Improvement of rice grain quality

A report for the Rural Industries Research and Development Corporation

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The New South Wales rice industry has long recognised the importance of quality. In fact quality, the ability to consistently deliver branded product within the quality specifications of the various market segments, is a key factor in the success story of the industry.

In rice one important quality parameter is % whole grain, the percentage of whole grains of rice in a sample of white or polished rice, after the hull and bran layer has been milled off. This is the premium core rice product. Broken grains are severely discounted in value.

In the ten years to 1992 commercial milling for medium grain rice achieved a % whole grain of 58.4%, with a range of 65 down to 51.4%. On a million tonne rice crop this 13% variation in % whole grain represents a difference of 130,000 tonnes of whole grain in one year.

The RIRDC funded rice industry project “Improvement of rice grain quality” conducted by NSW Agriculture attempts to identify factors that impact on % whole grain millout and evaluate the ability of the ricegrowers to maximise the quality of the rice grain produced through management of rice growing and harvesting practices.

During the rice harvests of 1993, 1994, 1995 and 1996 a total of 433 commercial rice crops over all growing areas were sample harvested on a weekly basis for an average of over 8 weeks. The 3630 individual grain samples collected were appraised by the industries Rice Appraisals Centre. This quality data, along with records of the originating commercial rice crop and local weather conditions, provided an extensive data base on the factors potentially impacting on grain quality.

The resulting analysis of this data to date provides a valuable insight into the factors affecting % whole grain and the ability of ricegrowers to maximise the quality of harvested grain. This knowledge, along with policy settings of the industry in regard to receival and payments, will provide a sound basis for improving grain quality in the future.

This project was funded from industry revenue which is matched by funds provided by the Australian Government.

This report, an addition to RIRDC’s diverse range of over 1000 research publications, forms part of our RICE R&D program, which aims to improve the profitability and sustainability of the Australian rice industry in conjunction with NSW Agriculture and other agencies.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- purchases at www.rirdc.gov.au/eshop

Simon Hearn
Managing Director
Rural Industries Research and Development Corporation
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- Alan M. Boulton, Project Technical Officer, Yanco - February, 1996 to June, 1997

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A particular acknowledgement is made for the ready co-operation of the Ricegrowers’ Co-operative Limited in the supply of additional staff to help the sequential harvesting program.

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EXECUTIVE SUMMARY

INTRODUCTION
The percentage of whole grain after milling, % whole grain, has long been of concern to the NSW rice industry. There is a wide variability in % whole grain results between medium and long grain varieties, individual crops (less than 20% up to over 68%) and between seasons (35 to 64%), which impacts on total returns.

Genetic and environmental factors were generally accepted as major determinants of grain quality, including the % whole grain after milling. Grower management factors have a major affect within these limits, but were poorly well accepted by growers.

It was concluded that the best proof of the role of management practices on % whole grain was to measure what happens with the quality of commercial rice grain on growers farms, and relate the results directly to what happens on the farm and the local climatic environment. Out of this the RIRDC Project DAN 86A “Improvement of rice grain quality” was developed. The project commenced on the 1 January 1993 and concluded on the 30th June 1997

OBJECTIVES & STRATEGIES
The AIM was to improve the quality of paddy rice, in particular the percentage of whole grain after milling, through the adoption of appropriate crop management technology and practices.
By:
1. Identifying the management practices in commercial ricegrowing that most effect rice grain quality, in particular % whole grain.
2. Identifying the barriers and constraints to the adoption of management practices to improve grain quality.
3. Develop and implement a rice extension programme to encourage the transfer and adoption of rice management technology that maximises rice grain quality.

METHODOLOGY
Primary Objective- Sequential Harvesting & Grain Quality Assessment
The approach used was to select a range of commercial rice crops representative of all crops, and sequentially sample harvest them over a period of 8 to 10 weeks commencing prior to physiological maturity of the grain. The grain quality of the samples harvested at each sampling time was assessed by the Ricegrowers Co-operative Limited Rice Appraisals Laboratory using the standard commercial procedures. Further biomass samples were collected once after maturity to provide data on total biomass, grain yield and yield parameters.

Crop growth and management data was originally obtained for the period up to P.I. from the NIR Rice Tissue Test. Local climatic data for the grain ripening and drying period was obtained from existing regional weather and supplemented by some strategically located portable equipment.

The resulting extensive database contained a large and diverse range of information on the growth, management, yield and grain quality, and climatic conditions during harvest of the sampled crops. The data represented some 433 commercial rice crops from all ricegrowing regions, 3630 individual grain samples from 8 - 10 weekly harvests from late February to early June over four rice harvest seasons from 1993 to 1996.
Secondary Objective - Survey of Knowledge, Attitudes and Constraints
In March/April 1993 focus discussion groups were held in five Agronomy Districts at Griffith, Coleambally, Deniliquin, Finley and Jeridierie. Farmers from one of the 50 regular Rice Discussion Groups were invited to a special meeting to discuss rice grain quality. The District Agronomists acted as facilitators and recorders for each group.

Secondary Objective - Extension Programs on Grain Quality
The NSW rice industry has, through NSW Agriculture, an organised and structured extension network. Grain quality issues would be promoted using a range of extension methodology and activities which are supported by the rice industry through the RIRDC rice program.

RESULTS & CONCLUSIONS

Results
The 1993 sequential harvest provided an extensive data base of crop, grain moisture and whole grain information for 84 crops of the medium grain variety Amaroo. This sequential harvesting data showed that as a rice crop matures, the percent whole grain (% WG) will rise and peak when all or most of the grains reach physiological maturity (PM). Results showed that all crops have a potential to achieve high % W/G returns with peaks averaging around 65%, within a range of 62 to 70 %WG.

Initial analysis showed two broad groups of crops:-

Group One - crops with an average slow rate of %WG decline after reaching 62% Whole Grain, associated with a slow rate of %GM decline averaging 2.5% per week.

Group Two - crops with a fast average rate of %WG decline associated with a faster %GM decline of 3.5% per week.

A Grain Moisture Model was then developed that relates the environment and grower management practices to the decline in %GM. From a given moisture level, a rate of decline is then established using weather data and an assessment of the moisture status of the soil underneath the crop sample area. Once developed the application of the model to the 1993 data gave an average error for estimated grain moisture of 2.12%.

A Whole Grain Model was then developed to predict the percentage whole grain using the rate of grain moisture decline as the major input. Applying the model to the 1993 crops showed an average error for estimated % Whole Grain of 6.3%

The model was tested against the 80 Amaroo crops from the 1994 harvest. The model performed to a similar of accuracy as for the 1993 year.

The 1994 model was applied to the 1995 data with the grain moisture decline model adequate to explain the variation of grain moisture. However, the whole grain decline model component was not adequate, as %WG declined much quicker than anticipated. It was seen that the rapid drop in %WG observed in some crops was associated with rainfall events after the %GM had reached 20 - 22 % moisture. An attempt was made to improve the model with a rainfall factor, which was only partially successful.

The results from the 1996 harvest tended to confirm the model relationship results established for the medium grain variety Amaroo from the previous harvests. The Grain Moisture Model continued to predict a drying line within 2% of the measured moisture. However the Whole Grain Model was more variable with the average continuing to be around 6% whole grain, similar to the 1993 and 1994 harvest data and better than the 1995 data.
Discussion & Conclusions

Amaroo and Medium Grain Varieties

One constant over the four years of data is that all crops have a high potential % WG around 62 to 70% WG, with a norm of about 65 to 66%. A further examination of the data showed that after the peak %WG was reached that the %WG remained relatively stable until the %GM dropped below 20-22%GM. After this point, over the remaining 6 to 8 weeks sampling period, a wide range of situations occurred varying from a relatively stable %WG with little decline to a rapid decline to very low levels of %WG, and many variations in between. In some cases a long period of relative stable %WG is followed by a sudden decline in one week of up to 30%WG or more.

The subsequent modelling analysis showed that evaporative demand, as measured by calculated ET$_{o}$, was strongly linked to the decline in grain moisture. However, a major modifier of this was the moisture content of the surface soil under the crop. This soil moisture, can reduce the impact of the evaporative demand to 80% of the full drying effect that occurs when the soil is very dry and firm.

The Grain Moisture Model provided a very adequate predictor of grain moisture decline from a known point or moisture content over the four years of data. It was only modified slightly over the period of the project by modifying the minimum level of grain moisture. The level of accuracy was around + or -2%, which held up fairly well over the four seasons and across all the varieties tested.

The Whole Grain Model developed during the analyses also performed well, but not as accurately as the moisture model. Initially the error was +or - 6% for Amaroo.

The original whole grain model was modified in 1994 to take into to account the fact that %WG remained fairly stable until the grain moisture reached 20 to 22%. After this the %WG would only decline significantly when the evaporative demand exceeded around 2mm per day.

The 1995 harvest data confirmed the general model, except in cases where a rapid decline in %WG occurred. These large changes in %WG, linked to rainfall, sometimes exceeded 30%WG over the period of a week. A rainfall factor of improved the prediction, but was still not satisfactory. The relationships could no doubt be improved by more specific rainfall data collected nearer to the sampled crop site and some of this data may be available.

The other medium grain varieties Jarrah and Millin generally follow the same patterns except that the rate of % WG decline is faster and rainfall events, particularly for early sown crops, are likely to cause severe declines in %WG even for small rainfall events.

Long Grain Varieties

The Grain Moisture Model seems to simulate the moisture changes for long grain varieties adequately. However, the Whole Grain Module has major deficiencies. The long grain varieties seem to differ to the medium grain varieties in two respects:

- Long grains do not seem to have a constant high potential peak whole grain millout and the maximum values can fluctuate significantly.
- The %WG seems to be more stable and perhaps not as affected by evaporative demand and rainfall as the medium grain varieties.
Conclusions
In conclusion the project study has shown that:-

1. All medium grain crops have a potential high whole grain yield of around 65%
2. The potential % whole grain remains stable until the grain moisture drops below 20-22%
3. After 20-22% grain moisture the rate of % whole grain decline directly related to evaporation
4. At daily evaporation rates of less than 2mm per day % WG does not decline
5. After 20-22% grain moisture rainfall can cause a major decline in % whole grain of up to 30% or more in a week
6. Surface soil moisture under the crop canopy modifies the impact of evaporative demand
7. The earlier maturing medium grain varieties have a similar response to Amaroo
8. Long grain varieties such as Langi, Doongara and Kyeema respond differently

4.2 Survey of Knowledge, Attitudes & Constraints
The 1993 focus groups program was an interesting exercise. One statement made at one of the meetings summed the general standard of knowledge, attitudes and action related to the issue of % whole grain. The statement was “growers have 25% control over grain quality, the other 75% is in the lap of the gods”. However, there would not be universal agreement on what was the 25% that could be controlled, let alone debating the percentage.

Overall we do not seem to have an adequate understanding rice grain quality, in general, and % whole grain in particular. What they do know is confounded by a combination of half truths, myths and misunderstandings. As well there is not general acceptance that it is their problem, rather than the problem of others. There was also a perception that practices that may improve quality are at the expense of yield, and/or increased cost of production.

Results and Discussion
The survey outlined a range of issues that relate to quality, and the ricegrowers attitudes and actions. Obviously there was a need to educate farmers about quality and whole grain issues. However, just as obviously the issue is a complex one, which will not be resolved just by more knowledge and understanding of the whys and hows.

The real problems of whole grain quality still are a major issue. Specifically the issues raised in the original groups are still current, only two of which, those relating to crop management and weather conditions, are directly covered by the project and its results. These issues are as follows:-

- Crop management
- Weather conditions
- Field Trafficability
- Header Settings
- Receival Policies and Capacities
- Rice milling and handling
- Appraisal System
- The Premium System
4.3 **Extension Program on Grain Quality**

The results coming out of the project have been incorporated into the mainstream rice extension activities since the completion of the first harvest in 1993. Two publication outputs have been the Ricecheck Recommendations Book and an IREC Farmers Newsletter article “Improving % whole grain millout”.

5. **RECOMMENDATIONS**

The following recommendations are made as output from the project:-

5.1 **Extension of best management practices**

*That Best Management Practices on producing high whole grain quality grain, and the underlying technology, be promoted to ricegrowers through the rice extension programs.*

5.2 **Extension report on the project**

*That an extension publication Report on the Project be written and published, and distributed to all ricegrowers.*

5.3 **Industry policy issues**

*That the industry needs to consider all the impacts of policy and operational decisions on the attitudes and actions of ricegrowers in relation to % whole grain and harvesting and delivery practice.*

5.4 **Analysis of project data & future research**

*That the project data be analysed further, and consideration be given to future investigations.*

5.5 **Publication of the results in a scientific paper**

*That the results of the project and the simulation modelling be published in a scientific paper.*

5.6 **Development of a decision support system**

*That the need and practicality of developing a decision support system to assist growers in draining and harvest decisions related to moisture drydown be investigated.*

5.7 **A grain quality workshop**

*That a Grain Workshop involving representatives of Ricegrowers’ Association of Australia, the Ricegrowers’ Co-operative Limited and NSW Agriculture be held to discuss the results of the project and the future quality objectives and the needs of commercial policies and practice, technology and research.*
1. BACKGROUND

Grain quality has always been an important feature of the marketing strategies of the NSW rice industry that have successfully met the needs of domestic and international markets. There are many aspects of quality that relate to cleanliness, appearance, size and shape of the grain, taste and cooking quality, and milling and processing results.

Grain quality is an important component in the marketability of rice products and hence affects the returns to ricegrowers and the profitability of rice growing. Grain quality parameters may be affected by variety, seasonal conditions and grower management practices.

The premium core product of rice processing is the whole polished rice grain after the hull and bran layer have been milled off. Polished broken grain is a secondary product of milling which is severely discounted in value. Some broken polished grain is inevitable and is used as a small, but variable component of white rice product, depending upon market specifications. Excessive broken grain reduces the return to the industry and the growers.

The percentage of whole grain after milling, % whole grain, has long been of concern to the NSW rice industry. There is a wide variability in % whole grain results between medium and long grain varieties, individual crops (less than 20% up to over 68%) and between seasons (35 to 64%), which impacts on total returns.

In 1969 the industry introduced a rice appraisal scheme, which introduced a small premium payment for variations of % whole grain, in an attempt to improve % whole grain results. Continuous sampling of paddy rice occurred as rice was delivered after harvest to obtain a representative sample of a ricegrowers crop, which was then milled and graded to obtain a laboratory assessment of % whole grain and other quality parameters in the rice delivered.

The original approach, which continues largely unmodified, was to take $4 per tonne off the price pool to establish a premium reserve. The average % whole grain and an upper and lower range scale of % whole grain was established for each season, and growers achieving around the average received $4/tonne premium. The maximum premium was $8/tonne for those at the top of the scale whilst those achieving at the bottom of the range received no premium.

The scheme was not popular as most growers contended that they had little or no ability to affect % whole grain, and did not regard the premium as a significant factor. The premium range was increased to $12/tonne in 1995.

Research has indicated that crop and harvest management practices can greatly influence the level of whole grain millout achieved. Nitrogen fertility, environmental conditions during grain ripening and drying (as changed by season and time of sowing), and timing of draining and grain moisture content at harvest are all factors that will help determine final % whole grain within the limits imposed by the variety and season.

On the other hand many ricegrowers believed that rice grain quality, and in particular whole grain millout, is not a manageable outcome, but is largely dependent upon variety and seasonal environmental factors. This attitude was reinforced by the small reward/penalty of the appraisal scheme associated with delivery of good or poor quality grain.

In 1992 the % whole grain achieved after commercial milling of medium grain varieties was 51%, the lowest for at least a decade. This compared to a ten year average of 58% and a high of 65%. Conservative estimates by the industry indicated a reduction in 1992 pool returns of $8 million from this harvest attributable to low % whole grain yields.
The result for long grain varieties was better (compared to normal), only slightly below average at 44%. This compares to a 10 year average of 46.6% and a high/low range of 51 and 35% respectively. The results of the commercial % whole grain results for medium and long grain varieties for the 1983 to 1992 harvests are contained in Figure 1.

![chart showing % whole grain results for medium and long grain varieties 1983-1992](image)

**Figure 1:** Commercial % whole grain results for medium and long grain varieties 1983 - 1992

An examination of % whole grain results from the Rice Appraisal Scheme for the medium grain variety Amaroo showed a wide range of variation. (Figure 2) In 1992 the average % whole grain appraisal result was around 57% with 5.1% of crops yielding 45% or less. Only 8.1% of crops assessed yielded more than 65% whole grain.

In the 1991 harvest the average was around 61%, with only 0.7% of crops yielding less than 45% whole grain. However, 19.7% of crops gave whole grain appraisals exceeding 65%.

These results highlight the problem facing the industry that in a poor whole grain season there can be easily be a extra 10% of broken grains to market at a discounted price. On a production of 1 million tonnes this means an extra 100,000 tonnes of broken grains to market.

Many rice growers appeared to have a somewhat ambivalent attitude to grain quality and % whole grain. There was also a generally low level of awareness of the issues involved and the effects on income and profitability. The reality is that there appeared to be little financial inducement for individual rice growers to be concerned with quality. There was also a perception that rice growers could not affect the result anyway.

On the issue of quality rice growers, including industry leaders, had a wide range of opinions. On one hand there were rice growers who had a good basic understanding of the role of grower management in producing high quality rice, but are constrained by what they are prepared to do because of their assessment of the balance between the costs of aiming to deliver high quality rice and the rewards received in the form of premiums. On the other hand there was a strong body of opinion that the seasonal factors were the major determinants of whole grain yields over which growers had little control. Another strongly held opinion is that adoption of the practices on farm that are recommended for achieving high % whole grain do not necessarily result in high quality rice being delivered.
In summary genetic and environmental factors were generally accepted as major determinants of grain quality, including the % whole grain after milling. However, grower management factors, whilst they are known, are not well accepted by growers.

The rice industry recognised the importance of the problem. It also recognised that its policies and practices on grain receival, particularly moisture limits and receival capacity, storage and processing, and payments to growers, particularly premiums for high quality, influence the results.

Notwithstanding these influences it is accepted that awareness, understanding and acceptance of the on farm management factors and their role in % whole grain yields is a precursor to any change in growers practice and improvement in % whole grain yields.

How can this be achieved?

The industry will continue to examine its policies and practices that impact on grain quality. NSW Agriculture will continue to focus on quality in the breeding program and continue experimental work on quality and agronomic management. What more is needed?

Firstly, it was concluded that the final proof of the role of management practices on % whole grain was to measure what happens with the quality of commercial rice grain on growers farms, and relate the results directly to what happens on the farm and the local climatic environment.

Secondly, recognising that a change in practices must be preceded by a change in knowledge, understanding and attitudes, it is important to know the current knowledge and attitudes to grain quality and any barriers and constraints to change.

Thirdly, the results of these investigations must be combined to develop and implement an appropriate extension program to change knowledge, attitudes and practices related to achieving potential high % whole grain.
Out of this the RIRDC Project DAN 86A “Improvement of rice grain quality” was developed.

Initially the project was approved for two years, from the 1 January 1993 to 31\textsuperscript{st} December 1994. This allowed field sampling for the 1993 and 1994 rice harvests. After these two successful harvests the project was subsequently approved to cover the 1995 and 1996 harvests. The project concluded on the 30\textsuperscript{th} June 1997.

The majority of expenditure for the project was used to employ and resource a Technical Officer to undertake the work of the project. This staff was initially located at Griffith and then at Yanco. Additional field support for the extensive sequential harvesting program was provided by the Technical Officer located at Finley with the RIRDC Rice Project DAN81A “Performance evaluation of commercial rice crops”, and the Ricegrowers’ Co-operative Limited.

Quality appraisal of all grain samples was undertaken by the Rice Appraisal Centre of the Ricegrowers Co-operative Limited.
2. OBJECTIVES & STRATEGIES

The **AIM** was *to improve the quality of paddy rice, in particular the percentage of whole grain after milling, through the adoption of appropriate crop management technology and practices.*

The Primary **OBJECTIVE** is:-

1. *To identify the management practices in commercial ricegrowing that most effect rice grain quality, in particular % whole grain.*

The Secondary Objectives are:-

2. *To identify the barriers and constraints to the adoption of management practices to improve grain quality.*

3. *To develop and implement a rice extension programme to encourage the transfer and adoption of rice management technology that maximises rice grain quality.*

The **STRATEGIES** to be used include:

**Primary Objective** -
- To sequentially harvest grain samples from selected rice crops to measure the decline of grain quality after physiological maturity and to relate the results to crop and harvest management practices and environmental conditions.

**Secondary Objectives** -
- To survey rice growers and those associated service personnel to establish current levels of knowledge and understanding of grain quality issues; to determine attitudes to the role of management in affecting grain quality; and to identify the key barriers and constraints to improving quality.

- To identify the key rice management practices that need to be changed to improve quality and the factors that will facilitate or constrain such change.

- To target those key management practices in an extension integrated and co-ordinated extension programme.
3. METHODOLOGY

The methodology used for each objective is outlined below:-

3.1 Primary Objective - SEQUENTIAL HARVESTING & GRAIN QUALITY ASSESSMENT

To identify the management practices in commercial ricegrowing that most affect rice grain quality

By sequentially harvesting grain samples from selected rice crop to measure the decline of grain quality after physiological maturity and to relate the results to crop and harvest management practices and environmental conditions.

The approach used was to select a range of commercial rice crops representative of all crops by a set of variable criteria, and sequentially sample harvest them over a period of 8 to 10 weeks commencing prior to physiological maturity of the grain. The grain quality of the samples harvested at each sampling time were assessed by the Ricegrowers Co-operative Limited Rice Appraisals Laboratory using the standard commercial procedures. Further biomass samples were collected once after maturity to provide data on total biomass, grain yield and yield parameters.

Crop growth and management data was originally obtained for the period up to P.I. from the NIR Rice Tissue Test. Further survey obtained data from P.I. up to the completion of harvest. Local climatic data for the grain ripening and drying period was obtained from existing regional weather and supplemented by some strategically located portable equipment.

The resulting extensive database contained a large and diverse range of information on the growth, management, yield and grain quality, and climatic conditions during harvest of the sampled crops. The data represented some 433 commercial rice crops from all ricegrowing regions, 3630 individual grain samples from 8 - 10 weekly harvests from late February to early June over four rice harvest seasons from 1993 to 1996.

Crop Sampling & Harvesting

The process of crop sampling and harvesting to obtain the grain samples and yield data was a most labour intensive part of the project. In the first year of the project 84 commercial crops of the Amaroo medium grain variety were sequentially sampled. In the second year of the project 132 crops were sampled. Whilst Amaroo remained the main variety, crops from four other commercial varieties were included. In 1995 and 1996 100 and 117 crops respectively were sampled, across a range of varieties.

Overall the late maturing medium grain variety Amaroo was the main variety tested, accounting for 54% of the crops sampled. At the commencement of the project this variety accounted for some 60% of total rice production. The earlier maturing varieties Millin and Jarrah accounted for some 26% of total crops sampled. Grain cracking is a major problem in the medium grain varieties.

Long grain varieties Langi, Kyeema and Doongara were also included to a total of 20% of crops sampled. Whole grain yields of long grain varieties are normally lower than those of the medium grain and do not usually vary to the same extent.

A summary of crops sequentially sampled by year and variety is contained in Table 1. A more detailed outline of the number crops sampled by year, variety and geographic location is contained in Appendix I.
Variety

<table>
<thead>
<tr>
<th>Year of Harvest</th>
<th>Amaroo</th>
<th>Millin</th>
<th>Jarrah</th>
<th>Langi</th>
<th>Kyeemah</th>
<th>Doongara</th>
<th>Expt varieties</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>84</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>84</td>
</tr>
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<td>5</td>
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<td>14</td>
<td>14</td>
<td>-</td>
<td>-</td>
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<td>-</td>
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<td>38</td>
<td>44</td>
<td>24</td>
<td>20</td>
<td>7</td>
<td>433</td>
</tr>
</tbody>
</table>

Table 1: Number of crops sampled by variety and year of harvest

Crop selection
The crops selected had not only to be a commercial rice crop, but representative of all the growing, management and climatic conditions present in the “real world” of ricegrowing. To this end extensive effort went into ensuring that the crops selected were representative of all the major factors that may impact on grain quality (Table 3):

◊ All the major ricegrowing regions of the Murrumbidgee Irrigation Area, the Coleambally Irrigation Area and the Eastern and Western Murray Valley (e.g. Table 2)

<table>
<thead>
<tr>
<th>Griffith</th>
<th>Yanco</th>
<th>Coleambally</th>
<th>Berriquin</th>
<th>Wakool</th>
<th>Deniboota</th>
<th>Denimein</th>
<th>Total</th>
</tr>
</thead>
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<td>14</td>
<td>15</td>
<td>14</td>
<td>20</td>
<td>10</td>
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</tr>
</tbody>
</table>

Table 2: Location of project crops for 1993 harvest

◊ A range of sowing time from early October to mid November, depending upon variety.

◊ A range of nitrogen fertility conditions (based on P.I. nitrogen status) from low to high.

◊ A range of rice varieties, but with emphasis on the medium grain varieties. (Table 1)

<table>
<thead>
<tr>
<th>Shoot Number @ P.I.</th>
<th>Tissue Nitrogen @ P.I.</th>
<th>Sowing Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>316 to 1623/m²</td>
<td>0.79% to 2.89%</td>
<td>21 Sept to 27th November</td>
</tr>
</tbody>
</table>

Table 3: Range of values for Project crops for the 1993 harvest

The database from the NIR Rice Tissue Test, which each year contained data from some 1500 individual rice fields provided an excellent resource for the selection process. It provided information for each crop from field history, sowing time through to P.I. date and nitrogen status.

Crop Sampling and Threshing.
Once the crops were selected and the growers involved agreed to participate in the project an area of approximately 100 m² (10m x 10m) of uniform crop area representative of the general crop situation was pegged out. This provided sufficient area to provide at least 8 harvest areas of 2.5 m² (1.6m x 1.6m) to provide a minimum of 2kg of grain at each harvest.

After normal harvest moisture is reached one of the harvest samples was accurately measured to provide a grain yield measure. An additional sample of 1m² area was harvested for yield parameters,
including total shoot biomass, shoot number, harvest index, 1000 grain weight and % sterility. There was also sufficient buffer area to allow for additional samples and errors.

The sequential harvest sampling was commenced prior to physiological maturity of the grain, (28 to 30% grain moisture), to ensure that the harvest period included the physiological maturity stage. Sequential harvesting continued every week, or as close as work schedules and weather conditions allowed.

The sample crop areas for the weekly grain samples were cut around 20cms below the panicle base and placed in hessian bags, to minimise potential for sweating prior to threshing). On the same day these samples were threshed through a Hege Plot Harvester and cleaned.

The grain samples were then moisture tested, initially through a Motomco moisture meter. In the second year a comparison was made with moisture testing on a NIT (Near Infrared Transmission spectroscopy) instrument (Appendix I). This instrument was used in all subsequent testing for moisture and protein testing.

As far as possible the sampling and handling, and grain threshing techniques used tried to ensure that the measured grain moisture mirrored the result that would be arrived at under commercial header harvesting conditions. During 1993 a comparison of grain moisture results was made between paddock threshing and storing the grain in glass jars before testing and the adopted project system of storing in hessian bags, threshing and moisture testing at a central location. The adopted system gave a result slightly more than 1.1% less than the glass jar technique. Appendix III outlines a comparison on five crops.

Nevertheless there is continuing concern that the system of handling, threshing and moisture testing the grain gave slightly higher results than those resulting from normal commercial machinery harvesting. A preliminary attempt was made to quantify this potential difference between the % grain moisture and % whole grain results in a comparison between hand sampling/threshing (as used in the project) and commercial machine harvesting.

In this one comparison there was a fairly consistent relationship between the two methods although the grain moisture was around 1% higher and the whole grain yield 1 - 2% lower. Nevertheless the results provide some evidence that the trends of the project results are closely related to the commercial farm situation. However, the relationship needs further clarification.

After threshing and moisture testing the samples were sent to the Rice Appraisal Laboratory within 24 hours of sampling.

**Quality Appraisal**

The quality appraisal process aims as far as possible to duplicate the process and conditions that occur in the commercial milling process.

Each grain sample received was firstly dried down by forced aeration to approximately 14% moisture (maximum 14.3% moisture for storage), after which they were stored for at least 9 weeks to allow the samples to temper.

After the storage period the procedures for appraisal are as follows:-

1. The sample is mixed and reduced, and a 1200gm sample weighed.
2. Cleaned in a Carter-Day Dockage Tester to remove straw, dust, empty hulls, shrivelled grain, and other foreign material by aspiration and screening.
3. A 1000gm sample is then passed through a Satake Huller to remove the hulls which are weighed.
4. The brown rice is then passed through a Magill No 3 Batch Mill to remove the bran layer and to polish the grain to produce white rice (approximately 30 seconds for bran layer removal and 30 seconds for polishing). This white rice sample is then aspirated to remove any bran or rice flour and weighed.

5. The white rice sample is then passed through an indent cylinder to remove the broken grain, which is then weighed and the % WG calculated.

6. The samples are then manually assessed to measure the content of discoloured and chalky grain.

**Crop data**

Extensive data on each individual crop was collated. Firstly the NIR Rice Tissue Test Data Base, which was used to select the project crops, provided data from paddock selection up to PI (panicle initiation) testing, including paddock history, sowing date and method, pre-PI fertiliser use, PI tiller number and %nitrogen content. An initial simulation model was developed from the 1993 harvest which was then tested on the subsequent harvest data to test the accuracy of prediction. The original model was then modified if necessary.

After harvest co-operating ricegrowers were surveyed to collect data from PI up to harvest, including data on flowering dates, early pollen microspore water depth, and commercial harvest and yield information.

**Weather Data**

Weather data covering the project harvest period was collected from regional weather stations and some temporary sites. The key information recorded was temperature, humidity, rainfall, solar radiation and wind.

**Analysis of Data**

After each harvest analysis of the extensive range of data covering grain quality appraisal results, crop growth and management information, and weather data was undertaken to explore changes (both in rate and magnitude) in grain moisture and % whole grain, and relationship between these changes and external factors related to the crop and/or the weather conditions at harvest. Initially some standard statistical techniques were used but were not particularly productive.

Next a grouping approaching was employed using linkage cluster analysis. This yielded some useful insights into the role of the rate of grain moisture decline. However, much of the analysis to date has used simulation modelling techniques to relate weather conditions during the harvest period to changes in % moisture content and % whole grain.

A daily time step simulation model was fitted to the moisture content and whole grain data collected for each sample day and each paddock. The model was initialised by the first observation of moisture content for each crop. From that first sample, the model attempted to predict the grain characteristics at future sample times. The philosophy of model development was to minimise the number of steps required to explain the total variation of moisture content and whole grain millout observed. For each year, the model was scrutinised for it's capacity to predict moisture content and whole grain, and adjusted accordingly.

The parameters of the model were estimated for all observation of each variety each year. The simulation process used a least squares method to reduce the difference between the observed and predicted values.
3.2 Secondary Objective - SURVEY OF KNOWLEDGE, ATTITUDES AND CONSTRAINTS

To identify the barriers and constraints to the adoption of management practices to improve grain quality.

By

surveying rice growers and those associated service personnel to establish current levels of knowledge and understanding of grain quality issues; to determine attitudes to the role of management in affecting grain quality; and to identify the key barriers and constraints to improving quality.

and

identifying the key rice management practices that need to be changed to improve quality and the factors that will facilitate or constrain such change.

In March/April 1993 focus discussion groups were held in five Agronomy Districts at Griffith, Coleambally, Deniliquin, Finley and Jerilderie. Farmers from one of the 50 regular Rice Discussion Groups were invited to a special meeting to discuss rice grain quality. The District Agronomists acted as facilitators and recorders for each group.

The facilitators introduced the topic along the lines "that whole grain millout as one measure of grain quality was 51% for the 1992 season compared to the 10 year average of 58% and a high of 65%. Please discuss and raise any issues you see which relate to grain quality".

The role of the facilitators was to promote and encourage discussion and ensure contributions from all participants. They were instructed not to give any personal opinions or answer questions. This was an attempt, as is the focus group method, to not influence the discussion in any way.

3.3 Secondary Objective - EXTENSION PROGRAMS ON GRAIN QUALITY

To develop and implement a rice extension programme to encourage the transfer and adoption of rice management technology that maximises rice grain quality

By

targeting those key management practices in an integrated and co-ordinated extension program

The NSW rice industry has, through NSW Agriculture, an organised and structured extension network. It uses a range of extension methodology and functions which are supported by other rice industry through the RIRDC rice program. Key elements are:-

- **Rice Discussion Groups**  A system of nearly 50 ricegrower neighbourhood groups that meet 4 to 5 times each year to discuss ricegrowing technology, recommendations, crop development and problem issues. Group membership varies from around 10 to 20.

- **Preseason Rice Meetings**  A series of 8 grower meetings held prior to sowing each year to provide an update of latest technology, recommendations, and advice on specific problems.

- **Rice Field Days**  Rice Field Days are held each year to focus on current issues relating to the season, and current research and demonstration programs, including the inspection of experimental or demonstration plots on Research Station and/or ricegrower fields. Format varies from one central field day to a series of district fields depending upon priorities or availability of plots. Additional field days may also be held on specific issues, such as weed control.
• **Ricecheck Program**  This is the industry’s objective crop management program, which delivers objective recommendations to growers each year on crop management and growth standards. It provides a framework for growers to compare their crop growth and management performance with the recommendations, with a view identifying problems and correcting management and outcomes the next season. The recommendations are published in an annual *Ricecheck Recommendations* booklet each year.

• **Publications & Media Output**  Radio, TV and newspapers are regularly used to provide information. A range of publications are published each year to provide detailed information to ricegrowers.

• **Co-ordinated Research and Extension Team**  The research and extension components of the NSW Agriculture Rice Team have a close working relationship which enables a seamless flow of both research output, field experience and problem definition between the two groups.
4. RESULTS & CONCLUSIONS

4.1 SEQUENTIAL HARVESTING & GRAIN QUALITY

INITIAL RESULTS - 1993 HARVEST
The 1993 sequential harvest provided an extensive data base of crop, grain moisture and whole grain decline for 84 crops of the medium grain variety Amaroo.

A preliminary examination of the sequential harvesting data showed that as a rice crop matures, the percent whole grain (% WG) will rise as more grains within individual panicles in the crop sample reach physiological maturity and peaks when all or most of the grains reach physiological maturity (PM). This is consistent with there being a range of maturity within individual panicles and between panicles in a crop, with the peak %WG occurring as the later grains on the panicles ripened and reached PM. After this the %WG would then decline to a greater or lesser extent as the grains lost moisture, with %WG in some crops declining much faster than in others.

Only 71 of the 84 crops were sampled early enough to establish when the % W/G peak occurred. Sequential sampling of the remaining 13 crops started after the crop had reached physiological maturity and therefore after the crop had began to decline in its % WG.

Results for the 71 crops showed that all crops have a potential to achieve high % W/G returns. The peaks average was 66.8% with a high of 70.4% and a low of 62.4% (SD=1.98). The average grain moisture averaged 24.2% when the % W/G peaked, but the variation was greater (SD=3.62).

The sequential harvest data was then analysed using two approaches. Firstly they were separated into groups using a linkage cluster analysis on the shape of their % W/G curves after reaching 62% W/G. These groups were then compared with each other to identify any significant difference in their means.

Secondly the crops were analysed on an individual basis where the grain moisture and % W/G decline was modelled.

Grouping Analysis
The 71 crops were separated into various groups by a linkage cluster analysis whereby the crops with similar percentage Whole Grain decline curves were arranged in order of similarity. From this dendrogram the crops were divided into just two main groups:-

* Group One - 40 crops with an average slow rate of percentage of Whole Grain decline after reaching 62% Whole Grain. This group declined an average of around 10% WG to 55% within 8 weeks of peak %WG.

* Group Two - 31 crops with a fast average rate of percentage Whole Grain decline after reaching 62% Whole Grain. In comparison this group declined an average of over 20% WG within the 8 weeks of peak %WG.

The average %WG decline of the two groups over the 9 week period after reaching 62% WG is shown in Figure 3.
Apart from the difference in the rate of decline of %WG between the two groups, the main feature was the difference in the rate of % grain moisture (GM) decline. Group 1, the group with the slow rate of %WG decline, had a comparatively slow rate of %GM loss. The average %GM loss was approximately 2.5% per week. Group 2 was comparatively quicker drying, with an average %GM loss of 3.5% per week.

A direct comparison of the rate of grain moisture decline over the 9 weeks after peak %WG of the two groups shown that Group 1 had a significantly slower rate of grain moisture decline after 21% GM than Group 2 (at 1% level). (Figure 4)
Figure 5: Effect of rate of % Grain Moisture decline after 21% Grain Moisture on % Whole Grain at final harvest.

The rate of grain moisture decline was then established by fitting a non linear regression for each crop. A correlation was then determined for the % whole grain achieved at the end of eight weeks sampling to the rate of grain moisture decline after 21%GM was reached.

Having established that the rate of grain moisture decline after 21%GM affected the final decline in %WG at the final sample harvest the factors which could most effect the rate of grain moisture decline were examined. A range of crop management, growth and yield parameters from each group of crops are listed below with groups tested to see if they are significantly different (Table 4).

<table>
<thead>
<tr>
<th>Management Factor</th>
<th>GROUP 1 - slow drying crops</th>
<th>GROUP 2 - quick drying crops</th>
<th>Significance at 5% LSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOWING DATE</td>
<td>25 OCT 92</td>
<td>21 OCT 92</td>
<td>NO</td>
</tr>
<tr>
<td>P.I DATE</td>
<td>15 JAN 93</td>
<td>13 JAN 93</td>
<td>NO</td>
</tr>
<tr>
<td>STERILITY</td>
<td>20%</td>
<td>14%</td>
<td>YES</td>
</tr>
<tr>
<td>1000G WT</td>
<td>25.161 gm</td>
<td>25.479 gm</td>
<td>NO</td>
</tr>
<tr>
<td>P.I. SHOOTS</td>
<td>886/m²</td>
<td>876/m²</td>
<td>NO</td>
</tr>
<tr>
<td>P.I. NIR_N</td>
<td>1.525%</td>
<td>1.447%</td>
<td>NO</td>
</tr>
<tr>
<td>P.I. NIR_PHO</td>
<td>0.321%</td>
<td>0.315%</td>
<td>NO</td>
</tr>
<tr>
<td>P.I. NIR_SUL</td>
<td>0.129%</td>
<td>0.125%</td>
<td>NO</td>
</tr>
<tr>
<td>P.I. NIR_K</td>
<td>1.049%</td>
<td>0.947%</td>
<td>NO</td>
</tr>
<tr>
<td>YIELD</td>
<td>9.37t/ha</td>
<td>9.03t/ha</td>
<td>NO</td>
</tr>
</tbody>
</table>
Table 4: Comparison of mean crop management, growth and yield parameters for Crop Groups 1 & 2.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Crop Group 1</th>
<th>Crop Group 2</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chalk</td>
<td>3.93%</td>
<td>3.26%</td>
<td>No</td>
</tr>
<tr>
<td>Biomass</td>
<td>2.158 kg/m²</td>
<td>1.957 kg/m²</td>
<td>Yes</td>
</tr>
<tr>
<td>Harvest Shoots</td>
<td>692/m²²</td>
<td>623/m²²</td>
<td>Yes</td>
</tr>
<tr>
<td>Harvest Index</td>
<td>51%</td>
<td>47%</td>
<td>No</td>
</tr>
</tbody>
</table>

The analysis shows that only three factors were significant at a 5% level. The slow drying crops of Group 1 had significantly more floret sterility than the fast drying Group 2 crops, and higher biomass and harvest shoots numbers. These parameters of group 1 are consistent with crops grown under higher levels of nitrogen nutrition.

Modelling Analysis
The grouping analysis had shown that all the crops sampled achieved a high %WG at physiological maturity and that afterwards the %WG would decline slowly or quickly. The rate of %WG decline appeared linked to the rate of decline of %GM. The faster the rate in %GM the greater the rate of %WG decline and the lower the final measured %WG. The question arose that if rate of %GM drove the rate of decline of %WG then what factors influenced the rate of %GM and could the process be simulated in a model and the rate of %GM be predicted. Furthermore following this could the rate of %WG be similarly simulated and the rate of %WG decline predicted.

A model was then developed that relates the environment and grower management practices to the decline in %GM, followed by a second model that related to the rate of %WG decline. Initially a rate of grain moisture decline needs to be established with all crops as it is a major factor that influences percentage whole grain yields. To project the decline in grain moisture the model first needs a measured observation of the grain moisture. A rate of decline was than established using weather data and an assessment of the moisture status of the soil underneath the crop sample area.

**GRAIN MOISTURE MODEL**

\[
\sigma \% \text{ Grain Moisture} = K_m \times \text{Evap} \times (\% \text{GM} - \text{min mois}) \times \text{Soil Factor}
\]

- \(K_m\) - Constant = 0.00565
- \(\text{Evap}\) - Evapotranspiration rate *
- \(\text{Moist}\) - Current % Grain Moisture
- \(\text{Min Moist}\) - Minimum % grain moisture level of model = 14%
- \(\text{Soil Factor}\) - Based on a subjective assessment of surface soil moisture

* Reference crop evapotranspiration (ET\(_o\)) calculated using a locally calibrated Penman equation

The level of soil moisture is an important factor with this model, because it will vary over the period of grain drying depending upon evaporative demand, crop condition and drainage practices of the grower. At each sequential harvest stage the surface soil moisture condition was subjectively assessed in a range from flooded through to dry and very firm. This rating was then optimised to give numerical multiplication rates for use in the grain moisture model.
<table>
<thead>
<tr>
<th>Ground Moisture Key</th>
<th>Soil Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>A - Complete water coverage</td>
<td>1.0</td>
</tr>
<tr>
<td>B - Puddled water coverage</td>
<td>1.0</td>
</tr>
<tr>
<td>C - Ground very moist</td>
<td>1.0</td>
</tr>
<tr>
<td>D - Moist and firm</td>
<td>2.0</td>
</tr>
<tr>
<td>E - Slightly moist and very firm</td>
<td>2.6</td>
</tr>
<tr>
<td>F - Dry and very firm</td>
<td>6.2</td>
</tr>
</tbody>
</table>

All of the 84 Amaroo crops sampled in the 1993 harvest were used with this model. Only one grain moisture observation is needed as a commencement point for the model and is unaffected whether taken before or after the % whole grain peak. Once developed the application of the model to the 1993 data gave an average error for estimated grain moisture of 2.12%. A model was than developed to predict the percentage whole grain using the rate of grain moisture decline as the major input.

### % WHOLE GRAIN MODEL

\[
\sigma \% \text{ Whole Grain} = K_{wg} \times (\sigma \text{ moist} - (\text{Threshold } \sigma \text{ moist}))
\]

- \( K_{wg} \) = Whole Grain Constant = 0.032
- \( \sigma \text{Moist} \) = modelled grain moisture decline
- Threshold \( \sigma \text{Moist} \) = A rate of moisture decline below which below no % whole grain decline occurs.

Applying the model to the 1993 crops showed an average error for estimated % Whole Grain of 6.3%

Many other environmental and management factors were evaluated with this model without any improvement. No correlation between the errors and any other factor was evident. With the average error above 6%, the model gives an incomplete picture of the percentage whole grain process. What this model does show is the main influences to percentage whole grain and how they effect the rate of decline. The model also appears to predict quite well the point at which the % whole grain first begins to decline.

An example of Actual and Predicted % Grain Moisture and % Whole Grain for an individual crop is provided in Figure 6.
In summary from a known % GM level the Grain Moisture Model uses evaporative demand modified by the moisture in the soil surface (as affected by drainage management and evaporative demand after draining) to predict changes in %GM. In turn the Whole Grain Model uses the changes in % GM to predict changes in %WG.

The model is initialised with one observation of %GM and one of %WG. It is possible to set the initial whole grain at 65% WG if grain moisture is above 25%.

The average error of prediction is 2.12% for grain moisture and 6.3% for whole grain.

**1994 HARVEST RESULTS**

The 1994 sequential harvest provided grain moisture and whole grain decline data for an additional 80 crops of the medium grain variety Amaroo.

The model developed on the 1993 crops was tested against the 80 Amaroo crops from the 1994 harvest. The model performed to a similar of accuracy as for the 1993 year.

The model was also tested with 16 crops of the early maturing medium grain variety Jarrah. The moisture decline model arising from the 2 years of Amaroo harvest data was adequate to explain the variation on moisture decline of Jarrah. However, the whole grain decline model was not as accurate, with Jarrah declining approximately 10% faster than Amaroo.

As a result of the two years data and validation of the model on over 160 crops of Amaroo it was concluded that:-

1. All crops reach a high level of % whole grain, around 65%.
2. %WG remained relatively stable until grain moisture dropped below 20 - 22%.
3. The decline in % whole grain was correlated with the evaporative demand above 2mm on any day.
1995 HARVEST RESULTS
In 1995 sequential harvest data from an additional 39 Amaroo crops was tested with the model. The data confirmed the first two conclusions of 1994 regarding peak %WG levels and relative WG stability down to 20% GM, but the % whole grain correlation was not satisfactory.

The 1994 model was applied to the 1995 data with the grain moisture decline model adequate to explain the variation of grain moisture. However, the whole grain decline model component was not adequate, as %WG declined much quicker than anticipated.

It was seen that the rapid drop in %WG observed in some crops was associated with rainfall events after the %GM had reached 20 - 22 % moisture. In one case the %WG fell from 58.3%WG to 4.9%WG in a week, a fall of 53.4%, possibility linked to a fall of 4.6 mm rain. There were many other crops in the 1995 harvest that dropped around 30%WG in one week, which could be related to rainfall.

Figure 7: Comparison of measured (symbols) and simulated (lines) % whole grain and % grain moisture for a crop typically affected by rainfall during the 1995 harvest.

Figure 7 shows a rain affected crop where the grain moisture model simulates changes in %GM which correlate well with the actual measured changes. In contrast, the whole grain model simulates changes in %WG in line with actual measured results up until the end of April. After this, when a rainfall event occurred, the actual measured results dropped sharply, some 30%WG, at complete variance with the result simulated with the model a rainfall event coincided.

An attempt was made to improve the model with a rainfall factor. This aspect of the model was not well developed, but is along the following:-

Change in %WG = 0.23*rain (mm)

This factor accounts for most, but not all the rapid drops in %WG observed not only in the 1995 harvest data, but in some crops in the 1993 and 1994 harvests as well.
1996 HARVEST RESULTS
The results from the 1996 harvest tended to confirm the model relationship results for and the medium
grain variety Amaroo from the previous harvest.

The Grain Moisture Model continued to predict a drying line within 2% of the measured moisture. However the Whole Grain Model was more variable with the average continuing to be around 6%
whole grain, similar to the 1993 and 1994 harvest data and better than the 1995 data.

DISCUSSION & CONCLUSIONS
Amaroo and Medium Grain Varieties
One constant over the four years of data is that all crops have a high potential %whole grain approaching
the maximum of 70 to 71% at some stage of their grain ripening and drying period around physiological
maturity. In practice the range is around 62 to 70% WG, with a norm of about 65 to 66% (although it is
interesting to note that in 1984 the commercial average %WG achieved was 65%).

The actual peak level reached probably depends upon the uniformity of individual grain maturity
within panicles and between panicles as affected by factors such as tillering variability of the variety,
crop plant density and nitrogen nutrition, as well as evaporative demand conditions, drainage practice
and the timing of the weekly harvesting relative to the %WG peak. In some crops ripening under
conditions of high evaporative demand, where grain moisture is changing rapidly the weekly sample
harvest may also not coincide with the peak whole grain. Other crops drying down under less
demanding conditions can remain at or near the peak whole grain for quite a time.

This result presents two challenges which epitomise the reasons for and objectives of this project:-

- What factors impose on the crop to cause %WG to decline
- What management can the ricegrower undertake to maximise the potential %WG

A further examination of the data showed that after the peak %WG was reached that the %WG remained
relatively stable until the %GM dropped below 20-22%GM. After this point, over the remaining 6 to 8
weeks sampling period, a wide range of situations occurred varying from a relatively stable %WG with
little decline to a rapid decline to very low levels of %WG, and many variations in between. In some
cases a long period of relative stable %WG is followed by a sudden decline in one week of up to 30%WG
or more. Two examples of the extremes of %WG decline are shown in Figure 8.
Figure 8: Examples of extremes of % whole grain decline showing a crop (a late crop, moderate nitrogen) that held its quality at the high end and one (early crop, low nitrogen) that declined to a low level.

Grouping analysis of the 1993 harvest data showed that the relatively stable group of crops with a slower rate of %WG decline (1% WG per week for 7 weeks) was associated with a %GM loss of approximately 2 ½ % per week. This compared to the group of crops with a quicker rate of %WG decline (3 ½% per week for 7 weeks) which was associated with a higher %GM loss of approximately 3 ½% per week.

Further more once the crops were in the grain moisture range of 18 to 22% the average drop in %WG for the slower rate of %WG decline crop group remained at around 1% per week. For the quicker %WG decline group the rate of %GM loss at this stage was 5 ½ % per week. This data strongly suggested that the rate of decline of grain moisture was a major factor in driving the decline in whole grain yields.

The subsequent modelling analysis showed that evaporative demand, as measured by calculated ET$_{ev}$, was strongly linked to the decline in grain moisture. However, a major modifier of this was the moisture content of the surface soil under the crop. This soil moisture, probably field capacity or wetter, can reduce the impact of the evaporative demand to 80% of the full drying effect that occurs when the soil is very dry and firm.

This is likely because the presence of moisture in the soil surface provides a modified climate within the crop canopy due both to evaporation from the soil surface and the transpiration of moisture from the crop leaves. When a high level of soil moisture is present such as shortly after crop drainage then it is likely that the leaves will be fresh and green and actively transpiring.

The model provided a very adequate predictor of grain moisture decline from a known point or moisture content over the four years of data. It was only modified slightly over the period of the project by modifying the minimum level of grain moisture. The level of accuracy was around ± or -2%, which held up fairly well over the four seasons and across all the varieties tested.

The Grain Moisture Model remains as:-

\[
\sigma \% \text{ Grain Moisture} = K_m \times \text{Evap} \times (\%\text{GM} - \text{min mois}) \times \text{Soil Factor}
\]
There is some continuing concern about the relationship between the grain moisture content arising from the hand sampling and threshing used in the project and that of commercial header harvesting. The single preliminary comparison suggests that the hand technique is higher around 1%. However the low error associated with the grain moisture modelling suggests that the relationship may be fairly constant. However this issue does need further investigation.

The Whole Grain Model developed during the analyses also performed well, but not as accurately as the moisture model. Initially the error was + or - 6%.

The original whole grain model was modified in 1994 to take into to account the fact that %WG remained fairly stable until the grain moisture reached 20 to 22%. After this the %WG would only decline significantly when the evaporative demand exceeded around 2mm per day.

The whole grain model became:

\[ \sigma \% \text{ Whole Grain} = 0.032 \times (23\% - \sigma \text{ Moisture}) \times (\text{evaporation} - 2.1\text{mm}) \]

The 1995 harvest data confirmed the general model, except in cases where a rapid decline in %WG occurred. These large changes in %WG sometimes exceeded 30%WG over the period of a week. The addition of a rainfall factor of

\[ \sigma \% \text{WG} = 0.23 \times \text{rain (mm)} \]

Improved the prediction, but was still not satisfactory.

This issue of the impact of rainfall needs further attention. One immediate difficulty is that the rainfall event (time and amount) used in development and testing of the rainfall factor is not necessarily the same as that which caused the decline. All rainfall records used are from regional or district located weather stations. The normal variability of rainfall events makes it difficult to extrapolate from a weather station to a distant crop. The greater the distance the greater the likely error.

As well the impact is likely to vary with the % GM, it is possible that the dryer the grain the greater the impact? As well some heavy rainfall events would be likely to have more than a transient impact on soil moisture and the rate of %GM decline.

The relationships could no doubt be improved by more specific rainfall data collected nearer to the sampled crop site and some of this data may be available.

The other medium grain varieties Jarrah and Millin generally follow the same patterns except that the rate of % WG decline is faster and rainfall events, particularly for early sown crops, are likely to cause severe declines in %WG even for small rainfall events.

**Long Grain Varieties**

The Grain Moisture Model seems to simulate the moisture changes for long grain varieties adequately. However, the Whole Grain Module has major deficiencies.

The long grain varieties seem to differ to the medium grain varieties in two respects:

- Langi and Doongara and to a lesser extent Kyeema, do not seem to have a constant high potential peak whole grain millout and the maximum values can fluctuate significantly. The peak values can range between a high 65% and a low 52%.
- The %WG seems to be more stable and perhaps not as affected by evaporative demand and rainfall as the medium grain varieties.
Undoubtedly the long grain situation needs to be the subject of further study. In the first instance the project data needs to be more thoroughly investigated. However, there may be a need to undertake additional field sampling.

In conclusion the project study has shown that:-

1. **All medium grain crops have a potential high whole grain yield of around 65%**

   The peak whole grain varied between 62 and 70%, and occurs around physiological maturity, or 24-25% GM. The actual % WG peak reached probably depends upon the uniformity of grain maturity within and between individual panicles as affected by factors such as crop plant density, uniformity of tillering, variety, and nitrogen nutrition, as well as evaporative demand conditions, drainage practice and the duration of the peak. % WG.

   This is a very important result which suggests that if crop and harvest management is optimised then high % WG exceeding 60% can be achieved every year.

2. **The potential % whole grain remains stable until the grain moisture drops below 20-22%**

   This provides a narrow window of harvest opportunity to avoid % WG decline as maximum delivery moisture is normally limited to 22% GM, with penalties for exceedence.

3. **After 20-22% grain moisture the rate of % whole grain decline directly related to evaporative demand**

   Best management practice aims to put physiological maturity and grain drying into a period when evaporative demand is lowest (by managing time of sowing and adequate nitrogen nutrition).

   Local weather data (Appendix VII) shows that ET, levels in early February are around 20% higher than those of early March which are 40% higher than those in early April. However, whilst extremes of evaporative demand need to be avoided there needs to be a balance as delayed sowings can reduce yield.

4. **At daily evaporation rates of less than 2mm per day % WG does not decline**

   Evaporation less than 2 mm can not be avoided. 10 day means of less than 2mm do not occur till April, and then only on less than 5% of occasions. However, avoiding the periods of high evaporative demand of February and early March can still provide a benefit in terms of more moderate weather and better whole grain results.

5. **After 20-22% grain moisture rainfall can cause a major decline in % whole grain of up to 30% or more in a week**

   The risk of rainfall is present at all time, providing another reason to harvest in the safe harvest window after physiological maturity. The impact of rainfall may increase with increasing dryness of the grain. The impact of rainfall on %WG decline needs further investigation.

6. **Surface soil moisture under the crop canopy modifies the impact of evaporative demand**

   A moist soil modifies the impact of evaporation by up to 80% compared to a firm dry soil surface. This has important implications for drainage practice as draining too early not only has an impact by not filling immature grains (resulting in reduced yield and more cracked grain), but also increases the impact of evaporation on the rate of % GM and %WG decline.

7. **The earlier maturing medium grain varieties have a similar response to Amaroo**

   Jarrah and Millin are similar to Amaroo except that the rate of %WG decline may be faster and the varieties may be more sensitive to rainfall. The differences with Millin and Jarrah may be due to genetic differences and/or to the fact that early sowings of these varieties will mature earlier under a more harsh drying environment.

8. **Long grain varieties such as Langi, Doongara and Kyeema respond differently**

   The long grain varieties have a generally lower and more variable peak whole grain level than medium grain varieties, but tend to hold their levels of %WG longer. The response of long grain varieties to evaporative demand needs to be further investigated.
4.2 SURVEY OF KNOWLEDGE, ATTITUDES & CONSTRAINTS

1993 FOCUS GROUPS
The 1993 focus groups program was an interesting exercise. One statement made at one of the meetings summed the general standard of knowledge, attitudes and action related to the issue of % whole grain. The statement was “growers have 25% control over grain quality, the other 75% is in the lap of the gods”. However, there would not be universal agreement on what was the 25% that could be controlled, let alone debating the percentage.

The full report on the focus group study “Report on current ricegrower knowledge and attitudes to rice quality - 1992/93” is contained in Appendix V. The general conclusions of the discussions, provided by the facilitators, is as follows.

- Farmers cannot identify why millouts have declined.
- More questions were posed than answered.
- “In conclusion they felt that the conditions required to obtain a consistently high whole grain millout was a mystery”
- “I detected there was little extra they could do over what they are doing now to improve their appraisal
- "Growers say appraisals cannot be linked to the management of their crops”.
- "There are no set criteria or checks which if adopted guarantee better millouts".
- “I detected that whole grain millout was their main measure of grain quality although they refer to it as their appraisal.
- "Discussion mainly related to on-farm and receival issues. Farmers had poor knowledge of the milling process and found it hard to relate to this”.
- “Paddock variations, both soil type and fertility, paddock layout, uneven maturity of current varieties and getting draining time right were the major on - farm factors which they see as having an influence”.
- “To get good quality grain a grower should use less nitrogen
  - avoid topdressing at P.I.
  - have an even maturing crop, ie. avoid landformed paddocks, avoid varieties with late tillers and avoid muddy water sites.
  - have lower fertility paddocks.
  - have good water management, particularly at draining.
  - harvest at high moisture
  - sow late.
- “There is no instantaneous feedback mechanism during harvest which would allow header adjustment (we don't know how important this is anyway). Also appraisal results are communicated well after harvest and are often different to what was expected”.
- “There is a lack of knowledge about quality and what is defined by quality”.
- Farmers are still better off to lift yield than lift quality.
- “It is interesting that farmers have recommended greater financial incentives and disincentives for quality while at the same time they are unclear as to what control individual farmers have over quality”

Overall we do not seem to have an adequate understanding rice grain quality, in general, and % whole grain in particular. What they do know is confounded by a combination of half truths, myths and misunderstandings. As well there is not general acceptance that it is their problem, rather than the problem of others. There was also a perception that practices that may improve quality are at the expense of yield, and/or increased cost of production.
RESULTS AND DISCUSSION
The survey outlined a range of issues that relate to quality, and the ricegrowers attitudes and actions. Obviously there was a need to educate farmers about quality and whole grain issues. However, just as obviously the issue is a complex one, which will not be resolved just by more knowledge and understanding of the whys and hows.

The results of the project have provided much better information on the processes affecting whole grain and what needs to be done at the grower management level to improve results. This knowledge and understanding will help, but will not necessarily change the surrounding issues that affect what growers think about it (attitudes) and what they will do about it (related/resulting actions).

This view is reinforced by the response to improved knowledge and understanding arising out of the extension program that has presented the project findings. Growers are better informed, but we still need to disseminate the results and implications more widely and for some time to come. New information as well as new varieties and other impacting issues will require constant review of the situation and needs.

However, the real problems of whole grain quality still are a major issue. Specifically the issues raised in the original groups are still current. Only two issues, those relating to crop management and weather conditions, are directly covered by the project and its results. These issues can be grouped as follows:-

- **Crop management** The impact of varieties and synchronous tillering, nitrogen and general nutrition, nutrition and growth variability due to landforming, time of sowing, crop uniformity timing of draining and harvesting.

- **Weather conditions** The impact of weather conditions and the reality of avoiding poor conditions.

- **Field Trafficability** The losses, costs and risks of harvesting “moist/wet fields”.

- **Header Settings** The impact of header settings on whole grain and quality, and the efficiencies of harvesting at higher moisture. Do the strict limits on trash content of paddy result in overthreshing during harvesting.

- **Receival Policies and Capacities** The limits for grain moisture at receival centres and the penalties for exceedance, as well as the capacities of the industry to receive and dry grain.

- **Rice milling and handling** The impact of the rice milling processes on industry whole grain results.

- **Appraisal System** The difficulty of relating appraisal results from a whole farm to individual fields and their related practices.

- **The Premium System** Is it enough? and what is the best penalty/reward system.
4.3 EXTENSION PROGRAM ON GRAIN QUALITY

The results coming out of the project have been incorporated into the mainstream rice extension activities since the completion of the first harvest in 1993. Field days, discussion groups, preseason meetings have all been used to provide growers with the knowledge and understanding of the processes affecting rice %whole grain, and the recommended practices to improve % whole grain.

Two publication outputs have been:-

- **Ricecheck Recommendations Book** A section on **Harvest Grain Quality** is now a regular feature of the publication, and is revised annually.

- **“Improving % whole grain millout”** An article was published in the IREC Farmers Newsletter, No 145 Large Area, June 1995. A copy of the article is contained as Appendix VI.

The extension needs of this complex issue are ongoing. As discussed in the preceding section on knowledge, attitudes etc the extension needs cannot be considered in isolation to the other impacting issues. However it is important that the results of the project be made widely available. To this end an **Extension Report on the Project** should be published.
5. RECOMMENDATIONS

The following recommendations are made as output from the project:-

5.1 EXTENSION of BEST MANAGEMENT PRACTICES

*That Best Management Practices on producing high whole grain quality grain, and the underlying technology, be promoted to ricegrowers through the rice extension programs.*

These practices recognise that weather conditions, particularly evaporation and rainfall, are important factors, but that management aims to and can minimise the impact of these factors. These BMP will include:

- Harvest at higher harvest grain moisture content as soon as possible after physiological maturity.
- Drain on time and quickly
- Fertilise for adequate crop nitrogen
- Harvest medium grains before long grains
- Use harvest contractors if necessary
- Sowing time trade-offs
- Establish and Grow Uniform crops

5.2 EXTENSION REPORT ON THE PROJECT

*That an extension publication Report on the Project be written and published, and distributed to all ricegrowers.*

5.3 INDUSTRY POLICY ISSUES

*That the industry needs to consider all the impacts of policy and operational decisions on the attitudes and actions of ricegrowers in relation to % whole grain and harvesting and delivery practice.*

If ricegrowers are to consistently harvest and deliver rice grain of high % whole grain then improved knowledge is not enough. The industry needs to consider policies and practices in regard to:

- Harvest moisture limits and exceedence penalties
- Capacities to receive and dry high moisture grain
- Rewards/premiums to provide real incentives
- The Appraisal system

5.4 ANALYSIS OF PROJECT DATA & FUTURE RESEARCH

*That the project data be analysed further, and consideration be given to future investigations* particularly in regard to:

- The relationship between management practices and achieving high % whole grain
- Improving the simulation model particularly in regard to the early maturing medium grains and long grain varieties.
- Better understanding of the impact of rainfall on % whole grain

5.5 PUBLICATION OF THE RESULTS IN A SCIENTIFIC PAPER

*That the results of the project and the simulation modelling be published in a scientific paper.*
5.6 DEVELOPMENT OF A DECISION SUPPORT SYSTEM

That the need and practicality of developing a decision support system to assist growers in draining and harvest decisions related to moisture drydown be investigated.

Can the knowledge provided by the project be used to assist ricegrowers to achieve better decision making and harvest results.

5.7 A GRAIN QUALITY WORKSHOP

That a Grain Workshop involving representatives of Ricegrowers’ Association of Australia, the Ricegrowers’ Co-operative Limited and NSW Agriculture be held to discuss the results of the project and the future quality objectives and the needs of commercial policies and practice, technology and research.

The problem of grain quality needs to be better defined, what it is, what is needed, and the role and activities of the parties involved.
6. APPENDICES

The following appendices are attached:-

I  Number of Crops Sampled - Year of Harvest, Geographic Location and Variety

II Comparison of Grain Moisture Testing Techniques

III Comparison of the effects of field threshing/moisture sampling and central location threshing/moisture sampling techniques on grain moisture results.

IV Comparison of the effects of hand sampling/threshing and commercial machine harvesting on grain moisture and % whole grain results.

V Report on Current Knowledge and Attitudes to rice quality - 1993

VI Extension Article in IREC Farmers Newsletter

VII Potential Daily Evapotranspiration - Griffith - February to May
**APPENDIX I: Number of Crops Sampled - Year of Harvest, Geographic Location and Variety**

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APPENDIX II: Comparison of Grain Moisture Testing Techniques

AIM: To determine the variation between the standard Motomco Moisture and the NIT (Near Infrared Transmission spectroscopy) instrument methods of commercial rice grain moisture testing.

METHOD: During the 1994 harvest of the rice grain quality project, 570 grain samples from the sequential harvesting were moisture tested using both the Motomco and N.I.T machine. Samples were only compared from the MIA and CIA with both long and medium grain varieties used.

RESULTS: The two moisture testing methods proved to have a high correlation (R²=0.97) for all samples with results between 14% and 22% having the smallest average difference.

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<td>&gt; 22% % &lt; 27%</td>
<td>-0.39</td>
<td>1.294</td>
<td>0.635</td>
</tr>
<tr>
<td>86</td>
<td>&gt; 27%</td>
<td>-0.83</td>
<td>1.649</td>
<td>0.558</td>
</tr>
</tbody>
</table>

TABLE: Results of comparison between Motomco and N.I.T moisture measurements

CONCLUSION: That the NIT instrument could be used to test all grain samples for moisture content.
APPENDIX III: Comparison of the effects of field threshing/moisture sampling and central location threshing/moisture sampling techniques on grain moisture results.

**Aim**
To determine if sampling the technique affects the moisture content of the rice grain at harvest.

**Method**
During 1993 harvest 5 crops were sampled using two different methods:

**Technique 1 (Glass)** - Samples were cut then thrashed in paddock using a single head thresher. The grain was then stored in sealed glass jars for approximately five hours before moisture testing at Yanco using a N.I.T. Machine.

**Technique 2 (Bag)** - Samples were cut then stored in hessian bags for approximately five hours. The samples were then thrashed at Yanco using a header and the grain moisture tested using the N.I.T. Machine.

**Results**
Moisture results from the five crops are shown in Table 1. Technique 2 of storing cut samples in jute bags usually yielded lower moisture contents than those stored in glass jars. Results showed that there was a significant difference in the two means using a paired student T-test at 0.05.

<table>
<thead>
<tr>
<th>CROP</th>
<th>VARIETY</th>
<th>METHOD 1 - Field threshing</th>
<th>METHOD 2 - central location threshing</th>
<th>DIFFERENCE % grain moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>Amaroo</td>
<td>28.1</td>
<td>26.1</td>
<td>-2.0</td>
</tr>
<tr>
<td>Two</td>
<td>Kyeema</td>
<td>23.0</td>
<td>21.7</td>
<td>-1.3</td>
</tr>
<tr>
<td>Three</td>
<td>Amaroo</td>
<td>25.9</td>
<td>26.1</td>
<td>+0.2</td>
</tr>
<tr>
<td>Four</td>
<td>Amaroo</td>
<td>31.2</td>
<td>30.1</td>
<td>-1.1</td>
</tr>
<tr>
<td>Five</td>
<td>Amaroo</td>
<td>31.6</td>
<td>30.1</td>
<td>-1.5</td>
</tr>
<tr>
<td>Mean Difference</td>
<td></td>
<td></td>
<td></td>
<td>-1.14</td>
</tr>
</tbody>
</table>

**Table 1:** Grain moisture results for different sampling techniques.

Note: Technique two was used for the sequential harvesting of the project. However, it was felt that this method was still giving higher grain moisture readings than those recorded by the grower machine harvesting techniques.
APPENDIX IV: Comparison of the effects of hand sampling/threshing and commercial machine harvesting on grain moisture and % whole grain.

**Aim**
To compare the effects of hand sampling/threshing (as used in the project sampling) and commercial machine harvesting on grain moisture and % whole grain results.

**GRAIN MOISTURE**
It is accepted that moisture content measured in rice grain samples will be affected by the techniques used to harvest, thresh and handle the grain prior to moisture testing. A small trial was conducted to assess the impact of two techniques using the “project” technique of hand sampling and commercial machinery header harvesting.

This trial conducted on one commercial crop compared five hand cuts to five samples taken from a header. Each of the corresponding hand and header samples were taken from the same location in the crop, when the header passed over the location that a hand cut had been taken. The hand cuts were treated normally, but the header samples were sealed in plastic bottles to prevent moisture loss or gain.

<table>
<thead>
<tr>
<th>Site</th>
<th>Hand-cut</th>
<th>Header-cut</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21.2</td>
<td>19.4</td>
</tr>
<tr>
<td>2</td>
<td>19.7</td>
<td>19.3</td>
</tr>
<tr>
<td>3</td>
<td>19.9</td>
<td>19.3</td>
</tr>
<tr>
<td>4</td>
<td>20.1</td>
<td>19.2</td>
</tr>
<tr>
<td>5</td>
<td>20.6</td>
<td>19.5</td>
</tr>
</tbody>
</table>

This one case showed a fairly consistent difference of around 1% lower for the header cut samples. It shows that there is a greater than 99% probability that the sample averages are different, so have been effected differently by the collection process.

**% WHOLE GRAIN**
The grain samples used for the moisture testing comparison were appraised for % whole grain. The results are:-

<table>
<thead>
<tr>
<th>Site</th>
<th>Hand-cut</th>
<th>Header-cut</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>68.8</td>
<td>65.6</td>
</tr>
<tr>
<td>2</td>
<td>67.4</td>
<td>65.4</td>
</tr>
<tr>
<td>3</td>
<td>66.3</td>
<td>65.7</td>
</tr>
<tr>
<td>4</td>
<td>64.4</td>
<td>63.4</td>
</tr>
<tr>
<td>5</td>
<td>68.0</td>
<td>65.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample Method</th>
<th>Count</th>
<th>Mean</th>
<th>Standard Dev.</th>
<th>Std Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand-cut</td>
<td>5</td>
<td>66.98</td>
<td>1.706</td>
<td>0.763</td>
</tr>
<tr>
<td>Header-cut</td>
<td>5</td>
<td>65.2</td>
<td>1.022</td>
<td>0.457</td>
</tr>
</tbody>
</table>

Again this one trial showed a consistent lower % whole grain with the header harvested samples in all counts. This shows that there is a greater than 90% probability that the sample averages are different,
so have been effected differently by the collection or threshing process. This was displayed by the samples correlation \( r = 0.84 \).

**Discussion.** The results of this one harvest trial gives a preliminary indication, that the procedures used in the project do not exactly repeat the grain moisture and \% whole grain results obtained. However the results show a consistent relationship to the commercial harvesting results providing some evidence that trends of the project results and the conclusions drawn are closely related to the commercial farm situation. However the relationship needs further clarification.

The moisture difference i.e. higher moisture in the project samples, may be caused by “sweating” of the rice foliage and grain collected with the sample, during transport of the samples prior to threshing allowing transfer of foliage moisture to the grain and or a differential transfer of moisture during the threshing process. Conversely the commercial harvesting may also “aerate” the rice grain during the threshing and straw separation processes.

The differences in WG percentages i.e. the lower \% whole grain in the commercial could be contributed to by various factors. The Hege Plot Harvester, used to thresh the project samples, may have a lighter threshing action than most commercial harvesters, resulting in less damage to the whole grains that are removed and not removing as many of the green immature grains, that when appraised are more likely to breakup and decrease whole grain millouts.
"REPORT ON CURRENT RICEGROWER KNOWLEDGE AND ATTITUDES TO RICE QUALITY -1992/93"

John Lacy, District Agronomist, Finley, John Fowler, District Agronomist, Deniliquin, Andrew Storrie, District Agronomist, Griffith, and Don McCaffery, District Agronomist, Coleambally

AIM

Objectives

1. To determine ricegrower knowledge, understanding and attitudes to grain quality.
2. To identify the barriers and constraints to the adoption of management practices to improve rice grain quality.

Method

This report is based on a sociological research method which will complement the technical survey of farmer crops.

Focus discussion group meetings were held in 5 District Agronomist districts in March/April 1993. Farmers from one regular rice discussion group chosen by the District Agronomist were invited to a special meeting to discuss rice quality. Size of group ranged from 4 to 16 farmers. The District Agronomists acted as both facilitators and recorders for each group.

The facilitators introduced the topic along the lines "that whole grain millout as one measure of grain quality was 51% for the 1992 season compared to the 10 year average of 58% and a high of 65%. Please discuss and raise any issues you see which relate to grain quality".

The role of the facilitators was to promote and encourage discussion and ensure contributions from all participants. They were instructed not to give any personal opinions or answer questions. This was an attempt as is the focus group method to not influence the discussion in any way.

The facilitators and districts were:

Andrew Storrie, Griffith,
Don McCaffery, Coleambally
John Fowler, Deniliquin
John Lacy, Finley and Jerilderie.

Results

Common issues are highlighted. Other issues raised by the focus groups are itemised.

1. Agronomic

   - Nitrogen has a significant effect on quality. Some groups felt that high nitrogen levels lowered quality. Low rates reduce quality, but has the positive effect of producing fewer light grains.
   - Nitrogen topdressed crops have lower quality. One reason for this may be the formation of late shoots.
   - Draining too early, particularly where it leads to hayed off areas has a major effect on-millout. Later draining is better for millout but can create major harvesting problems if bays are too wet. Quote "I am better off financially to have a dry paddock
which harvests easily than a wet paddock which has a better appraisal". Picking the right time to drain is difficult because of weather changes and soil type variation.

- Landformed paddocks create variable soil conditions leading to uneven maturity and lower quality.
- It is difficult to customise urea rates to fill, cut and other soil areas.
- Earlier sowing causes crops to mature in hotter weather producing lower millouts. Later sown crops have better millouts. "March harvests are more frequent nowadays compared with a decade ago. The weather can often be too hot resulting in sun cracked grain".

2. **Varieties**
   - Major contributor to lower quality is the move to semi-dwarf varieties which do not have synchronous tillering. "Calrose had more even maturity. The heads would go over evenly in a matter of days. Modern varieties take 2 to 3 weeks". "Discoloured and immature grains are mixed in with dry grains so that an average 20% moisture sample may range in moisture from 10% to 30%". There is also big variations within a panicle. Experience from 2 seasons ago "My Amaroo had green grains at the base of the panicle resulting in too high a moisture for my header sample. I could see the crop was dry but sample said no. About 8mm of rain fell. The crop was then dry the next day and moisture content was 15%. This resulted in a poor millout and nil appraisal. So 98% of the crop was ready earlier, but the sample moisture content indicated the crop was too green".

3. **Seasonal influence**
   - Cooler temperatures and late sowing enhance millout. Low overall millout is not so much changes in management, but changes in weather from season to season.
   - For the 1992 harvest (a year of poor millout) there was little hayed off rice, but hot weather in March. We should see if there is a relationship between millouts and March temperatures over a number of years.

4. **Harvesting**
   - Low grain moistures lead to poor whole grain millouts. Paradox that the lower the moisture the better for stripping, but the lower the quality.
   - Farmers worry about harvesting close to 22% because of the high penalties for loads which exceed the limit.
   - Contractors will not strip a crop at 21.5% for fear they will have to stop harvesting. They wait until 18% to ensure an uninterrupted harvest. Also truck moistures can increase by 1% compared to header samples so no-one strips until moisture is down to 21%.
   - Swing to aerial sowing means a large area is sown over a short period, but it is impossible to harvest this area over a short time and at the correct moisture. There is not enough header capacity.
   - Old headers and faster drum or reel speeds may crack grain. Drum settings are important. Concaves are closed up for crops with green grains which simultaneously leads to cracking dry grains.
   - Do header drivers check settings enough? Is this important?
   - Rotary/axial headers may give better millouts because of reduced grain agitation.
   - Dirty samples are not necessarily the worst quality.
   - How do the stripper fronts compare to conventional header fronts?
5. **Receipt to Milling**

- Farmers do not know much about the storage and milling process after rice is delivered. Questions asked were:
  - Are appraisal results the same as commercial milling results?
  - Does quality decline during storage and due to handling?
  - Why is the millout of seed crops better than commercial crops?
  - How long after delivery are truckload samples milled? What are the storage conditions? How are they dried down to 14%?
  - Is grain cracking occurring on farm or in the milling process? Is more cracking occurring in bigger trucks?
  - What is the difference in price between cracked grains and whole grains? What are the markets for each?
  - Is there less cracking at higher proteins? Is rice protein tested? Is protein important?
  - How does the quality of rice in market shelf compare to paddy quality?
  - If a grower delivered 200 truckloads what happens to the samples? Are any combined?
  - If milling and appraisal methods have not changed is the extra double handling of grain the problem?
  - Do some mills give better millouts than other mills? e.g. Yenda better than Griffith.
- Sample moisture testing is unreliable with the method needing standardisation. Often 1% difference between sheds. Temperature variations are directly related to moisture readings i.e. hot day - lower moisture, cold day - higher moisture. Moisture changes from morning to afternoon in an untarped truck.

6. **Appraisals**

- Farmers are better off to grow higher yields via quantity i.e. $/ha than quality i.e. $/tonne. Appraisal premiums are not high enough to entice growers to improve quality.
- Appraisals do not mean much to growers. They do not make changes to crop management on the basis of grain appraisal.
- Appraisal results are often the opposite to what was expected.
- Appraisals based on whole crops are not accurate because of bay to bay variation.
- Is it the appraisal millouts which have fallen or mill millouts?
- Proposals suggested were:
  - need to do a cost benefit study on how high appraisal payments should be to impact on farmers' management.
  - Appraisal samples from RMB bins would be more accurate and useful than truck sample appraisals
  - Should be deductions for low appraisals and premiums for high appraisals.
  - A floating 20th percentile be used. Those delivering grain into the bottom 20% would be severely docked.
    The level would float with seasonal variation.
  - Whole grain millouts below 40% should have heavy penalties.
  - Should relate appraisal premiums to delivery dates i.e. grains delivered after a certain date be severely penalised.
7. **Other Comments**
   - Higher yields have lowered quality.
   - Fresh paddocks give better millouts.
   - Salinity is seen as an increasingly important factor in poor millouts due to areas of crop haying-off prematurely.
   - “Pelde is very responsive to super. Since I started using super my appraisals have improved”.
   - Slow and uneven drying of soil in non-landformed paddocks which have humps and hollows results in grain moisture all over the place.
   - Does foundation seed have better appraisals than paddy rice?
   - U.S farmers leave more grains in the heads, don't run the drum as hard and leave the concave more open.
   - Appraisals change a lot from year to year yet management is much the same. Suggests that weather variation could be a major factor.
   - Farmers have no way of predicting at harvest what their whole grain millouts will be. When harvesting they get instant feedback on pearling and cleanliness and can make adjustments for this. However, they cannot make adjustments for chalkiness or coloured or cracked grain because there is no instant feedback mechanism.
   - Growers have 25% control over grain quality, the other 75% is in the lap of the Gods.
   - One group defined quality as % chalkiness and how much of the grain was cracked.

8. **Questions/Proposals**
   1. Identical paddocks were managed similarly yet whole grain millouts were quite different, why?
   2. Does late P.I. nitrogen topdressing lead to lower millout?
   3. Do either phosphorus or trace element deficiencies or low pH's lower millout? (2 groups)
   4. Growers should be prevented from sowing before recommended times.
   5. We need synchronous heading varieties.
   6. Does cold weather in January have any direct influences on quality?
   7. Need a cost benefit analysis of higher grain moisture receivals and subsequent better millout versus lower moisture receivals and poorer millouts.
   8. Silos should open later and close later so that grain can be delivered on the same day of harvest.
   9. Industry should get away from augers and use conveyor belts
   10. Pelde is the longest serving variety we have, so it could be used as a base variety over time to assess quality changes over time.
   11. Does water quality influence grain quality?
   12. Do agricultural chemicals eg. herbicides have any impact on quality?
   13. Are there any growers who are consistently achieving good millouts? If so, what is their management?
   14. What is happening to millouts overseas eg. U.S.
CONCLUSIONS (Facilitator Comments)

- Farmers cannot identify why millouts have declined.
- More questions were posed than answered.
- "In conclusion they felt that the conditions required to obtain a consistently high whole grain millout was a mystery"
- "I detected there was little extra they could do over what they are doing now to improve their appraisal"
- "Growers say appraisals cannot be linked to the management of their crops".
- "There are no set criteria or checks which if adopted guarantee better millouts".
- "I detected that whole grain millout was their main measure of grain quality although they refer to it as their appraisal."
- "Discussion mainly related to on-farm and receival issues. Farmers had poor knowledge of the milling process and found it hard to relate to this."
- "Paddock variations, both soil type and fertility, paddock layout, uneven maturity of current varieties and getting draining time right were the major on - farm factors which they see as having an influence".
- "To get good quality grain a grower should
  - use less nitrogen
  - avoid topdressing at P.I.
  - have an even maturing crop, ie. avoid landformed paddocks, avoid varieties with late tillers and avoid muddy water sites.
  - have lower fertility paddocks
  - have good water management, particularly at draining.
  - harvest at high moisture
  - sow late.
- "There is no instantaneous feedback mechanism during harvest which would allow header adjustment (we don't know how important this is anyway). Also appraisal results are communicated well after harvest and are often different to what was expected."
- "There is a lack of knowledge about quality and what is defined by quality".
- Farmers are still better off to lift yield than lift quality.
- "It is interesting that farmers have recommended greater financial incentives and disincentives for quality while at the same time they are unclear as to what control individual farmers have over quality".


The quality of rice grain is an important factor affecting the values and marketability of the crop. The % whole grain millout is a key component of rice quality and is the percentage of whole grains in a sample after removing the hulls, bran layer and broken grains.

Following the low millouts in 1992 a project team was formed to investigate the factors influencing % whole grain and to determine options to improve % whole grain.

To obtain data on grain quality in farmers paddocks, 80 commercial Amaroo crops were sampled weekly for 10 weeks for grain moisture, % whole grain millout and soil dryness. The first sample was at approximately the late dough stage. The crops were taken from a range of locations, planting dates and PI shoot number and nitrogen content. The subsequent analysis of the 160 crops across the two years has revealed the following.

Figure 1 shows the typical change in moisture content and % whole grain millout of the observed rice crops. It is characterised by an initial period of high % whole grain. Following this there is a period of decline in % whole grain until a minimum value is reached for that crop. After that time, % whole grain remained constant over time. This pattern of change in % whole grain millout was observed in all crops and can be summarised in following 4 major findings.

Figure 9: Observed (symbols) and simulated (line) % whole grain and grain moisture for a typical 1994 rice crop drained on time
MAJOR FINDINGS FROM THE PROJECT
a) All medium grain crops had a high whole grain millout of 65%.
b) The % whole grain remains at the maximum level until grain moisture content first drops below 20-22% moisture.
c) The fall in % whole grain millouts at less than 20-22% moisture is directly related to evaporation.
d) At daily evaporation rates of less than 2mm/day, grain quality does not decline.

WINDOW OF BREAKAGE
There is a distinct window of grain breakage when % whole grain millout declines. The window opens only after the crop first reaches 20-22% moisture and closes when daily evaporation falls below 2mm per day, or when the crop is harvested. The length of this window is under farmer control, but the severity of decline is dependant on the weather, especially daily evaporative demand.

Figure 2. shows the decline in moisture and % whole grain of rice in the bay next to the crop shown in Figure 1. The crop in Figure 2 was drained too early i.e. the soil was trafficable at 30% moisture. The crop shown in Figure 1 was drained on time and was just trafficable at 22% moisture. The crop in Figure 2 reached 20% moisture 15 days before Figure 1. This increased the length of time for % whole grain decline as well as increased the severity of decline. This resulted in a minimum % whole grain of 10-15% for figure 2 compared to 55-60% for the crop in Figure 1.

![Figure 10: Observed (symbols) and simulated (line) % whole grain and grain moisture content for a 1994 rice crop drained too early.](image-url)
FACTORS CONTROLLED BY FARMERS WHICH WILL IMPROVE % WHOLE GRAIN MIlLOUT

1. Harvest at higher harvest moisture content
   Aim to harvest between 20-22%. Millouts will still be high even when daily evaporation is high provided grain moisture is a minimum of 20%.

2. Drain on time
   Ensure crops are drained so that bays are only just trafficable at 22% moisture (see Figure 1. This rice bay was drained on time). The grain moisture for this bay and thus potential for grain cracking did not drop below 20% until 22nd April when daily evaporations were low at 4.3 mm/day. Consequently the % whole grain was high at a range of grain moistures.

3. Fertilise for adequate crop nitrogen
   Crops with adequate nitrogen as a result of pasture history, pre flood nitrogen or top-dressed nitrogen will be later maturing and thus maturing when evaporation is lower compared to crops with inadequate nitrogen. The lower the daily evaporation the lower the rate of fall of % whole grain.

4. Harvest medium grains before long grains
   If at similar moisture contents the medium grain varieties should be harvested before the long grain varieties, as the rate of decline in % whole grain is faster in the medium grains. However do not delay harvest of Langi because of the risk of shedding and Jarrah because of fast drying.

5. Use harvest contractors if necessary
   If a clash of harvesting dates is unavoidable resulting in significant delays consider contractors to allow crops to be harvested at the ideal 20-22% moisture.

6. Sowing time trade-offs
   The lower the daily evaporation the lower the rate of fall of % whole grain. Thus a late sown crop which matures when evaporation is low will have a higher % whole grain than a crop sown at the recommended time. Because late sown crops yield less than crops sown at recommended times deliberate delays to sowing times are not recommended.

7. Uniform crops
   Even maturing paddocks which do not have high moisture patches are easier to harvest at 20-22% moisture than patchy crops. Newly lasered paddocks create non uniformity as does uneven establishment.

FACTORS OUTSIDE FARMER CONTROL

1. Above average evaporation
   The higher the evaporation after the crop reaches 20% and the longer the period between 20% moisture and harvest the greater the fall in % whole grain. This has 2 implications:

2. Rainfall
   If the grain moisture is less than 20% and it rains, the % whole grain will fall. This effect needs further investigation.

DO YOU HAVE CONTROL OVER % WHOLE GRAIN?

If you have an uninterrupted harvest at 20 - 22% grain moisture you have 100% control.
   The longer the harvest is delayed after 20% grain moisture, the less control you have over % whole grain, except for May harvests.
   Abnormally high evaporation over which you have no control could influence % whole grain by up to 30%.
   Rainfall occurring at 20% grain moisture or less will reduce % whole grain.
INDUSTRY ISSUES

1. Harvest moisture limits
The practicality of harvesting at 20-22% is difficult because of the penalties for grain moisture exceeding 22%. A change in the maximum acceptable moisture to 23-24% would increase the cost of drying. There is obviously a trade off where the extra income from better quality rice needs to be evaluated against increased drying costs. Due to drier air conditions early in the harvest season, it is likely that the threshold moisture content for delivery could be increased at that time, and be reduced as the weather changes.

2. Rice receival rates
Daily maximum receival rates less than header capacity will result in delays in harvest. These delays in harvesting can lead to reduced grain quality as the crop declines in moisture content.

ACKNOWLEDGMENTS
The authors would like to acknowledge Andrew Varley for valuable assistance in data collection for this project. Financial support from the Rice Research Committee of RIRDC is gratefully acknowledged.

### APPENDIX VII: Potential Daily Evapotranspiration – Griffith February to May

<table>
<thead>
<tr>
<th>Period</th>
<th>Mean</th>
<th>5%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early February</td>
<td>7.6</td>
<td>4.2</td>
<td>6.4</td>
<td>7.7</td>
<td>8.9</td>
<td>11.1</td>
</tr>
<tr>
<td>Mid February</td>
<td>7.3</td>
<td>3.9</td>
<td>6.3</td>
<td>7.2</td>
<td>8.5</td>
<td>10.3</td>
</tr>
<tr>
<td>Late February</td>
<td>6.7</td>
<td>3.6</td>
<td>5.9</td>
<td>6.6</td>
<td>7.6</td>
<td>9.7</td>
</tr>
<tr>
<td>Early March</td>
<td>6.3</td>
<td>3.8</td>
<td>5.5</td>
<td>6.2</td>
<td>7.1</td>
<td>8.9</td>
</tr>
<tr>
<td>Mid March</td>
<td>5.7</td>
<td>2.8</td>
<td>5.1</td>
<td>5.7</td>
<td>6.4</td>
<td>7.5</td>
</tr>
<tr>
<td>Late March</td>
<td>5.0</td>
<td>2.4</td>
<td>4.1</td>
<td>4.9</td>
<td>5.9</td>
<td>7.8</td>
</tr>
<tr>
<td>Early April</td>
<td>4.4</td>
<td>1.7</td>
<td>4.0</td>
<td>4.4</td>
<td>5.0</td>
<td>6.1</td>
</tr>
<tr>
<td>Mid April</td>
<td>4.0</td>
<td>2.1</td>
<td>3.4</td>
<td>3.9</td>
<td>4.7</td>
<td>5.6</td>
</tr>
<tr>
<td>Late April</td>
<td>3.3</td>
<td>1.9</td>
<td>2.9</td>
<td>3.3</td>
<td>3.7</td>
<td>4.6</td>
</tr>
<tr>
<td>Early May</td>
<td>3.0</td>
<td>1.4</td>
<td>2.5</td>
<td>3.2</td>
<td>3.7</td>
<td>4.3</td>
</tr>
<tr>
<td>Mid May</td>
<td>2.6</td>
<td>1.5</td>
<td>2.1</td>
<td>2.6</td>
<td>3.0</td>
<td>3.8</td>
</tr>
<tr>
<td>Late May</td>
<td>2.3</td>
<td>0.9</td>
<td>1.7</td>
<td>2.2</td>
<td>2.7</td>
<td>4.1</td>
</tr>
</tbody>
</table>

Early - 1st 10 days of month (1-10th)
Mid - 2nd 10 days of month (11-20th)
Late - remaining days of month

Technical Report Number 1, David J Erskine and Richard C Smith
CSIRO, Centre for Irrigation Research, Griffith, NSW 1983.