0	236.3	20
September	17.1	28.1	25.9	10
October	18.5	28.0	178.8	15
November	20.5	31.3	101.2	13
December	22.0	34.4	111.0	7
1996				
July	12.7	25.0	106.8	9
August	15.4	25.5	72.0	11
September	13.9	28.8	8.4	2
October	19.9	28.7	280.8	14
November	20.3	31.3	52.7	8
December	22.1	32.5	277.6	10

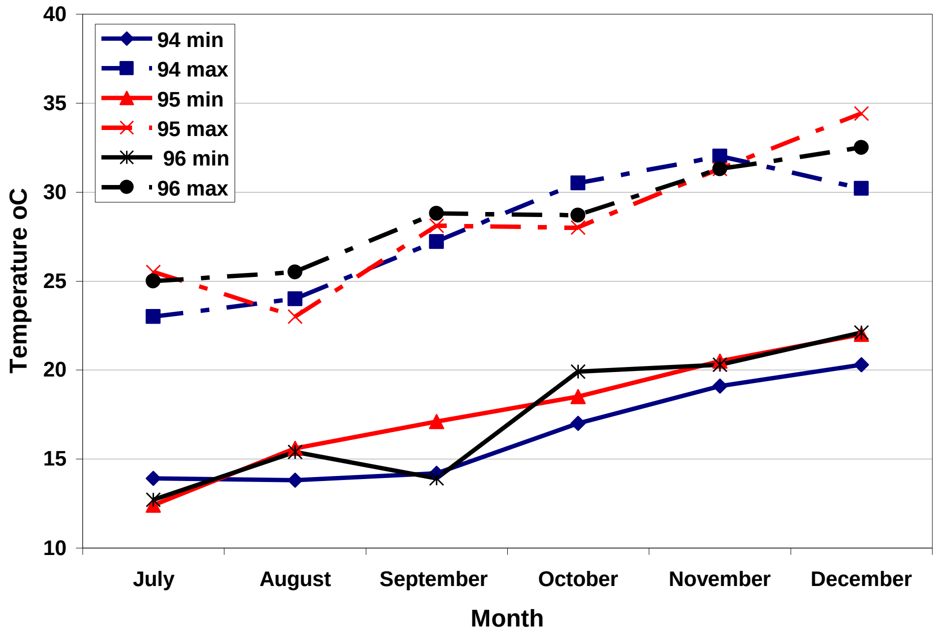


Figure 7 **Monthly minimum and maximum temperatures (°C) during the 1994, 1995 and 1996 ratooning seasons (July-December) at BSES Tully**

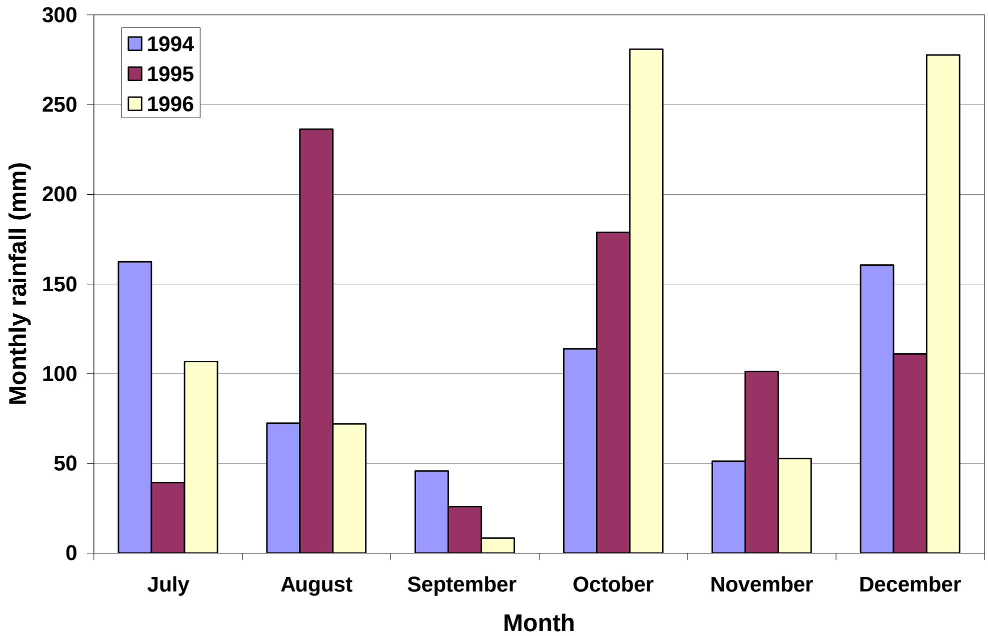


Figure 8 **Monthly rainfalls during the 1994, 1995 and 1996 ratooning seasons (July to December) at BSES Tully**

4.2.1.2 Effect of disease inoculation on ratooning

Pineapple disease was isolated from all inoculated treatments in both experiments, indicating that the inoculating techniques were appropriate. However, it was not isolated from any other treatments, indicating there was no natural infection with pineapple disease.

Inoculation of stalks with pineapple disease significantly reduced the number of ratoon shoots produced by the plant in the trial established in July compared with the other disease treatments (Figure 9, Table 6). This effect occurred in both damaged and undamaged stalks, as there was no significant damage-by-disease interaction. However, this result was only obtained with the slow ratoon development experienced under the low temperatures during July-September (Table 9, Figure 7). Inoculating the stalks with pineapple disease had no additional effect on ratooning under the higher temperatures experienced in the October experiment compared with the other disease treatments (Table 7).

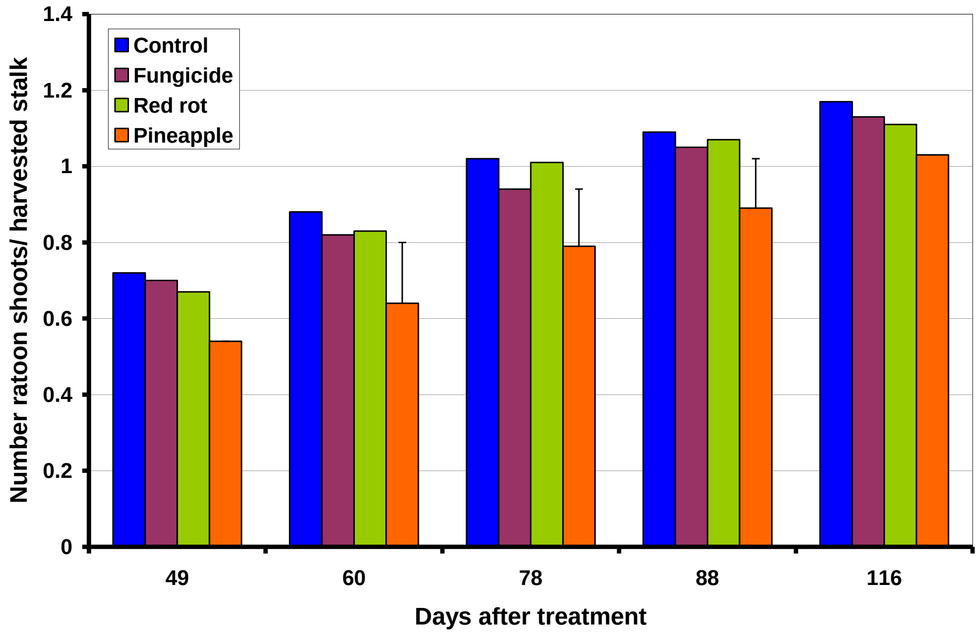


Figure 9 **Effect of inoculating stubble stalks with fungicide and pineapple and red rot diseases on ratooning of Q127 harvested in July in the basecutter-damage simulation trial SPN94-1. LSD$_{(0.05)}$ bars shown where applicable.**

Red rot had no effect on ratooning in either experiment. It was not isolated from any of the treated plots, and it appears inoculation of this disease was unsuccessful. Application of fungicide had no effect on ratooning, although this is not surprising considering the field environment in which it was being used.

4.2.1.3 Disease incidence in stubble

Stalk health was assessed on all stalks in the two stools excavated from each plot in both the early and late season experiments. Each stalk was given a disease incidence rating approximately 20 mm below the first subsurface node according to its appearance from white and healthy to discoloured with an unhealthy or diseased appearance. Diseased in this context did not refer to any particular disease. Measurements in the October experiment indicated that the first node was about 31 mm below the soil surface on average. A standard position was selected to rate stalks to ensure that the system was consistent. In addition, the disease status of each node or bud was assessed to determine the spread of disease within the stalk. We assumed that if the nodes were diseased, this would influence the bud attached to this node.

Damaging the stalks with a major split resulted in a 2.8 times increase in the number and proportion of diseased nodes in the Q127 harvested in July compared with the undamaged stalks (Table 10). Inoculating the stalks with pineapple disease also resulted in a significant increase (1.6 times) in both of these parameters relative to the nil-disease treatment. This result with pineapple disease was independent of stalk damage, as there was no significant damage-by-disease interaction. The disease rating at the first internode was significantly increased as a result of stalk damage or inoculating with pineapple disease (Table 10). Splitting the stalk increased the disease rating by 2.6 times compared with 1.6 times as a result of inoculating the stalk with pineapple disease. However, the level of disease expression in the pineapple-disease treatments was additional to symptoms expressed in the other three disease treatments. Red rot had no additional effect on disease symptoms. This was not surprising as it could not be isolated from tissue samples taken from these stubble stalks. Application of fungicide had no significant effect on disease symptoms, although it may have slightly reduced symptom intensity. The significant feature of these results was that splitting the stalks enhanced disease infection of the stalk.

Table 10 Disease incidence resulting from stalk damage and disease inoculation of stubble stalks of Q127 harvested in July 1994 in the basecutter damage simulation trial SPN94-1

Treatment	Diseased nodes/stalk[1]		Disease rating/stalk
	Number	Proportion (%)	
Damage			
Nil	0.59	8	3.9
Major split	1.66	22	10.2
lsd $_{(0.05)}$	0.42	5	1.7
Probability	< 0.01	< 0.01	< 0.01
Disease			
Nil	1.03	13	6.4
Fungicide	0.79	11	5.1
Red rot	1.01	14	6.2
Pineapple	1.67	22	10.3
lsd $_{(0.05)}$	0.59	7	2.5
Probability	0.03	0.03	< 0.01

[1] Sampled 40 d after treatments implemented on 21 July 1994 (SPN94-1).

Treatments had a similar effect on the incidence of disease symptoms in the experiment established late in the season in October (Table 11). However, the effect from splitting was not quite as marked as in the July trial. Splitting only increased the number and proportion of diseased nodes and also the disease rating by factors ranging from 1.6-1.7 over the undamaged stalks in October compared with 2.6-2.8 in July. However, the additional impact of pineapple disease over the nil-disease treatment was similar in both trials (1.6 compared with 1.5). This could be a reflection on sampling being carried out at an earlier age in the October experiment (28 DAT) compared with the July experiment (40 DAT). Alternatively, it could be related to the fact that growth was more rapid during this period as indicated by the shoot-emergence data (Figure 6). Red rot again had no additional effect because inoculation was unsuccessful. Application of fungicide did not appear to have any benefit in reducing symptom expression.

Table 11 Disease incidence resulting from stalk damage and disease inoculation of stubble stalks of Q127 harvested in October 1994 in the basecutter damage simulation trial SPN94-4

Treatment	Diseased nodes/stalk[1]		Disease rating/stalk
	Number	Proportion (%)	
Damage			
Nil	0.91	11	5.1
Major split	1.50	19	8.9
lsd (0.05)	0.31	4	1.3
Probability	<0.01	<0.01	<0.01
Disease			
Nil	1.08	13	6.1
Fungicide	1.04	12	6.3
Red rot	1.11	13	6.2
Pineapple	1.57	19	9.3
lsd (0.05)	ns	5	1.9
Probability	0.06	0.03	<0.01

[1]Sampled 28 d after treatments implemented on 28 October 1994 (SPN94-4).

Splitting the stalks had a marked effect on ratoon regrowth and disease incidence in these experiments. Therefore, it is possible that differences in split length may have contributed to the different responses observed in the July and October experiments. Analysis of the damage-disease treatments only showed that, while there was some variation in split length between treatments in each trial, these were not significant (Table 12). However, the length of the splits were, on average, 34 mm or 13% longer in the July trial, which may have provided a greater opportunity for infection. The data from the October trial also showed that disease symptoms were not restricted to the length of the split and extended past the end of the split in all treatments by an average of 28 mm. The actual distance on individual stalks varied with the proximity of the end of the split to a node, as nodes tended to slow or prevent the spread of symptoms. This effect was more pronounced in the pineapple-disease treatments, which may have been associated with a greater disease loading, due to the combination of the pineapple disease and natural infection.

Table 12 Stubble stalk and major split details for the four split-by-disease treatments in the July[1] and October[2] 1994 basecutter-damage simulation experiments

Treatment		Depth below soil surface		Proportion of stalk split (%)	Depth disease extends below split (mm)
Damage	Disease	Stalk (mm)	Split (mm)		
July					
Split	Nil	230	142	62	NA[3]
Split	Fungicide	203	128	64	NA
Split	Red rot	220	148	68	NA
Split	Pineapple	208	133	65	NA
Mean		215	138	65	
Probability		0.20	0.17	0.56	
October					
Split	Nil	193	97	50	29
Split	Fungicide	208	103	50	28
Split	Red rot	198	114	58	19
Split	Pineapple	203	104	52	35
Mean		201	104	53	28
Probability		0.37	0.21	0.21	0.56

[1] Trial SPN94-1 established 21 July 1994.
[2] Trial SN94-4 established 28 October 1994.
[3] Not available.

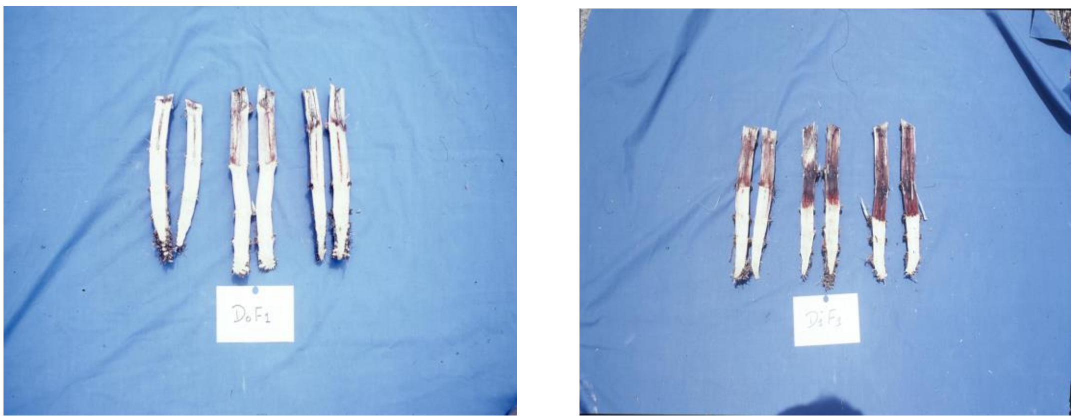
Disease infection occurred in both damaged and undamaged stalks, although the level of infection was much higher in the stalks damaged with major splits. The symptoms for both the undamaged and damaged stalks for the nil-disease, fungicide and red-rot treatments were virtually identical and typified by a dark red discolouration of the stalk tissue. These are illustrated in Figures 10a and 10b, 11a and 11b, and 12a and 12b, respectively. This was the result of natural infection of the stalk tissue by indeterminate rots.

In the undamaged stalks, the fungal infection tended to be restricted by the first node as illustrated in Figures 10a, 11a and 12a. However, as the data indicate, infection did move past this node in some stalks, probably through hollows (or pipes) in the centre of the stalk as shown in Figure 11a. A major split in the stalk enabled the fungus to infect the stalk to a greater depth, as shown in Figures 10b, 11b and 12b. Spread of the fungus was stopped or slowed by the node adjacent to the end of the split, as indicated in these photographs. These fungal rots could not be controlled by the fungicide treatment used in these trials. These symptoms are similar to those observed in the field (Figure 2).

The tissue of stalks inoculated with pineapple disease were also dark red in colour but were also desiccated in appearance (Figures 13a,b). It is quite likely that these had also been subjected to natural infection. The consistency in the results from these two experiments suggests that stalk damage is the precursor but infection by fungal rots is the main inhibitor to ratooning. The extra impact from the pineapple disease inoculation would tend to support this, as it is suggested natural infection also occurred in this treatment. Unfortunately, a definitive answer was not achieved due to the failure of the fungicide treatment to control natural infection.

(a) **(b)**

Figure 10 **Comparison of disease symptoms in the undamaged control treatment (a) with the major split control (b). Infection has stopped at the node in two stalks in 10b**

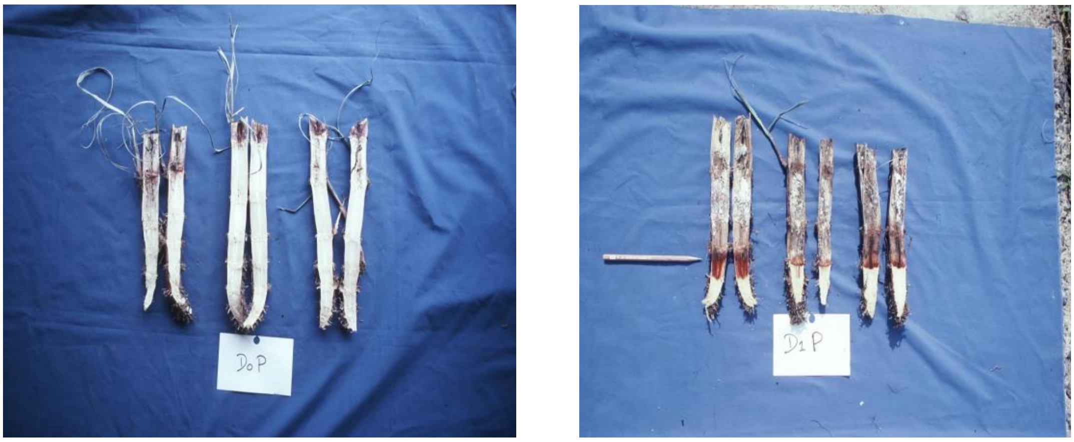


(a) **(b)**

Figure 11 **Comparison of disease symptoms in the fungicide treatments showing infection moving down the hollow centre of the undamaged stalk in (a). However, the intensity of symptoms is not as great as in (b), where the stalk has been split**

(a) (b)

Figure 12 **Comparison of the disease symptoms in the red-rot treatments illustrating the effect of the nodes limiting the spread of infection in both the undamaged (a) and split (b) treatments**



(a) (b)

Figure 13 **Comparison of the pineapple-disease treatments comparing the mild symptoms in the undamaged treatment (a) with the discolouration and severe desiccation of the tissue in the split-stalk treatments (b).**

The data in Tables 10 and 11 do indicate that some disease infection occurs in undamaged stalks (Figures 10b, 11b, 12b 13b). This appears to be slightly more pronounced in the October experiment. This may have been influenced by the rating system including water soaked tissues, which were not actually diseased. The rating system appears to have provided a realistic evaluation of disease infection of the stalks, particularly in relation to symptoms and ratoon regrowth data.

Correlation analyses were carried out to confirm that disease infection and consequently rating was influenced by damaging or splitting the stalk. Selected treatments (no damage/fungicide; pineapple, red rot; damage/pineapple) were omitted from these analyses. The damage/ fungicide and damage/ red rot treatments were included to provide a larger data set, as disease rating for these two treatments was not significantly different to the damage/ control treatment. The results showed that disease rating was significantly and positively correlated ($P < 0.01$), with the length of split in the stalk in both the early ($r = 0.71$) and late ($r = 0.68$) season trials. These results clearly indicate that a major split in stubble stalks was a predisposing factor in infection of the stalks by indeterminate rots in these trials. Disease pressure was exacerbated by inoculation with pineapple disease. The pineapple disease fungus was only isolated from stalks that had been inoculated with this organism. Therefore, there was no natural infection of other treatments by pineapple disease. Similarly, red rot was not isolated from any treatment

The data were examined to determine if there was a link between ratoon regrowth and presence of stubble disease. This was assessed using correlation analyses between the disease parameters (number and proportion of diseased nodes, disease rating per stalk) shown in Tables 10 and 11 and ratoon shoot number per stalk. Although the number and proportion of diseased nodes both showed a strong inverse relationship with ratoon shoot numbers, these relationships were not as strong as the correlation between ratoon shoot numbers per stalk and disease rating per stalk. The data in Table 13 clearly indicate that there is a highly significant negative correlation between disease rating and ratoon shoot emergence at all assessment times in both the July and October trials. This relationship was slightly stronger in the July experiment, possibly because of the slower growth, higher level of disease and greater length of exposure to disease. The strength of the relationship did decrease slightly over time, but this was not unexpected, as only a single disease assessment was carried out. However, the correlation analyses shown in Table 13 confirm that infection of the stalk by indeterminate rots does have an adverse effect on ratooning. These data indicate that at least 80% of the variation in ratoon regrowth can be attributed to the level of disease infection of the stubble stalks. Disease infection was facilitated by damage to the stalk, and it is suggested that the risk will increase as the level of damage to the stalk increases.

Table 13 Correlation values (*r*) for the relationships between number of ratoon shoots per stubble stalk and disease rating per stalk in the first-ratoon crops of basecutter-damage simulation trials established in July and October 1994. Probability values are shown in parentheses

DAT[1]	July[2]	DAT	October[3]
49	-0.95 (0.00)	13	-0.77 (0.02)
60	-0.95 (0.00)	21	-0.91 (0.00)
78	-0.94 (0.00)	42	-0.91 (0.00)
88	-0.95 (0.00)	66	-0.89 (0.00)
116	-0.90 (0.00)		

[1]Days after treatment shoot numbers recorded.
[2]Disease evaluation 40 DAT on 30 August 1994.
[3]Disease evaluation 28 DAT on 25 November 1994.

4.2.1.4 Bud morphology

Bud morphology was assessed on each stalk in the excavated stools, as we expected that this may provide a better understanding of how stalk damage or disease might influence the ratooning process. There was an average of eight buds per stalk in these two trials. This may be an underestimate, as buds at the base of the stubble are very close, lack definition and are, therefore, extremely hard to count. The general distribution and bud characteristics in the July and October trials are presented in Table 14. Approximately 55-60% of the buds were on the lower half of the stalk. It is of interest that, in both trials, the suckers originated from the lower part of the stalks. The number of buds that had produced suckers was consistent with the sucker counts of one sucker per four harvested stalks per plot.

Table 14 Proportion of buds of different characteristics distributed over the whole, upper and lower section of stubble stalks assessed in the July and October 1994 stalk-damage-by-disease inoculation trials

Stalk section	Proportion of buds (%)[1]					
	PHS	EM	SW	SPR	DOR	Dead
July[2]						
Whole stalk	3	6	27	31	26	8
Upper stalk	0	3	10	6	20	7
Lower Stalk	3	3	17	25	6	1
October[3]						
Whole stalk	3	12	11	41	11	23
Upper stalk	0	6	4	11	7	12
Lower stalk	3	6	7	30	4	11

[1]PHS = pre-harvest shoots; EM = emerged shoots; SW = swollen buds; SPR = sprouted buds; DOR = dormant buds; Dead = dead buds.
[2]Assessed 39 DAT; established 21 July 1994 (SPN94-1).
[3]Assessed 28 DAT; established 28 October 1994 (SPN94-4).

Buds at the base of the stalks are compressed and may not be well defined, and total bud numbers may be underestimated. The first three or four buds below the soil surface occupy a higher proportion of the stalk, because of the longer internodes as illustrated in Figures 10-13. Consequently, estimates of number or proportion of diseased buds tend to be relatively low (Tables 10 and 11). This does not clearly indicate the extent or the potential of the damage. Length of split may be a better indicator, as the split length in these trials also tended to be the minimum infection length. Because bud distribution is non-linear, the proportion of the buds at risk probably increases exponentially with longer splits in the stalk. This could be due either to direct infection or indirectly from toxins released by the fungus.

The data on emerged buds were also reasonably consistent with shoot counts. However, the percentage of buds contributing to ratoon regrowth was fairly low during the early ratoon phase, particularly in the July trial. This can only be considered as indicative, as further stool excavation would have been required to determine if later shoot development was the result of bud emergence from the stubble or from the new ratoon shoots. The major difference between the two samples was the higher proportion of sprouted and dead buds in the October sample (Table 14). The higher incidence of dead buds may be a function of improved definition in the October samples. The role of the sprouted buds was not clear, but they did not appear to be contributing to the ratooning process, and we suggest that they may have a possible role as the source of suckers.

Treatment had very little influence on the proportion of buds in each category (Table 15). Damaging the stalk with a major split significantly reduced the number of buds producing shoots that had emerged in both July and the October trials (Tables 15 and 16). This is consistent with the stalk count data in Figures 5 and 6. The proportion of dead buds was also increased from damage in July but not October. It has to be assumed that this resulted from damage to the buds when the stalks were split. The significant effect from diseases on swollen buds in October is difficult to understand (Tables 15 and 16). Since fungicide and red rot had a similar effect to pineapple disease, we suggest that this may be a classification problem rather than a real result.

Table 15 Probability values attached to the main and interaction treatment effects in the ANOVA for proportion of buds per stubble stalk as influenced by stalk damage and disease inoculation in the July and October 1994 trials

Source	**Probabilities**					
	PHS[1]	**EM**	**SW**	**SPR**	**DOR**	**Dead**
July[2]						
Damage	0.93	0.02	0.91	0.22	0.53	0.02
Disease	0.90	0.24	0.88	0.50	0.35	0.54
Damage x disease	0.87	0.59	0.45	0.22	0.87	0.97
October[3]						
Damage	0.10	0.02	0.47	0.07	0.32	0.59
Disease	0.16	0.59	0.03	0.44	0.71	0.98
Damage x disease	0.44	0.30	0.69	0.50	0.39	0.25

[1]PHS = pre-harvest shoots; EM = emerged shoots; SW = swollen buds; SPR = sprouted buds; DOR = dormant buds; Dead = dead buds.
[2]Assessed 39 DAT; established 21 July 1994 (SPN94-1).
[3]Assessed 28 DAT; established 28 October 1994 (SPN94-4).

Table 16 Mean values for significant effects on bud data due to stalk-damage and disease-inoculation treatments in the July and October 1994 trials

Treatment	Proportion of buds (%)		
	Emerged July[1]	Dead July	Emerged October[2]
Damage			
No damage	6.7	6.3	14.1
Major split	4.2	9.8	10.2
lsd $_{(0.05)}$	2.1	2.8	3.4
	Swollen October		
No disease	14.7	-	-
Fungicide	9.2	-	-
Red rot	9.1	-	-
Pineapple	8.4	-	-
lsd $_{(0.05)}$	4.5		

[1]Assessed 39 DAT; established 21 July 1994 (SPN94-1).
[2]Assessed 28 DAT; established 28 October 1994 (SPN94-4).

We had hoped that examination of the bud morphology may have given an insight into ratoon regrowth processes. However, it provided little additional information. The main information emerging from these data is that shallow damage should not result in ratoon failure. There is a major source of buds in the lower or deeper section of the stubble to ensure ratooning will proceed. Ratoon failure from shallow stalk damage would have to be associated with release of toxins by fungal rots.

4.2.2 1995 stubble-damage-by-disease trials

A trial was planted in 1994 on Block 7 at BSES Tully to cater for the 1995 trials. The trial included four replicates of five varieties (Q117, Q124, Q127, Q135 and Q138) of differing ratooning habit. Unfortunately, severe lodging occurred in the 1995 crop and it was not possible to utilise this site. However, there was sufficient erect Q127 and Q138 in Block 34B at BSES Tully to enable two trials, SPN 95-2 and 95-3, to be established and allow the trial program to continue.

The results from the 1995 trials were disappointing. Ratooning was not adversely affected by either stalk damage or inoculation with pineapple disease in both Q127 and Q138 with one exception at 27 DAT for Q127. This is clearly indicated by the non-significant probabilities obtained for treatment effects on ratoon shoots per harvested stalks for both Q127 and Q138 on nearly all assessment dates (Table 17). Although treatments had a significant effect on ratooning 27 DAT in Q127, the results were rather meaningless and tended to suggest that damage was promoting ratooning (Table 18). Similar results were apparent for the results obtained at 20 and 34 DAT with Q127.

Lower probabilities were obtained for the later assessments (48, 55 and 83 DAT) in Q138 (Table17). The results for these three assessment dates suggested a trend to lower ratoon-shoot emergence with the higher level of damage incurred in the deep-split combinations with fungicide and pineapple disease and multiple-split treatments. This is illustrated by the ratooning data for Q138 at 55 DAT (Table 18). Unfortunately, these trends were not significant. However, this may have been due to normal variation, as there was little differentiation between shallow, intermediate and deep splits in their effects on ratooning in this experiment. Inoculation with pineapple disease had no effect on ratooning in either trial.

Table 17 **Probability values attached to the effect of damage, fungicide application and pineapple disease inoculation treatments to stubble in the ANOVA of number of ratoon shoots per stubble stalk in Q127 and Q138 on eight assessment dates in the two trials established in July 1995 at BSES Tully. Site treatment means also included.**

Assessment date (DAT[3])	Number of ratoon shoots per stubble stalk			
	Q127[1]		Q138[2]	
	Probability	Mean	Probability	Mean
7	0.82	0.01	0.29	0.07
13	0.29	0.03	0.35	0.20
20	0.06	0.05	0.52	0.40
27	0.02	0.11	0.50	0.73
34	0.06	0.24	0.37	1.07
48	0.17	0.52	0.11	1.42
55	0.13	0.60	0.08	1.44
83	0.32	0.87	0.12	1.57

[1] Trial SPN 95-2 established 25 July 1995.
[2] Trial SPN 95-3 established 25 July 1995.
[3] Days after treatment.

Table 18 **Selected data showing significant or near-significant effects of damage, fungicide and disease inoculation on ratooning in Q127 and Q138 obtained in trials established at BSES Tully in 1995**

Treatment	Number of ratoon shoots per stubble stalk	
	Q127[1]	Q138[2]
Control	0.04	1.63
Fungicide (F)	0.09	1.56
Pineapple disease (P)	0.11	1.67
Shallow split	0.10	1.52
Intermediate split	0.09	1.55
Deep split (DS)	0.11	1.52
Multiple split	0.11	1.38
DS + F	0.17	1.22
DS + P	0.09	1.06
lsd $_{(0.05)}$	0.08	ns

[1] Assessed 27 DAT in trial SPN 95-2.
[2] Assessed 55 DAT in trial SPN 95-3.

Ratooning was quite slow in these trials, particularly in Q127, where ratoon-shoot emergence was very low until 48 DAT when it had reached 0.52 shoots/ stubble stalk (Table 17). This was slower than the ratooning rate in Q127 in 1994, where shoot numbers had reached 0.72 shoots/ stubble stalk by 49 DAT in the untreated control (Figure 5 Table 6). Ratooning was faster in Q138 than Q127, as shoot emergence had reached 0.73 shoots/ stubble stalk by 27 DAT (Table 17). This illustrates the difference in ratooning rate of these two varieties.

We considered that the slow rate of ratooning in 1995 was not due to lower temperatures. The trials were established in late July, and minimum temperatures in August and September 1995 were above 1994 values (Table 9; Figure 7). However, the average maximum temperature for August was slightly lower in 1995, but this should not have restricted ratooning. However, there was approximately 200 mm more rainfall in August 1995 than in 1994 with the rainfall being distributed over 20 wet days (Table 9; Figure 8). We suggest that this may have had a major influence on ratooning and the results in the 1995 trials.

Because of the failure of treatments to affect ratooning in either 1995 trial, we decided to restrict stool-assessment activities. A single stool was excavated from each treatment to briefly assess the effectiveness of stalk damage treatments and if stalks had any disease symptoms. Bud morphological assessment was not carried out, as it had already been decided to abandon that assessment because it was not contributing to our understanding of the problem. Stubble assessment indicated that there was some differentiation between split lengths and the proportion of the stalk split by the different treatments (Tables 19 and 20). The proportion of the stalk split by the deep-split treatments was generally in excess of 60%, which was as good as the 1994 trials. Therefore, some treatment response might have been expected based on the 1994 data.

Table 19 Summary of stalk damage and disease incidence[1] in Q127 in trial SPN 95-2 established at BSES Tully in July 1995

Treatment	Stalk length (mm)	Split length (mm)	Proportion stalk split (%)	Disease rating/stalk	Proportion stalk diseased (%)
Control	163	0	0	10	50
Fungicide (F)	124	0	0	4	27
Pineapple (P)	124	0	0	11	50
Shallow split	180	78	43	17	63
Intermediate split	106	64	64	23	73
Deep split (DS)	173	118	71	30	82
Multiple split	170	101	60	29	72
DS + F	95	84	88	32	97
DS + P	148	112	78	38	83

[1] Assessed 79 DAT on 12 October 1995.

Table 20 Summary of stalk damage and disease incidence[1] in Q138 in trial SPN 95-3 established at BSES Tully in July 1995

Treatment	**Stalk length (mm)**	**Split length (mm)**	**Proportion stalk split (%)**	**Disease rating/stalk**	**Proportion stalk diseased (%)**
Control	135	0	0	10	32
Fungicide (F)	184	0	0	2	23
Pineapple (P)	178	0	0	13	42
Shallow split	127	58	46	19	69
Intermediate split	153	92	62	13	71
Deep split (DS)	197	130	68	19	86
Multiple split	137	77	58	24	74
DS + F	138	87	67	27	73
DS + P	183	120	69	44	82

[1] Assessed 79 DAT on 12 October 1995.

The method of disease assessment was changed for these trials. All nodes were rated for disease infection on a 0-10 scale, with the ratings being summed for each stalk and an average disease rating calculated for each stool. The length of stalk showing disease symptoms was also measured to enable the proportion of the stalk diseased to be calculated. We considered that this would give a better appreciation of the disease status of the stalk.

The results from both trials clearly suggest that disease infection did occur and appears to have been enhanced by splitting the stalks (Tables 19 and 20). The data even suggest that fungicide may have reduced infection level in the undamaged stalk and that pineapple-disease inoculation may have been successful. However, the proportion of the stalk diseased was surprisingly high for the undamaged controls, particularly in Q127, although disease rating was lower than in split stalks. These assessments are primarily based on the red discolouration of the stalk and, while they do indicate some differences did exist, they are subjective. The rating system and measurement of proportion of stalk affected seemed to work very well and provided a good indication of both disease infection and treatment effects.

The stalk damage and disease assessment data (Tables 19 and 20) do suggest that treatments should have worked and adversely affected ratooning in both these experiments based on experiences with the 1994 trials. Although the damage and disease data were limited, correlation analyses were carried out to determine if ratoon-shoot emergence was influenced by the level of disease in the stalk as indicated by the disease rating. Surprisingly, these analyses showed that ratoon-shoot numbers were significantly correlated with the disease rating in the stalk (Table 21). This effect was more pronounced in Q138, showing a highly significant negative correlation at both 55 and 83 DAT, whereas Q127 was only significant at the 83 DAT assessment. Therefore, disease infection did have a negative influence on ratooning in these trials, although the effect was markedly less apparent than in the 1994 trials. Disease rating was significantly correlated with split length in Q127 (*r* = 0.92; *P* =0.03) but not Q138 (*P* = 0.37). A better result may have been achieved with more stalk assessment data.

Table 21 Correlation values (*r*) for the relationship between number of ratoon shoots per stubble stalk and disease rating per stalk[1] in the second-ratoon crop of a basecutter-damage simulation trial established in July 1995 on Q127 and Q138. Probability values for the relationship are shown in parentheses

DAT[2]	Q127	Q138
55	-0583	-0.908
	(0.09)	(<0.01)
83	-0.709	-0.928
	(0.03)	(<0.01)

[1] Disease evaluation 79 DAT on 25 July 1995 (SPN95-2 &3).
[2] Days after treatment shoot numbers recorded.

The 1995 data are unusual, because treatments did not affect ratooning compared with the control, based on the ANOVA. However, the level of damage has influenced disease incidence which, in turn, influenced ratooning. A major difference in the 1995 data compared with the 1994 data was the higher disease incidence in the control and the variability of the disease data. This probably prevented significant results being obtained in the analysis of variance for treatment effects. However, the results clearly indicate that ratooning was influenced by the incidence of disease in the stalk. We suggest that the continuous rain may have influenced the 1995 results. The spread of the fungus could have been enhanced by the rain in some instances, but its effects (through toxins) diluted or washed out of the stalk by the rain in other cases. This might explain the fact that there are symptoms of a disease presence but the symptoms are variable. If this was the case, it makes problem diagnosis associated with poor ratooning difficult.

Suckers were present in both trials at ratooning. Their influence on ratooning was evaluated to ensure they had not influenced the results. Suckers were not significantly correlated with ratoon-shoot numbers in either Q127 (*r* = -057; *P* = 0.11) or Q138 (*r* = -0.56; *P* = 0.11). However, sucker numbers were low in both varieties with the number of suckers per ratoon stalk being 0.03 and 0.12 in Q127 and Q138, respectively. Therefore, it was not surprising that they had no influence on ratooning.

The data on split length (Table 19 and 20) again indicate that it is difficult to achieve the desired split length, although the spread of data was reasonable in these trials. Allowance has to be made for the variable length of stalk remaining above ground and obviously cannot be adjusted on an individual basis. Also, it appears it is difficult to make the necessary adjustments to stop the split extending past the end of the shovel to achieve a shallow split. Therefore, it appears that the main objective should be to achieve some variability in split length or in the proportion of the stalk damaged, which appears to have been achieved in these two trials.

4.2.3 1996 stubble-damage-by-disease trials

Ratooning in both trials was slow and very erratic and did not appear to be related to treatment effects. Shoot populations continued to be monitored, because of previous experiences that suggested that ratooning was slow for the first 4 weeks after harvest. However, ratooning continued to be erratic and still did not relate to treatments.

Preliminary excavation of several stools outside the trial indicated that the stubble may have suffered greyback canegrub damage. We decided to excavate stools from the control and split-damage treatments initially to determine if the cane had been damaged by canegrubs. Examination of these stools indicated the stubble had been attacked by grubs prior to harvest, particularly Q127. This explained why ratooning had been erratic. Stalk and split lengths were measured on these stubble stalks to check if splitting treatments had been implemented successfully. The trial was terminated at that stage, with no further excavations or measurements being carried out. Ratooning data was considered to be flawed and of little value and therefore is not presented here

The stalk damage data presented in Table 22 indicated that damage treatments were quite effective. Split length in all three damage treatments was within acceptable limits of specifications.

Table 22 Mean stalk and split length data for Q127 and Q138 in the 1996 damage by disease trials (SPN96-1)

Treatment	Q127			Q138		
	Stalk length (mm)	Split length (mm)	Proportion stalk split (%)	Stalk length (mm)	Split length (mm)	Proportion stalk split (%)
No split	171	0	0	180	0	0
Shallow split	169	47	28	181	45	26
Intermediate split	172	79	49	189	88	50
Deep split	169	128	77	180	112	64
Multiple split	159	82	58	177	88	52

4.2.4 Summary

The results from these trials showed that basecutter damage could be simulated. The data from the 1994 trials showed that stalk damage itself is not the primary cause of ratoon regrowth failures. Damaging stalks by splitting them had an indirect effect, because it permitted or facilitated the colonisation of the damaged stalks by indeterminate stalk rots. Infection of the stubble by these rots was relatively low in the absence of damage to the stalks. However, the 1995 trials indicated that rain may facilitate the spread of disease down through the stubble stalk even if the stalk is not damaged. The data did indicate that there was a positive correlation between split length and the level of infection or disease rating.

In the 1994 trials, there was a strong negative correlation between ratoon-shoot population and stalk rots, clearly indicating that these rots are a major contributor to ratoon regrowth problems. However, the rots were not identified. The results from the 1994 studies showed that pineapple diseases would inhibit the ratooning process, if it infected stalks. However, it was only isolated where the stalks had been inoculated with the fungus; there was no natural infection in these trials. Therefore, despite its presence in many soils, these results suggest that pineapple disease is unlikely to be a limiting factor in the ratooning process. This was a surprising result, as the disease can have a major influence on the germination phase in plant crops. This raises an interesting question – why the difference between planting and ratooning effects from pineapple disease?

Bud-morphological data from the 1994 experiments showed that there were sufficient viable buds present in a stool for ratooning to proceed. We suggest that the stalk rots have an inhibitory effect on shoot emergence, possibly through the release of toxins. This effect could not be reduced by the fungicide application used in the 1994 experiments, although there was an indication that it had an effect in the 1995 trials.

The results from the 1995 trials were not as clear-cut as those in 1994. Disease infection did result from splitting the stalks and inoculation with pineapple disease in these trials. Variation in split length did have some influence on the level of symptom expression. Unfortunately, treatments had no effect on ratooning, because of the variability in disease infection, although the level of disease in the stalk did have some influence on ratooning. We suggest that toxins released by the fungi may have been diluted or washed away by continuous rain. This would have reduced the impact of the disease on ratooning.

4.3 Simulating the degree of stubble damage to affect ratooning

The initial experiment SPN94-1 had shown that a single major or deep split in the stubble stalk adversely affected ratooning. While this was significant, further information was required to try and elucidate the damage parameters that would adversely affect the ratooning process. A series of experiments was initiated to attempt to determine the type and extent of stalk damage required to adversely affect ratooning. Results from these experiments are provided in the following sections.

4.3.1 1994 stubble-damage simulation trials

Experiments were established in first-ratoon stubble of Q138, a strong ratooning variety, and Q127, a slow or weak ratooning variety. These two experiments, SPN94-2 and 94-3, respectively, were designed to investigate the effects of single splits 35, 75 and 115 mm in length in stubble stalks on ratooning.

Unfortunately, splitting the stalks had no significant effect on ratooning in either experiment (Table 23). Ratoon-shoot numbers were quite variable in both experiments, but there were no obvious reasons for this. Temperature and rainfall conditions were intermediate to those experienced during the two other trials (SPN94-1 and 94-4) conducted in 1994 (Table 9, Figures 7 and 8) and should not have contributed to the variability of the data. Sucker incidence was quite high in these trials.

Table 23 Effect on ratooning of different length single splits in stubble stalks of Q138 and Q127 in two simulated basecutter-damage trials established at Tully in September 1994

Stalk damage	Number of ratoon shoots per stubble stalk					
	Q138[1]			Q127[2]		
	31 DAT[3]	45 DAT	71 DAT	31 DAT	45 DAT	71 DAT
Nil	1.27	1.64	2.38	0.53	0.68	1.62
Nil-bent 60^{o} [4]	1.92	2.41	6.66	0.85	1.04	1.44
Split 35 mm	1.14	1.56	2.83	0.54	0.69	1.30
Split 75 mm	1.01	1.06	1.40	0.45	0.60	1.55
Split 115 mm	1.16	1.77	3.18	0.43	0.57	1.21
lsd $_{(0.05)}$	0.57	ns	ns	0.27	ns	ns
Probability	0.03	0.08	0.10	0.03	0.11	0.84

[1] Trial SPN 94-2 established 6 September 1994.
[2] Trial SPN 94-3 established 6 September 1994.
[3] Days after treatment.
[4] No split; stalk bent 60^{o} from vertical prior to cutting.

Bending the stalks to an angle of 60^{o} prior to harvest promoted ratooning (Table 23). This was a consistent effect in both trials, although it is not certain whether the force applied by a harvester in bending the stalks would achieve a similar result. However, it does raise an interesting question regarding the beneficial effects of the knockdown angles on a harvester. The result is also of interest as it may have an implication as a stimulatory effect promoting suckering prior to harvest as a result of bending the stalk due to sprawling or lodging of the crop.

Suckering was more prolific in these two trials particularly in the Q138. The ratio of suckers to stubble stalks 13 DAT was 1.51:1 for Q138 and 0.42:1 for Q127, which was higher than the other trials conducted in 1994. Correlation analyses were carried out to determine if the sucker content in each treatment plot had any influence on the ratoon-shoot population. There was a significant positive correlation between sucker and ratoon-shoot numbers, with Q138 in trial SPN94-2 at all three ratoon-shoot assessment dates (Table 24). Sucker and shoot numbers were also positively correlated in Q127 in trial SPN94-3, but only at the final ratoon-shoot assessment time when ratoon-shoot numbers started to increase (Table 23). Previous data had suggested that suckers had a negative effect on ratoon shoot numbers. The effect exerted by suckers on ratooning, i.e. positive or negative, may be influenced by environmental conditions and the level of suckering in the crop.

Table 24 **Correlation values (*r*) for the relationship between number of ratoon shoots and suckers per plot in stalk damage trials established in Q138 and Q127 in September 1994[1]. Probability values for the relationship are shown in parentheses**

DAT[3]	Q138	Q126
31	0.623	0.236
	(< 0.01)	(0.32)
45	0.586	0.241
	(< 0.01)	(0.31)
71	0.531	0.614
	(0.03)	(< 0.01)

[1] Trials SPN94-2 & 3 established 6 September 1994.
[2] Sucker to stubble stalk ratio 13 DAT.
[3] Days after treatment shoot numbers per stubble stalk recorded.

Measurements on the excavated stubble showed that the objectives for split length were not achieved in either trial (Tables 25 and 26). The shallow splits were good, but the depths of the intermediate and deep splits were about 25 and 50 mm short of the desired split length. This was the result of an over adjustment of the depth gauge on the de-suckering shovel to offset natural splitting of the stalk beyond the end of the shovel blade noted in experiment SPN94-1. Unfortunately, the natural split beyond the end of the shovel does not appear to have occurred in either of these trials, leaving the split lengths short of target in the two deeper split treatments. Consequently, the proportion of the stalk split was only about 30% for the 75 and 115 mm split treatments in both experiments (Tables 25 and 26). This is considerable less than the 65% of the stalk that was split in SPN94-1 (Table 12). This low level of damage may explain the failure of splitting to adversely affect ratooning in these two experiments.

Table 25 **Disease incidence[1] resulting from different length splits and stubble stalk and split details in a basecutter damage simulation trial (SPN94-2) established in Q138 in September 1994 at BSES Tully**

Stalk damage	Diseased nodes/stalk		Disease rating/ stalk	Depth below ground		Proportion of stalk split (%)
	Number	Proportion (%)		Stalk (mm)	Split (mm)	
Nil	1.1	14.4	7.1	230	9	4
Nil – bent 60° [2]	0.8	11.9	4.8	218	13	6
Split 35mm	0.8	11.5	6.2	223	37	17
Split 75mm	1.6	24.1	9.5	202	53	27
Split 115mm	1.7	22.1	10.1	218	62	29
lsd $_{(0.05)}$	ns	9.9	ns	ns	18	8
Probability	0.07	0.04	0.06	0.46	<0.01	<0.01

[1] Disease assessment 50 DAT on 26 October 1994.
[2] No split; stalk bent 60° prior to cutting.

Splitting the stalk significantly increased the number and proportion of diseased nodes and the disease rating of the stalk in the Q127 in trial SPN94-3 (Table 26). Similar results were obtained with Q138 in trial SPN94-2, but only the proportion of diseased buds was significant increased by splitting (Table 25). However, statistical probabilities were quite low for number of diseased buds (0.07) and disease rating per stalk (0.06). The level of infection was lower in Q127 than Q138, which may be a site effect. The length of the split was significantly correlated with disease rating in both Q138 (r = 0.46; P = < 0.01) and Q127 (r = 0.65; P = <0.01). Splitting the stalks did facilitate fungal infection of the stubble, even if it did not adversely affect ratooning, but, unfortunately, the level of infection was low. We suggest that the failure to affect ratooning may have been associated with both the short length of stalk infected by fungal growth coupled with a low infection level.

Table 26 Disease incidence[1] resulting from different length splits and stubble stalk and split details in a basecutter damage simulation trial (SPN94-3) established in Q127 in September 1994 at Tully

Stalk damage	Diseased nodes/stalk		Disease rating/ stalk	Depth below ground		Proportion of stalk split (%)
	Number	Proportion (%)		Stalk (mm)	Split (mm)	
Nil	0.4	5.4	3.0	178	9	5
Nil – bent 60° [2]	0.6	8.7	5.7	169	8	6
Split 35mm	0.8	10.8	6.3	190	34	18
Split 75mm	1.0	15.2	9.4	177	47	27
Split 115mm	1.0	13.6	8.8	183	59	32
lsd $_{(0.05)}$	0.3	4.3	2.3	ns	11	7
Probability	<0.01	<0.01	<0.01	0.40	<0.01	<0.01

[1] Disease rating 56 DAT on 1 November 1994.
[2] No split; stalk bent 60° prior to cutting.

The bud-distribution data again indicated that pre-harvest shoots tend to originate from the lower section of the stubble stalks (Table 27). The bud-morphological assessment showed that splitting stalks had no effect on bud distribution (Table 28), which is not unexpected, because of the lack of differentiation in split lengths. There appears to be sufficient buds present on a stalk to prevent ratoon failure but their role is unclear.

Table 27 Proportion of buds of different characteristics distributed over the whole and upper and lower sections of stubble stalks in Q138 and Q127 assessed in two basecutter damage simulation trials established in September 1994 at Tully

Trial	Proportion of buds (%)[1]					
	PHS	EM	SW	SPR	DOR	Dead
Q138[2]						
Whole stalk	7	11	37	12	25	8
Upper stalk	0	3	5	5	21	4
Lower stalk	7	8	32	7	4	4
Q127[3]						
Whole stalk	12	10	26	17	14	21
Upper stalk	1	7	9	6	10	14
Lower stalk	11	3	17	11	4	7

[1] PHS – pre-harvest shoots; EM = emerged shoots; SW = swollen buds; SPR = sprouted buds; DOR = dormant buds; Dead = bud dead.
[2] Assessed 50 DAT on 26 October 1994 (SPN94-2).
[3] Assessed 56 DAT on 1 April 1994 (SPN94-2).

Table 28 Probability values attached to the effect of damage in the ANOVA for proportion of buds per stubble stalk in Q138 and Q127 in the two damage trials established in September 1994 at Tully

Source	Probability[1]					
	PHS	EM	SW	SPR	DOR	Dead
Q138[2]						
Damage	0.94	0.29	0.96	0.96	0.84	0.10
Q127[3]						
Damage	0.84	0.55	0.81	0.90	0.10	0.88

[1] PHS – pre-harvest shoots; EM = emerged shoots; SW = swollen buds; SPR = sprouted buds; DOR = dormant buds; Dead = bud dead.
[2] SPN94-2 established 6 September 1994 in Q138.
[3] SPN94-3 established 6 September 1994 in Q127.

4.3.2 1995 stubble-damage simulation trials

This experiment was established in Block 34B on BSES because the cane was erect and other options were limited because of the extensive lodging in the 1995 crop. The effect of stalk-damage treatments on ratooning in this trial (SPN95-4) was disappointing. Damaging the stalks had no significant effect on ratooning on all six occasions that ratoon regrowth was assessed (Table 29). The Q127 harvested in September in this trial ratooned much faster than the Q127 harvested in this block in July. In September it reached 0.58 shoots/ stubble stalk at 25 DAT (Table 29), compared with 0.52 shoots /stubble stalk at 48 DAT for a July harvest (Table 17). This would be partly associated with the higher temperatures during the September to November period (Table 8; Figure 7). However, there were also 179 and 101 mm of rain in October and November (Table 9; Figure 8) that may have influenced the failure of stalk damage to cause a ratooning response in this trial.

Table 29 Probability and mean treatment values attached to the effect of damage treatments to stubble in the ANOVA of number of ratoon shoots per stubble stalk in Q127 on six assessment dates in a trial established in September 1995 at Tully

Assessment date (DAT)[2]	Number of ratoon shoots per stubble stalk	
	Probability	Mean
13	0.50	0.15
19	0.16	0.35
25	0.16	0.58
32	0.26	0.75
46	0.28	1.18
74	0.51	1.39

[1] Trial SPN 95-4 established 14 September 1995.
[2] Days after treatment.

Because ratooning did not respond to the damage treatments, stubble assessment was restricted to one stool from two replicates of each treatment. Split lengths were longer than specified, but this was not critical, as they provided a good range of values (Table 30). It could be suggested that the shallow and intermediate splits were too long to obtain sufficient differentiation on the effects of different split lengths. However, this does not explain why there was no differentiation between the different split treatments and the undamaged control. The shatter treatment split the stalk to a greater length than anticipated, resulting in a similar proportion of the stalk split to the shallow split (Table 30).

Table 30 Summary of stalk damage and disease incidence in Q127 as influenced by damage treatments in trial SPN 95-4 established in September 1995 at BSES Tully

Treatment	Stalk length (mm)	Split length (mm)	Proportion stalk split (%)	Disease rating per stalk	Proportion stalk diseased (%)
Control	150	0	0	13	57
Shallow split	141	60	43	21	64
Intermediate split	165	92	56	29	79
Deep split	158	139	88	43	91
Multiple split	174	93	54	36	79
Shatter	161	69	43	33	63

[1] Assessed 77 DAT on 30 November 1995.

The disease rating was consistent with treatments and clearly indicated that splitting the stalk enhanced disease infection, as the disease rating increased with the proportion of the stalk damaged by splitting (Table 30). Disease rating was significantly correlated with split length (r = 0.93; P = < 0.01). The proportion of the stalk diseased was also consistent with stalk damage except for the control. It appears that infection by disease (presumably fungal infection) can spread through the stalk in the absence of physical damage, but its spread is enhanced by damage to the stalk (Table 30). We suggest that the spread of the disease through the stalk, particularly an undamaged one, may have been enhanced by the heavy rain in October and November. Since at least 60% of the stalk was diseased in all treatments, disease incidence was too high to expect any differentiation in ratooning due to treatment. There was no relationship between disease rating and ratoon-shoot numbers at either 46 or 74 DAT. Alternatively, it could be the result of the rain diluting any toxins released by the fungi. This is quite plausible, as ratooning was quite rapid and does not appear to have been restricted at all.

The influence of suckers on ratooning was also examined, as we considered that they may have been influencing the results. Linear regression analyses was carried out to assess this relationship using plot ratoon-shoot number at 46 DAT and sucker numbers 4 DAT. This indicated that there was an inverse relationship between ratoon shoots and the number of suckers present, i.e. ratoon shoot development tended to be lower with high sucker incidence. Although the relationship was nearly significant ($P = 0.07$), it probably would not have contributed a lot to these results ($R^2 = 0.11$). This is in contrast to the sucker-ratoon shoot relationship obtained in the 1994 trials with Q127. However, sucker numbers in Q127 were quite low in the 1995 trial, 0.13 suckers per stubble stalk compared with 0.42 suckers per stubble stalk in 1994. This may explain the difference in the relationship between suckers and ratoon regrowth that was obtained with Q127 in these two years.

4.3.3 Summary

These stubble stalk-damage trials produced mixed results. They have shown that damage to the stalk does enhance fungal infection, although this will also occur in an undamaged stalk. However, our results show that the presence of a split or fungal infection in a stubble stalk, either singularly or in combination, does not mean that the ratooning process will be inhibited.

We suggest that there may be factors, other than stalk damage and disease infection, that can have a major influence on the ratooning process. Our experiments were initiated in September in both years. It appears environmental conditions are more favourable for ratooning during that period of the year and can overcome the disadvantage associated with stalk damage and disease infection. The results in 1994 suggest that suckers may exert a positive influence on ratooning under favourable suckering conditions, particularly in varieties like Q138 with a propensity to sucker. We consider that influences such as these can minimise the negative impact of stubble damage on ratooning.

4.4 Harvester studies

Harvester studies were undertaken to try to identify some harvesting and cultural practices that may be contributing to stubble damage. Do factors such as harvester speed, basecutter height above ground, basecutter blade wear, and row profiles have the potential to influence stubble damage at harvest? A number of harvester studies were undertaken as part of this project in an attempt to provide answers to those questions.

4.4.1 Harvester speed and basecutter height

The initial trials (SPN94-5 and 94-6) to investigate harvester-speed effects were established in burnt and green cane. The opportunity was taken to establish these trials because there was a belief that basecutter damage is higher under green-cane harvesting. The actual harvesting speeds achieved in these trials were 3.8 and 6.0 km/h, which was very close to the desired speeds. The latter speed was selected because it was considered an optimum or 'good' harvesting speed. We decided to use a lower speed to determine if slowing the harvester would improve its performance; this is a commonly held belief.

Harvesting speed had no significant effect on stubble damage in either burnt or green cane (Table 31). The level of damage was relatively low, ranging from 26 to 39%. The harvester was operating with new basecutter blades, which may have helped minimise stubble damage. There was a trend for slightly lower damage in green cane, which was contrary to popular belief. In addition, there was a trend for damage to be slightly higher at the lower harvesting speed of 3.8 km/h in both green and burnt cane. This could result from the stubble being hit by a second blade as the forward speed is below optimum for the basecutter speed. Ratooning was not influenced by harvester speed in either trial, as there were no significant effects on shoot numbers recorded at 47 DAH in both the burnt (P = 0.16) and green cane (P = 0.26) trials.

Table 31 Influence of harvester speed on stubble damage when harvesting burnt or green cane

Harvester speed (km/h)	Proportion of stubble stalks (%)[1]				
	No damage	**Split**	**Major split**	**Shatter**	**Snap**
Burnt[2]					
3.8	61	14	8	16	1
6.0	65	12	5	18	0
Probability	0.48	0.63	0.29	0.63	0.26
Green[3]					
3.8	65	7	8	15	5
6.0	74	3	2	20	1
Probability	0.05	0.06	0.07	0.07	0.05

[1] Mean of six varieties assessed 26 DAH.
[2] SPN94-5 harvested burnt 28 September 1994.
[3] SPN94-6 harvested green 28 September 1994.

In the 1995 trials, stalk damage was significantly higher in both Q127 and Q138 when the height of the basecutter above the ground or soil surface was increased (Tables 32 and 33). The average cutting heights were 32 and 65 mm above the soil surface, which was slightly higher than originally planned. Increasing the cutting height by approximately 30 mm increased the level of damage by 14 and 24% in Q127 and Q138, respectively. Raising the basecutter appears to increase the proportion of snapped stalks, presumably because it also altered the knockdown angle. These results clearly demonstrate that less stubble damage occurs when the basecutter operates closer to the soil surface. However, this does not mean the basecutter should operate below the surface, as this will increase dirt in the cane supply.

Table 32 Influence of the height of the basecutter above ground and harvester speed on stubble damage in Q127 in trial SPN95-5[1]

Harvester setting	Proportion of stubble stalks (%)[2]				
	No damage	Split	Major split	Shatter	Snap
Height					
Ground	60	11	3	0	26
Above ground	46	10	5	0	38
$lsd_{(0.05)}$	9	ns	ns	ns	8
Probability	< 0.01	0.88	0.16	0.18	0.02
Speed (km/h)					
4.0	52	10	4	0	33
6.0	58	8	3	0	31
7.9	50	13	5	0	32
$lsd_{(0.05)}$	ns	ns	ns	ns	ns
Probability	0.25	0.10	0.14	0.10	0.88

[1] Harvested 27 July 1995.
[2] Assessed 14 DAH.

Increasing harvester speed from 4.0 to 7.9 km/h had no significant effect on the level of damage to the stubble in Q127 (Table 32). This contrasts with the results from Q138, where stalk damage was significantly increased by 15% when harvester speed was increased by 3.5 km/h (Table 33). The major impact from increasing the harvester speed was to increase the proportion of snapped stalks.

Table 33 Influence of the height of the basecutter above ground and harvester speed on stubble damage in Q138 in trial SPN95-6[1]

Harvester setting	Proportion of stubble stalks (%)[2]				
	No damage	Split	Major split	Shatter	Snap
Height					
Ground	65	19	5	4	7
Above ground	41	18	17	6	18
$lsd_{(0.05)}$	21	ns	8	ns	7
Probability	<0.01	0.92	0.01	0.54	0.01
Speed (km/h)					
3.5	60	20	8	3	8
5.5	54	17	11	6	12
7.0	45	19	14	5	17
$lsd_{(0.05)}$	9	ns	ns	ns	6
Probability	<0.01	0.79	0.15	0.34	<0.01

[1] Harvested 27 July 1995.
[2] Assessed 13 DAH.

The increased level of damage associated with increasing speed and raising basecutter height did not have any effect on ratooning in Q138. Similarly, raising the operating height of the basecutter had no effect on ratooning in Q127, despite the increase in damage. However, increasing harvesting speed significantly reduced the number of ratoon shoots in Q127 during 32-83 DAH (Figure 14). There was no difference between the lower speeds of 4.0 and 6.0 km/h, but increasing speed to 7.9 km/h had a negative effect on ratooning. It is difficult to explain the reasons for this phenomenon. It was demonstrated earlier that bending the stalk to 60^{o} prior to cutting can stimulate ratooning, but not physically alter the stalk (Table 23). Therefore, it is possible that ratooning could be inhibited if the stubble was shaken a little more at higher speed without necessarily causing any damage to the stubble. However, it does suggest that high harvesting speed may adversely affect weak ratooning varieties such as Q127. These results again highlight the difference in ratooning characteristics of varieties and Q127 and Q138 in particular.

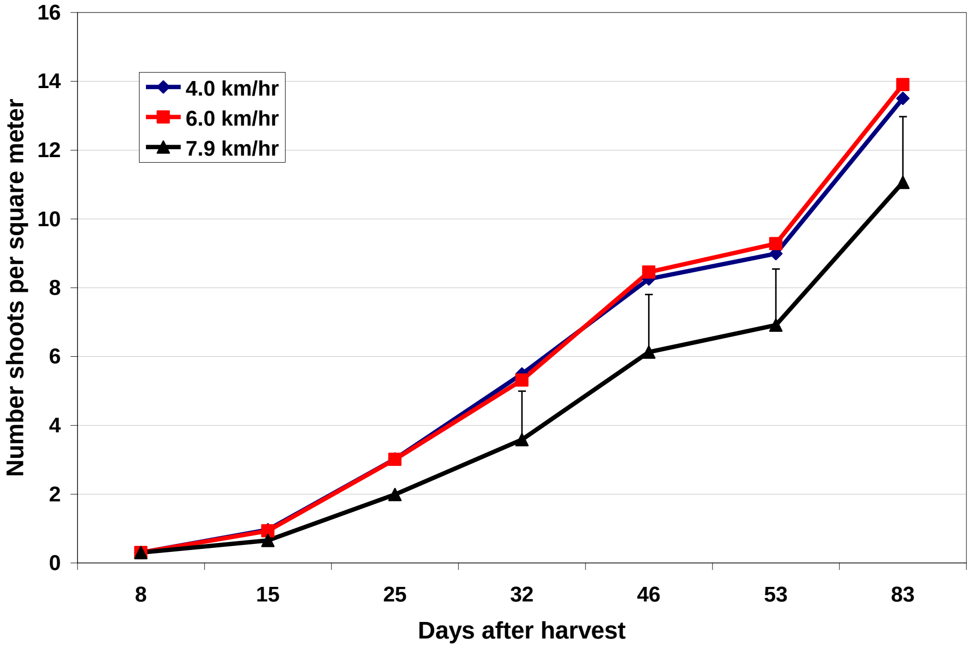


Figure 14 Effect of harvesting speed on ratooning of Q127 in trial SPN95-5 at Tully. $LSD_{(0.05)}$ bars shown where applicable

4.4.2 Worn blades and basecutter angle

Basecutter blade wear is an ongoing problem confronting the harvesting system. The effectiveness and efficiency of a blade decrease as it wears, because it loses length and also becomes rounded, and, therefore, loses much of its cutting capability (Kroes and Harris 1994). Harvester operators try to extend the life of the blade for as long as possible to save costs and time. Growers generally consider blade wear leads to increased level of damage to the stubble and would like to see the frequency of blade changing increased to reduce the level of stubble damage. Therefore, we considered it important to attempt to quantify the effects of blade wear on stubble damage and several trials were carried out to investigate this aspect.

A trial established by the Mackay Productivity Services was used as part of these studies. This trial was an unreplicated strip trial that had been established at harvest of a lodged plant crop of Q124 in the Racecourse mill area in Mackay. The early ratooning of the suckers was apparent when the damage assessment was carried out 5 DAH. Stubble stalks only were assessed for damage, as little damage was apparent in the soft sucker tissues and they were irregular in their occurrence. The level of damage was quite high in this block, even where the crop had been harvested with new blades. Approximately 85% of the stalks had suffered some form of damage where the crop had been harvested with worn blades (Table 34). The type of damage was severe, mainly comprised of major splits and shattering to depth. This may be a characteristic of this variety, or could be a reflection of crop condition, or a combination of both.

Table 34 Effect of worn blades on the proportion of damaged stubble stalks following the harvest of a plant crop of Q124 in a basecutter trial at Mackay

Blade type	Proportion of stubble stalks (%)[1]					
	No damage	Split	Major split	Shatter surface	Shatter depth	Snap
New	45	10	24	3	13	4
Worn	16	4	32	5	35	7
Prob[2]	<0.01	0.25	0.31	0.09	0.03	0.38

[1] Assessed 5 DAH in trial SPC96-1.
[2] Probability values from two-sample t-tests.

Ratooning in the first-ratoon crop was not adversely affected by the level of damage in this trial (Table 35). This was surprising, but may not be totally unexpected considering the level of suckering present in the plant crop. Mackay Productivity Service's staff reported that there were no yield differences between treatments recorded at harvest of the first-ratoon crop. The beneficial effect of heavy suckering in offsetting the effects of basecutter damage on ratooning was reported in a case study from the Tully basecutter survey (Section 4.1.2). We consider that this factor was operating in this case. However, it does highlight a potential problem in the future, because of the policy to select against suckering in the crop improvement program. Basecutter damage, which appears to have been masked in this instance by the presence of suckers, could become a major problem in the future.

Table 35 Effect of worn blades on ratooning following the harvest of plant Q124 in a basecutter trial at Mackay

Blade type	Number of ratoon shoots / square meter		
	36 DAH	66 DAH	101 DAH
New	9	11	17
Worn	8	11	18
Probability[1]	0.20	0.39	0.12

[1] Probability values from two-sample *t*-test.

The basecutter wear trial initiated in 1996 at Ayr (SPA96-1) introduced a new approach to conducting harvester trials. Harvester basecutter trials are difficult to setup, because of lost time due to changing basecutter blades or plates, and contractors are generally not willing to spend this additional time on a trial. Consequently, the trials are usually strip trials and include a minimum of treatments and replication, as used in the trial at Mackay. Two similar harvesters, Cameco in this instance, were used in this trial, with one fitted with new and the other fitted with worn blades. This enabled replication to be increased to eight, because each row could be a separate treatment, which increased the probability of achieving a result. It also ensured operator cooperation, as interruptions were minimal. The system appeared to function quite well, but does require some attention to simple operational matters such as ensuing harvesting speed is identical or at least very similar. In this trial, the average speed of both harvesters was very close to 7.5 km/h.

The main trial was established in second-ratoon Q96. There were a few rows of second-ratoon Q117 on the edge of the field, which enabled some information to be obtained on this variety.

Table 36 Influence of worn blades on proportion of damaged stubble stalks following the harvest of second ratoon Q96 and Q117 in a basecutter trial at Ayr, 1996

Blade type	Proportion of stubble stalks (%)[1]				
	No damage	Split	Major split	Shatter depth	Snap
Q96					
New	20	2	10	57	11
Worn	3	0	12	84	0
$lsd_{(0.05)}$	16	ns	ns	ns	ns
Probability	0.04	0.37	0.80	0.12	0.15
Q117					
New	35	7	21	38	0
Worn	21	4	7	67	2
$lsd_{(0.05)}$	10	ns	ns		
Probability	0.02	0.60	0.32	0.06	0.39

[1] Assessed at harvest 24 September 1996in trial SPA96-1.

Stalk damage in Q96 was very high following harvest with either new or worn blades (Table 36). While damage level was significantly less with new blades than worn blades, damage levels of 80 to nearly 100% at harvest is totally unacceptable. The majority of the stubble damage was associated with shattering of the stalk to depth. Similar results were obtained with Q117, although it fared marginally better with damage levels ranging from 65 to 80% for the two treatments (Table 36). The figures may have some bias, as it was difficult to find Q96 stubble to assess in this trial. The situation was better in Q117, with more stubble pieces being found; this may explain the slightly lower, but still unacceptable, damage figures.

The observations on a lack of stubble only became apparent when harvesting was almost completed and when damage assessments were commenced. Cutting height was examined at this stage. Both harvesters were cutting below ground level ranging from -10 to -25 mm for the new-blade treatments to -30 to -50 mm in the worn-blade treatments. Excavating some of the stubble showed that the Q96 was very shallow and most of the deeper stubble appeared to have rotted away. Therefore, lowering the cutting height below ground level increased the risk of removing stubble with the basecutter blades. This explained why there were low levels of stubble to assess in Q96. The situation was not as bad in Q117, as the stubble had not rotted away to the same extent and, thus, appeared to be slightly deeper in the soil. This could explain the difference in damage levels measured in these two varieties.

The basecutters of the Cameco harvester are mounted on legs (or struts) hanging down below the cabin. The inline angle for this type of basecutter is usually about 11º, which is fairly flat. This is common to all harvesters with fixed leg basecutters. Rows are raised because of furrow irrigation in the Burdekin and, in ratoon crops, there is a height differential between the row and interspace of about 200 mm. This results in a mismatch between the inline angle of the leg basecutter and the height of the row. The harvester operators at this trial site made the observation that cane was left unharvested as basecutter blades wear. It was a common practice to lower the cutting height to compensate for the inefficiency of the cutting action due to blade wear. This practice had been used in this trial.

Ratooning in this trial was monitored via shoot populations on two occasions, 71 and 168 DAH. These indicated that harvesting with worn blades had reduced stalk numbers by 50% on both occasions (Table 37). The crop stand in the third ratoons in 1997 was quite gappy, which was more pronounced in the worn basecutter-blade treatment. This effect carried through to harvest with cane yield being reduced by 27% as a result of harvesting with worn basecutter blades (Table 37). While using worn basecutter blades has been suspected of having a negative effect on ratooning, the yield reduction was much higher than expected. This suggested that there was a twofold explanation for the reduction in cane yield as a consequence of harvesting with worn basecutter blades; stalk damage and stubble loss.

Table 37 Influence of harvesting with worn blades on ratoon shoot population and cane yield in third-ratoon Q96 in a basecutter trial at Ayr

Blade type	**No shoots / square meter[1]**		**Cane yield[2] (t/ha)**
	71 DAH	**168 DAH**	
New	21.7	7.2	124
Worn	11.1	3.4	90
$lsd_{(0.05)}$	5.6	2.0	21
Probability	< 0.01	< 0.01	< 0.01

[1] Second-ratoon crop harvested 24 September 1996 at establishment of trial SPA96-1.
[2] Third-ratoon crop harvested 19 October 1997 at 13 months of age.

A leg basecutter where the inline angle could be altered hydraulically from the cabin was inspected at Chris Cannavan's farm, Home Hill, 2 d after trial SPA96-1 was established. This prototype, funded by SRDC, was fitted to an Austoft 7000 harvester. The harvester was operating in a field of second-ratoon Q96. This provided an opportunity to observe the effect of altering the operating angle of a leg basecutter when harvesting a crop grown on raised rows to determine if this would influence the amount of stubble removed by the basecutter.

Two rows by 50 m of cane were harvested with the inline basecutter angle set at 11°, 15° and 18°. The latter was the angle used by the operator in this block and the cutting height was -25 mm below the soil surface. Basecutter height was left to the discretion of the operator, as was the case for trial SPA96-1. Operating speed was 7.5 km/h and the rows were approximately 200 m higher than the interspace so conditions were very similar to the trial. The number of stubble pieces per 1.5-m section of row was counted at six locations in each angle strip. There was an average of 4, 6 and 9 stubble pieces per 1.5 m found in the 11°, 15° and 18° angle strips, respectively. Shoot counts (four by 2 m) were also done in these strips about 6 months after harvest. There were an average of 3, 5 and 12 ratoon stalks per square meter recorded in the 11°, 15° and 18° angle strips, respectively. These showed that stubble will be removed and ratoon stalk numbers reduced by harvesting second-ratoon Q96 with an inappropriate basecutter angle for the height of the row being harvested. This confirmed that the harvesting procedures at the trial were inappropriate resulting in stubble removal because of the basecutter angle (11°). This was further complicated because of the worn blades influencing cutting height.

Before starting the 1997 trial at Ayr (SPA97-1), preliminary observations were made to determine the most appropriate inline basecutter angle for the row height (165 mm) and a cutting height at, or slightly above, ground level. This was found to be 14-16°, because cane stubble was being left at 18° and too much soil was being cut at 11° because of the width of the row. The basecutter angle was set at 14°.

The level of stalk damage in the 1997 trial at Ayr (SPA97-1) showed a marked reduction compared with the 1996 trial. 69% of the stubble stalks showed no damage in the new basecutter blade treatment (Table 38). Using worn blades increased the level of damage by 10%. This is an acceptable level of damage, as it is unlikely damage levels could be reduced much further. Ratoon-shoot population was monitored at 43 and 258 DAH, but there were no significant treatment effects (P = 0.97 and 0.83, respectively). Although worn blades did increase stubble damage in this trial, they did not appear to impact seriously on ratooning. This result was achieved because appropriate harvesting techniques were used.

Table 38 Effect of harvesting plant Q117 with worn blades on the proportion of damaged stubble stalks in a 1997 basecutter trial at Ayr

Blade type	Proportion of stubble stalks (%)[1]					
	No damage	Split	Major split	Shatter surface	Shatter depth	Snap
New	69	10	5	9	1	6
Worn	59	15	12	3	3	9
$lsd_{(0.05)}$	8	ns	ns	1	ns	ns
Prob	0.03	0.16	0.06	< 0.01	0.46	0.42

[1] Assessed at harvest on 6 August 1997.

There is a tendency to harvest cane with the basecutter cutting below ground level to ensure all cane is picked up by the harvester and because there is a belief that stubble damage will be lower. The results from the 1996 trial (SPA96-1) indicate that cutting below ground level does not reduce stalk damage and, therefore, there is no advantage in using this practice when harvesting cane. Cutting below the ground is a common practice in the Burdekin district, particularly in ratoon crops, because of the high rows and to ensure all cane is picked up in the lodged crops. It appears likely that it is having a negative impact on productivity due to stalk damage and loss of stubble. It also has the potential to increase production costs, because it is likely to shorten the duration of the crop cycle because of declining yields in ratoons. The problem is likely to be pronounced with varieties that have a ratooning habit like Q96 with shallow stubble in ratoons due to rotting of the stubble. Stubble loss is also likely to be a problem with any cultural practice that reduces or minimises the depth of stubble. Shallow planting practices would appear likely to place ratoon longevity at risk and should be avoided.

The relationship between inline basecutter angle and row height and profile is something that tends to be overlooked in harvesting practices. Most harvesters have leg basecutters without the capacity to hydraulically adjust the inline angle. Consequently the inline basecutter angle tends to sit at 11º, irrespective of the row hight and profile. This angle will be satisfactory where a flat row profile is used. However, mounding the row will have a negative impact on harvester performance with new blades, which will be exacerbated as the blades wear and other inappropriate harvesting practices (eg. cutting height) are introduced. This will be an ongoing problem in areas with furrow irrigation, unless they use a harvester where the basecutter inline angle can be adjusted hydraulically. Adoption of new cultural practices that increase row height and change the profile would be expected to have a negative effect on harvester performance with current harvesters, unless they have the capacity to adjust the basecutter inline angle to suit the row height and profile.

4.4.3 Manual versus mechanical harvest

Other studies in this project attempted to simulate basecutter damage and determine its effect on crop growth. This experiment aimed to take this to the next phase and determine if the harvester basecutter affected crop growth and yield. A trial specifically designed for this study was planted at BSES Tully. The trial was implemented without any major problems. The technique was to harvest up to the row adjacent to a four-row column. The cane in the manual-harvest section was cut and removed first and the cane remaining cut with the harvester raising the basecutter as it moved through a manual-harvest section.

A good cutting height was achieved in the low basecutter setting treatment, with an average stubble stump height of 12 mm being left (Table 39). This meant that the basecutter was operating in very close proximity to, but above, the soil surface. The length of stubble remaining after harvest in the high basecutter setting was 79 mm, which was slightly higher than the objective (Table 39). It is interesting to note that the length of stubble residue in the manual treatment was 52 mm. Many operators would consider this too high, but it was the accepted norm under the manual-harvest system. Perhaps we need to recalibrate our objectives in this area.

Table 39 Comparison of manual harvest and mechanical harvest at two cutting heights on the length of stubble remaining above ground in a harvesting methods trial at Tully, 1995[1]

Harvest method	Length of stubble above ground [2] (mm)
Manual	52
Mechanical – low setting	12
Mechanical – high setting	79
lsd $_{(0.05)}$	16
Probability	< 0.01

[1] Trial SPN95-1 established 10 July 1995.
[2] Assessed 11 DAH.

There were differences between varieties in the level of stubble damage. There was significantly more damage in Q138 than Q127 (Table 40). The major difference was in the shatter category, although there was also a trend to higher damage levels in the split and major-split categories. Q138 is a harder variety with a higher fibre level than Q127 and this is considered the reason for the higher level of damage incurred at harvest in this variety.

Table 40 Effect of manual harvest and mechanical harvest at two cutting heights on proportion of stubble stalks damaged in Q127 and Q138 in a harvesting methods trial at Tully, 1995

Treatment	Proportion of stubble stalks (%)[1]				
	No damage	Split	Major split	Shatter	Snap
Variety					
Q127	67	16	6	3	7
Q138	48	20	12	15	4
lsd $_{(0.05)}$	13	ns	ns	8	ns
Probability	< 0.01	0.06	0.07	< 0.01	0.12
Harvest method					
Manual	86	10	1	1	2
Low basecutter height	30	27	17	16	9
High basecutter height	30	25	18	19	8
lsd $_{(0.05)}$	11	7	8	7	6
Probability	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

[1] Assessed 11 DAH in trial SPN 95-1.

The level of damage to the stubble was very high in both basecutter settings, with only 30% of the stubble stalks having zero or minor damage (Table 40). The damage was fairly evenly distributed over the split, major-split and shatter categories. There were no differences between the low and high basecutter cutting heights in the levels of damage recorded in any category. The high damage level was not associated with blade wear as new basecutter blades were fitted prior to commencing the trial. It is possible that the row profile may have been too flat for this harvester. The trial was harvested with an Austoft 7000 with an underslung box. These have a basecutter incline angle of approximately 18° and operate most effectively with a row height of at least 150 mm. The differences between damage levels in the manual and mechanical treatments were not unexpected. However, the data from the manual harvest suggests that zero or minor damage levels much higher than 60% are probably an unrealistic expectation from mechanical harvest.

Significantly higher shoot numbers were recorded in the manual-harvested plots than those harvested mechanically from 28 to 178 DAH (Figure 15). These differences had disappeared by the end of February 1996 (234 DAH), when the final shoot count was carried out. The effects of stubble damage at harvest on crop growth persisted for a considerable period of time before they disappeared. This was consistent across varieties, as there were no significant harvesting methods by variety interactions. However, there were differences between the ratooning rates of the two varieties, with Q127 being much slower than Q138 (Figure 16). This is consistent with other results in this project.

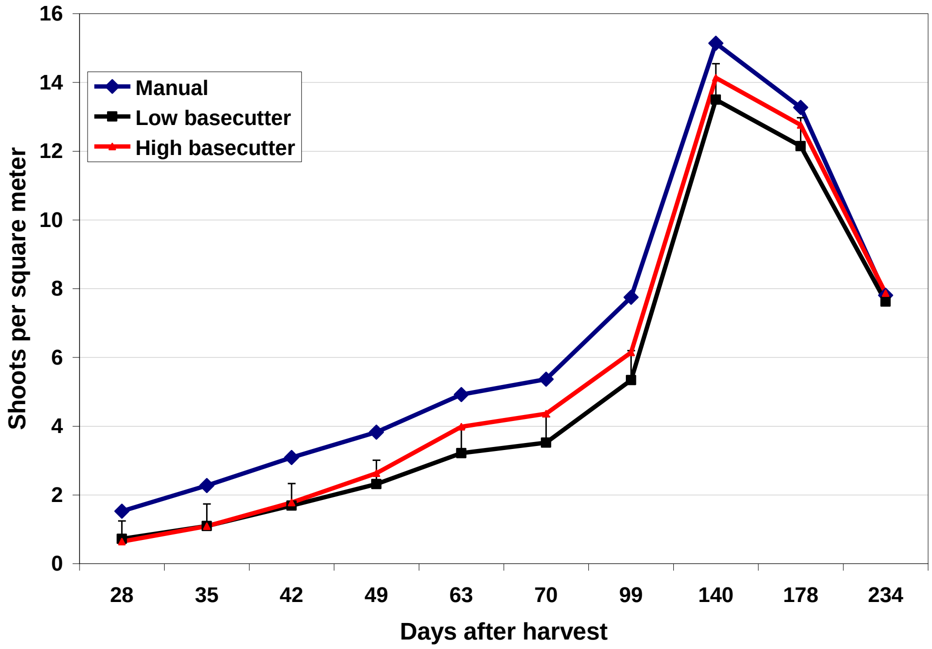


Figure 15 **Influence of manual and mechanical harvesting at different cutting heights on first-ratoon shoot populations in trial SPN95-1 conducted at Tully. LSD$_{(0.05)}$ bars shown where applicable**

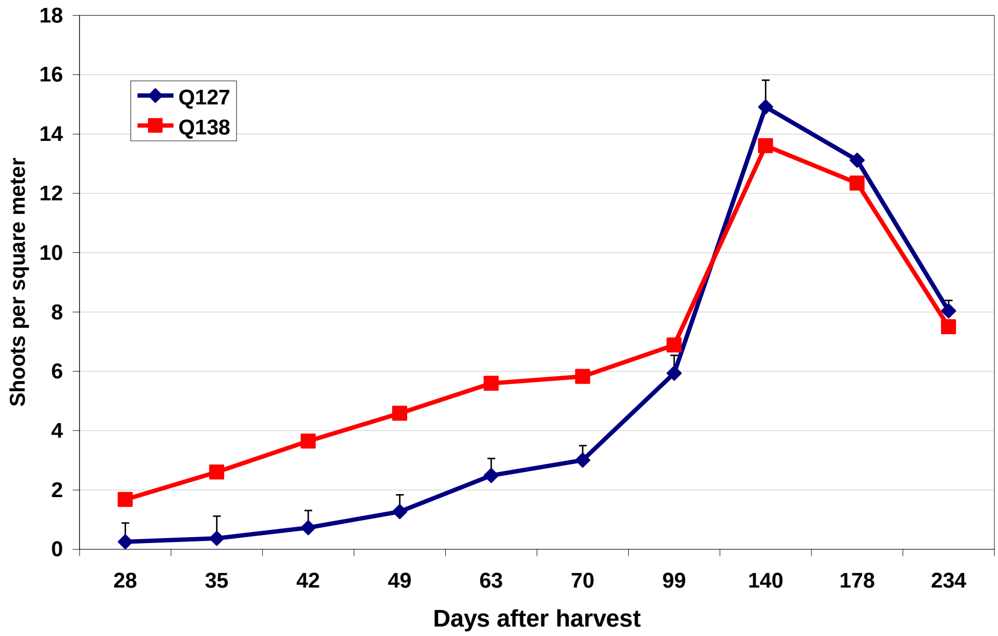


Figure 16 **Difference in ratooning rates of Q127 and Q138 in the harvesting methods trial SPN95-1 conducted at Tully. LSD$_{(0.05)}$ bars shown where applicable**

Although the stalk population in Q127 had eventually caught up to Q138 by early January 1996 (178 DAH), it was still significantly shorter in height at that time (Table 41). However, there were no differences in height between manual harvesting and the two mechanical harvest systems (Table 41). Mechanical harvest had no detrimental effect on crop stand, as there were no differences between treatments in the proportion of gaps present in the first-ratoon crop (Table 41). Unfortunately, harvest cane yields are not available, as there was a malfunction with the weighing equipment making the data useless. This was extremely disappointing, although it was unlikely that there would have been any treatment effect, as there were no difference apparent between treatment in stalk number and height. These results showed that mechanical harvesting can have a negative impact on crop growth, but the effects may not always persist until maturity. The full impact will be governed by other factors such as environmental conditions, suckering, depth of damage and the intensity and depth of disease infection. The results do indicate that the best policy is to minimise stubble damage by adopting appropriate harvesting practices.

Table 41 Influence of manual harvest and mechanical harvest at two cutting heights on stalk height and proportion of gaps in the first ratoons of Q127 and Q138 in a harvesting methods trial at Tully, 1995

Treatment	Stalk height[1] (mm)	Proportion of gaps[2] (%)
Variety		
Q127	104	6
Q138	125	6
lsd $_{(0.005)}$	13	ns
Probability	< 0.01	0.56
Harvest method		
Manual	115	7
Low basecutter height	114	6
High basecutter height	113	5
lsd $_{(0.005)}$	ns	ns
Probability	0.87	0.24

[1] Measured 179 DAH.
[2] Proportion of row length with gaps > 0.5 m at 255 DAH.

4.5 General discussions and conclusions

Stubble damage during harvest is a point of contention with growers concerned that the damage may affect ratooning. However, harvester operators are concerned that any attempt to minimise damage could increase their operating costs and time. While this matter has been discussed regularly, there were no data that quantified the level of damage occurring in the field nor the relationship between stubble damage and ratooning. In addition, if stubble damage was affecting ratooning, harvesting and cultural practices contributing to stubble damage needed to be identified.

This was addressed in this project by conducting surveys in harvested fields in the Tully Burdekin and Mackay districts to asses the level of damage that had occurred during harvest. These surveys clearly indicated that the stubble was being damaged during the harvest process with some 60-75% of the stalks suffering some form of damage. This effect was common across all three districts. It is of some concern that approximately 40% of stalks had been seriously damaged either with deep splits or a combination of shattering and deep splits. Other types of damage included shallow splits and snapping of the stalks.

This damage to the stubble were considered to have the potential to interfere with ratooning either from physical damage or because it could facilitate infection of the stubble by fungal diseases such as pineapple disease. The surveys showed that pineapple disease was common to all soils surveyed. This suggested that infection of the damaged stubble by this fungus had the potential to be a contributing factor to ratoon regrowth problems, as it can adversely affect germination in plant crops. Although the surveys showed that snapping the stalks below ground was a common problem, with 17% of the stalks affected, it was unclear if snapping would interfere with ratooning.

Evaluation of ratooning problems as part of the surveys showed that inappropriate harvesting practices contributed to the poor ratoons. This was typified by the results from harvesting lodged cane from both directions, rather than with the direction of lodging. This is a simple process that would reduce damage and its effect on ratoons but it is not done because it increases operating costs and harvesting time. We also noted in the survey that the adverse effects on ratooning could be negated by the presence of suckers. The proposed release of varieties with low suckering propensity will require adoption of good harvesting practices.

Trials simulating basecutter damage were carried out to determine if stubble damage was the primary cause of ratooning problems and what level of damage was required to have an effect. Alternatively, was damage the precursor to infection of the stalk by fungal diseases, which then adversely affected ratooning? These trials showed that splitting the stubble stalk significantly reduced ratoon-shoot numbers by about 40%. However, this was found to be an indirect effect on ratooning, because the depth or proportion of the stalk split was significantly correlated with the level of disease in the stalk but not the number of ratoon shoots produced. However, the level of fungal disease infection in the stalk was significantly correlated with the number of ratoon shoots produced. We concluded that damage was a precursor for infection of the stalk by disease and the latter adversely affected ratooning.

We also found that infection of stubble stalks can occur in the absence of damage, but this was generally a lower level of infection. Therefore, stalks snapped below ground level could be infected by fungal disease, but the level of infection and effect on ratooning would be expected to be less than in a stalk that had a deep split. The types of fungi infecting the stubble were classified as indeterminate rots. Pineapple disease was not isolated from any stalks with natural infection, but only from stalks that had been inoculated with that fungus. Inoculations with red rot were unsuccessful.

Trials to determine the degree of stalk damage required to influence ratooning were inconclusive. This was because the results were influenced to a greater extent by external variables like high rainfall and suckers. These types of factors can override the effects of damage and disease on ratooning. The data do suggest that it is probably the depth rather than the type of damage that is important. The data also suggested that a stalk needs to be split for about 50% of its length to have any appreciable effect on ratooning. This ensures that a considerable length of the stalk will become infected with fungal rots and provide the potential for ratooning to be adversely affected. The actual result will depend on other factors, particularly rain. In retrospect, we consider that too much time was spent on the simulation studies trying to establish levels and types of damage criteria. Alternatively, the studies should have been conducted in a drier environment, as it appears that a harsher ratooning environment may be required to achieve a desired result.

The level of stubble damage identified in the district surveys was high. There are a number of harvesting and cultural practices that have been suggested as contributing factors, depending whether it is considered from a grower's or operator's view. These include harvester cutting speed, basecutter height, blade wear and row profile. Damage increased at low harvesting speeds (3.8 km/h), but results were variable at higher speeds (7.9 km/h) compared with the damage level at 6 km/h. This latter speed is considered too slow for large harvesting contracts, except in high yielding crops. The Austoft 7000 harvester, as used in these trials, should have a maximum feed rate of about 8.7 km/h with new blades (Kroes and Harris 1994). This aspect requires further investigation, as it may be associated with other factors like row profile or basecutter angle or a combination of several factors.

Increasing the cutting height above the ground increased damage in some cases, but not others. Where damage increased, it was generally associated with an increase in the proportion of snapped stalks. Where cutting height had no effect in the manual versus mechanical study, it was because damage was excessive due to a high basecutter inline angle. This was because the row profile was too flat for the angle of the underslung basecutter. Therefore, altering cutting height was not going to overcome the problem; it required the row to have been mounded higher to suit the basecutter.

Blade wear can increase stubble damage, and it can also increase cane loss, because the cane is not cut properly and, consequently, not picked up by the harvester. Harvester operators compensate for this by lowering the cutting height to below ground level. The operators also like to extend the period between blade changes to save time and money. Cutting below ground can reduce yields because stubble is removed from the ground leaving a gappy stand of cane. Yields were reduced by 34 t/ha in a trial in the Burdekin area because of this practice. In this instance, using worn blades was the cause, but the effect was cutting deeper under the soil surface removing stubble and reducing yield.

Cutting below the ground is a common practice in the Burdekin area because of the high rows for furrow irrigation. These high rows do not suit the basecutter inline angle and the usual consequence is to lower cutting height to below ground level. The problem appears to be worse in ratoons because the row height is increased in ratoon crops. Mismatch between row height and profile and the basecutter inline angle is probably a major cause of stubble damage and contributing to potential yield losses. The benefits of adjusting basecutter inline angle to suit the row height was demonstrated in one Burdekin trial where damage levels of 30 and 40% were obtained with new and worn blades, respectively. This result was achieved because basecutter inline angle had been adjusted to suit the row height and the cutting height was set above ground. The use of harvesters with the capacity to hydraulically adjust basecutter angle will help alleviate this problem.

However, it will require a good extension program to get operators to accept the need for this equipment. It will also require an additional program to make farmers aware of need to implement the most appropriate cultural practices to suit their harvesting system.

Varieties are considered to have a minor role in this problem. Rotting stubble, as noted in Q96 in the Burdekin, will make a variety more prone to yield loss from below-ground harvesting. The solution lies in raising the cutting height, not changing the variety. Q138 tended to shatter more than Q127, presumably because of its harder rind and higher fibre content. This cannot be avoided, but may be reduced with the implementation of better harvesting systems. Slow ratooning will make a variety more prone to adverse effects from stubble diseases, but the risk can be reduced if appropriate harvesting systems are adopted.

5.0 OUTPUTS

Growers have been informed of the results of these studies at farmer group or shed meetings and on a one-to-one basis. Posters have been displayed and manned at BSES Field Days at Ayr, Ingham, Tully and Meringa. A *BSES Bulletin* article using data from this project was prepared by Ash Benson in 1997 (Appendix 1).

Growers have difficulty accepting that they have a role in role in minimising harvester damage by implementation of appropriate cultural practices.

The results from this project have also been presented to harvester operators at group meetings. However, this group have not been serviced effectively and there is a need for an ongoing effective extension program to address this issue.

Information from this project was incorporated into the *Harvesting Best Practice Manual* (Sandell and Agnew 2002), and also made available for use in Project BSS227 - Improved Harvester Efficiency.

6.0 EXPECTED OUTCOMES

The expected outcomes of this research are better harvester operation and improved cultural practices to minimise stubble damage. Specifically:

- Basecutter cutting height to be at or above ground level, particularly in the Burdekin district, to minimise stubble damage and removal.
- Basecutter inline angle to be adjusted to suit row height and profile. This will require the adoption of hydraulically adjustable basecutters.
- Wear of basecutter blades to be monitored and blades changed more frequently.
- Adoption of cultural practices to ensure that row profile and height match the requirements for the harvester system operating on the farm.
- Ensure planting depth will not enhance stubble removal.

7.0 FUTURE RESEARCH NEEDS

This research has highlighted the need for a better understanding of the relationship between cutting height and crop yields. The current practice of cutting below ground, particularly in the Burdekin, must be having a negative impact on productivity and profitability. Ultimately, this will require the development of an effective basecutter-height controller, but firstly it is necessary to determine optimum operating height.

Further research is recommended to develop a suitable monitor to optimise basecutter inline angle with row height and profile.

Research to determine why there are differences between plant and ratoon cane in relation to infection by pineapple disease could be beneficial to development of improved disease control measures for plant crops.

8.0 RECOMMENDATIONS

- Revitalise the extension program on harvester acceptable management practice with a focus on improved harvesting and cultural practices to minimise ‘basecutter damage’. This program should address cutting height, matching row profile and height to basecutter incline angle, and blade wear. Previous programs have had limited adoption, which is quite apparent from current harvesting and cultivation practices.
- Determine preferred basecutter settings for harvesting dual rows, particularly those planted on mounds, and the optimum mound height for current harvesters.

9.0 PUBLICATIONS ARISING FROM THE PROJECT

No formal publications have yet emanated from this project.

10.0 ACKNOWLEDGMENTS

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APPENDIX 1 – Article in *BSES Bulletin*

Basecutter's importance is generally overlooked

Improvements to the performance of many areas of a harvester will be a waste of time and money or partly negated, if the contribution or role of basecutter discs and basecutter blades to harvesting cane is not fully understood.

HARVESTERS have been modified to cut faster, handle higher tonnages of cane per hour through the choppers and elevator, and clean cane more effectively.

However, basecutter performance is not often considered, and maintenance of basecutter blades is almost ignored.

Increasing the speed of rotation of the basecutters has to some extent offset the problems caused by excessive harvesting speeds. This will not improve performance results if basecutter operating angles are not adjusted to suit row profiles and basecutter blades are not sharp and square.

Basecutter discs and blades influence the amount of cane harvested, cane pickup losses, soil levels in harvested cane and the productivity of following ratoon crops.

Types of basecutters

Many types of basecutter discs and variations have been tried on machines since chopper harvesting commenced in the early 1960s.

Some of these were:

- large single disc with 8-12 blades;
- twin scalloped discs (small scallops);
- twin scalloped discs with blades (large scallops);
- spider legs, with a blade attatched to each leg;
- twin triangular-shaped basecutter plates with three blades each;
- twin discs with five or six blades, per disc;
- twin curved discs with five or six blades, per disc.

The different basecutters were developed to suit harvester design, or improve performance by reducing choke-ups due to the presence of grass, weeds or cane trash. Other improvements were a reduction in soil intake, rejection of stones and other extraneous matter, more able to handle wet conditions and a reduction in cane pickup losses.

Most modern machines are fitted with twin disc basecutters, flat or curved, fitted with five or six blades, attatched to a leg type basecutter box.

Blades

Three blade thicknesses are commonly used, 4, 5 and 6 mm.

The 4 mm blade will cause less damage when cutting, but bends easily and wears at a higher rate. A 6 mm blade wears at a slower rate. However, it will cause more stalk shattering, particually when blunt. A 5 mm adjustable blade is normally used. Blade wear becomes a problem particularly on sandy or abrasive soils.

Blade wear comparison

Standard blade	300 tonnes harvested
Hard surfaced	1,000 tonnes harvested
Tungsten insert	5,000 tonnes harvested

Blade wear will vary with soil types

Extending blade life

Hard surfacing the cutting edge of a blade will increase blade life. This maintains the desired rectangular shape for a longer period, delaying rounding of the blade tip. Care should be taken with hard surfacing to ensure the blade is not too thick. However, a worn blade will cause more damage than a slightly thicker square 5 mm blade.

Trials have been conducted using blades with a tungsten insert. Blade life has been increased considerably, at the same time maintaining a square cutting edge.

The back of the blade will wear away leaving the cutting edge. Even though these blades are expensive, the increased life plus reduced stubble damage make them an attractive proposition for both contractors and farmers.

Basecutter operating angle

The angle basecutter discs are set at will influence:

- the amount of soil in cane supplies;
- cane pickup losses; and
- stool damage.

Basecutters may be operated at 8°-11° for a flat row profile. However, as the hill height increases to 150-200 mm, the operating angle must be adjusted to 15°-19° if

LEFT: Worn blade — increases stool damage and soil intake. Centre: Hard surfaced blade. Right: Reversible blade.

by Ash Benson, extension officer, Ayr

the machine is to harvest at or just below ground level.

Soil reduction

Soil levels in harvested cane were reduced by 50 per cent in trials on 200 mm hills when the cutting angle was changed from 11° to 18°. Less soil was removed from the hill at 18°, and the cane pickup losses were minimal.

Similiar results have been achieved for a number of trials where the cutting angle was increased by fitting 5° or 10° curved basecutter discs. The increased cutting angle compared with flat discs results in better soil rejection, as well as less soil being disturbed due to a shallower cutting depth.

CCS effect

A ccs depression has been recorded in these trials where higher soil levels occurred when basecutter discs were operated at flatter angles. The recorded figure agreed with the accepted standard of 0.15 unit of ccs lost for each per cent of soil in cane supplies.

Cane pickup losses

Where the basecutter angle is not adjusted to the hill height, cane pickup losses can increase dramatically. In a series of trials, cane loss averaged 2.5-3.5 t/ha more than for the appropriate basecutter angle for various hill heights.

Stool damage and basecutter operating angle

Recent trials in the Burdekin district with harvesting at three cutting angles, 11°, 15° and 18°, saw a marked difference in stalk numbers between the treatments in the following ratoon crop. The machine was operated to minimise cane pickup losses and a proportion of the stool was removed at the 11° and 15° settings.

The machine had sharp square basecutter blades during the trial.

Effect of basecutter angles on following ratoon.

Basecutter angle	Millable stalks
18°	17.8/m row
15°	8.0/m row
11°	4.5/m row

Blade wear effects

Soil increase

Trials have shown worn basecutter blades will cause an increase in soil entering cane supplies.

A 50 per cent increase was recorded in worn versus sharp basecutter blade trials. However, tests on soil increase with blade wear over a morning's harvesting on abrasive soils showed even higher soil increases.

Stubble damage

Results from trials comparing sharp and worn basecutter blades showed a 50 per cent reduction in ratoon shoot emergence and a similar result for millable stalk numbers.

Effect of worn blades on following ratoons.

Blade type	Millable stalks
Worn	5.1/m row
Sharp	11.1/m row

Stubble damage assessment showed almost 100 per cent stalk damage in the worn blade treatments, with less than 30 per cent stalk damage where sharp blades were used.

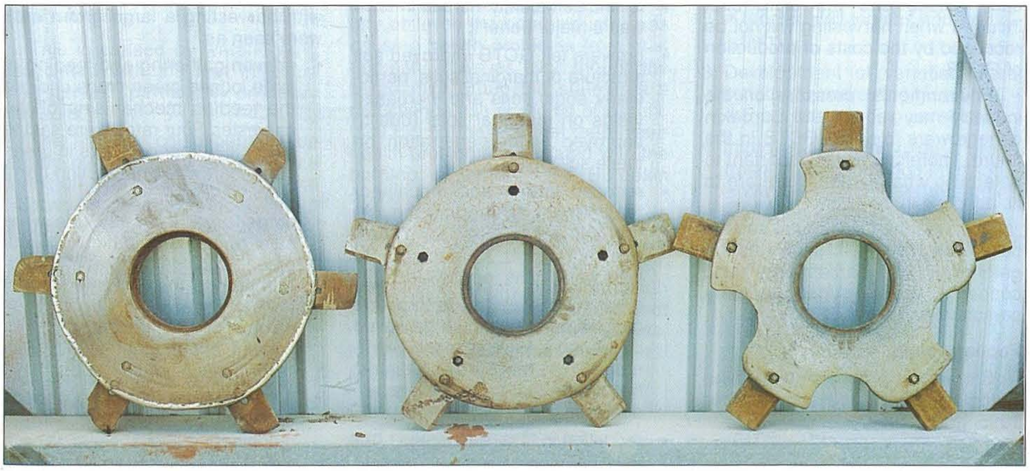
Blade numbers

Increasing the speed of rotation of the basecutter helps to reduce stubble damage once the forward speed of a harvester passes a certain point.

However, extra blades on the basecutter disc will reduce stubble damage because it will help ensure the cane stalk is cut by the blades and not damaged or broken off by the disc at high operating speeds.

Conclusion

The method of operation, for example, cutting speed, cutting depth and basecutter operating angle, plus the maintenance of various machine components will ultimately determine the quality of the harvested product, cane pickup losses and ratoon yields of following crops.



FROM left: Round blades which will cause stool damage. Blades in good working order. Scalloped basecutter disc.