



RICE CRC

FINAL RESEARCH REPORT

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Principal Investigator Details :	
Name :	John Lacy, Technical Specialist (Irrigated Farming Systems), NSW DPI Peter Evans, Education Officer (Rice), NSW DPI Felicity Steel, Technical Officer, NSW DPI and NSW DPI District Agronomists
Address :	Yanco Agricultural Institute PMB YANCO NSW 2703
Telephone contact :	(02) 69512738

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Rice CRC Final report- project No. 5101

Targeting NIR tissue test sampling using aerial imagery and the identification of the factors causing variable rice growth and crop yields

John Lacy¹, Mary-Anne Lattimore¹, Rachael Whitworth², Keiran O’Keeffe², Andrew Schipp³, Matt McRae⁴, Alex Murray⁵, May Fleming⁶, Felicity Steel⁴, Peter Evans¹

¹ Yanco Agricultural Institute, Yanco, NSW 2703

² NSW Dept Primary Industries, Centre for irrigated Agriculture, PO Box 1087, Griffith NSW 2680

³ NSW Department of Primary Industries, PO Box 393, Hay NSW 2711

⁴ NSW Department of Primary Industries Po Box 108, Finley NSW 2713

⁵ NSW Department of Primary Industries, PO Box 736, Deniliquin NSW 2710

⁶ formerly NSW Department of Primary Industries, PO Box 25, Moulamein NSW 2733

SUMMARY

The new precision agriculture tool, aerial infrared images has created an opportunity for rice farmers to assess crop variability. At ground level variability is difficult to assess. Aerial infrared images readily show crop variability.

The images supplied by Terrabyte Services show 5 colour image zones of crop vigour from low vigour to high vigour. The identified zones can show farmers where to sample crops for the NIR Tissue Test at panicle initiation. Previously farmers randomly sampled not really knowing whether the sampled areas were really representative of the crop.

The ability of the aerial images to show crop vigour differences has led to the issue of how farmer crops compare to each other and what factors cause variability within crops.

This project reports on the use of spatial infrared aerial imagery in the rice industry. It reports on two sub-projects. The first is the introduction and farmer use and adoption of aerial infrared imaging for identifying variability. The second sub-project reports on the identification of factors causing crop growth and grain yield variability.

The outcomes from the first sub-project have been very successful. After the first season there was great feedback. Farmer quotes include:

“There was more crop variation than I thought”

“I was surprised by cut and fill areas showing up after 20 years”

“The aerial images are an excellent tool at PI meetings”

“The variation is often not due to nitrogen”

Over the first 2 years the number of farmer participants increased from 270 to 549, crop numbers from 484 to 834 and crop area from 14000ha to 29500ha. Although the 2005 rice crop area was lower at 44,000 ha compared to 65000 ha in the 2004 season, 29000 ha was imaged representing 66% of the total area. This compares to 47% in 2003/04.

Perhaps the key outcome from the project is that aerial imagery has been successfully adopted by rice farmers and is now seen as an essential tool for improving the management of rice crops.

The second sub-project has shown there is large yield variability and large factor variability within crops and between crops. The yield coefficient of variation (CV) of the monitored crops ranged from 4% to 76% in the 2003/04 season. The variation of measured parameters within the one crop eg plant number, water depth, N uptake has been surprisingly high with the CV often as high as 60-80%. There is a need to gain an understanding of the reasons for this variability which will be the subject of further analysis of the data.

The future challenge for the rice industry and rice farming systems is to identify all the factors contributing to rice growth and yield variability and finding ways of overcoming the variability leading to more uniform and higher yielding crops.

BACKGROUND

Variability within rice crops has a significant impact on yields, profitability and industry sustainability. At ground level variability is difficult to assess. However aerial infrared images readily show crop variability. The images can show where to sample crops for the NIR Tissue test at panicle initiation and identify differences within individual paddocks and across farms.

Although a growing number of farmers and retail agronomists had been using infrared images since 1998 there was a need to have this service coordinated over the industry. There were 2 key farmer education issues. The first was to show crop growth and yield variation was not just the result of variable nitrogen nutrition but often due to other factors such as establishment, weeds, layout, water depth and soil type. The second issue linked to the first issue is the need for farmers and agronomists to physically “check out” crops to verify the factors causing differences between biomass zones.

There is a general belief among researchers, agronomists and farmers that crops with uniform crop growth and grain yields will potentially yield higher than non uniform crops. Hence the aim of crop management is to improve crop uniformity. Management to improve uniformity and management of zones within paddock boundaries is the aim of precision agriculture. Precision agriculture is a new technology to be utilised by rice growers with the potential to increase yields by 10%. This project utilises the precision agriculture tool of spatial infrared aerial imagery. The project reports on two sub-projects. The first is the introduction and farmer use and adoption of aerial infrared imaging for identifying variability. The second sub-project reports on the identification of factors causing crop growth and grain yield variability.

I. Sub-Project: Targeting NIR test sampling at panicle initiation (PI) using aerial imagery

OBJECTIVES

1. To set up a protocol of aerial imaging, map preparation, map distribution, interpretation and targeted nitrogen topdressing
2. To identify zones of similar biomass in each crop
3. To target NIR sampling within each zone
4. To relate topdressing rates to each zone
5. To educate farmers in interpreting maps and benefits of aerial maps
6. To identify, by ground truthing, factors responsible for the biomass variation
7. To foster collaboration between public and private advisers

METHODOLOGY

The 2002/03 season

A meeting of stakeholders interested in the use of aerial imagery was held in November 2002. Present was Graeme Batten, Tony Blakeney, Sue Ciavarella, Jon Cobden, Daryl Gibbs, John Lacy, Laurie Lewin, John Lucas, John Medway, Thane Pringle, Janet Wilkins.

The meeting decided the aim of the project should be to improve NIR Tissue Test sampling and raise farmers' awareness, interest and knowledge on aerial imaging and diagnosing crop variation. It was expected the project would lead to the use of variable nitrogen rate application. As part of the awareness phase it was decided the project could fund aerial maps for a sample of growers in each District Agronomist district. There was a need to delineate District and retail agronomist roles since a few retail agronomists were already supplying a commercial service to growers.

Process for the commercial service

1. Discuss with grower what is to be done.
2. Map crop area using an on ground GPS to obtain accurate boundary coordinates – a \$5/ha fee is charged.
3. Paddock flown pre-PI.
4. Terrabyte process and send results back as a 4 or 5 band colour map. Accuracy is to 2 metres.
5. Ground truthing or previous NIR knowledge also taken into account when splitting crop into zones. Growers use range of factors besides the images eg soils tests and previous year's data to determine zones.
6. Apply appropriate fertiliser rates to each zone based on NIR results. The smallest practical zone is 2 ha.
7. Plane logs data so if there is an error in the application there is capability to see where fertiliser rates are applied.

District Agronomist role

Distribute crop imagery maps (at no cost) to a sample of farmers at PI group meetings. Imagery is tied into irrigation company farm boundaries. Maps are accurate to 20-30 metres. Train farmers in the interpretation of the zones and where to sample for PI, implications for varying nitrogen rates.

Learn from the learning of the farmers in diagnosing the factors giving the zone differences
Collate district survey questionnaires then send copy to Janet Wilkins for overall collation.

Commercial Agronomist role

Provide value adding personal service to growers. Farm visit to GPS crop boundaries. Normal charge is \$5/ha. Aerial imagery data is emailed to commercial agronomist who has software to develop map and zone accuracy to 2 metres. Individual farmer map zone interpretation, NIR testing, nitrogen recommendations.

Priority for mapping

1. Commercial agronomist client clusters
2. District Agronomist groups. Selection to be based on the host farmer, farmers using the NIR test, regular group attendees closest to host farmer. Each participant should supply field map of the farm with farm number indicating location of rice crops with paddock names, sowing dates and variety.
3. Letters need to be sent to farmers ASAP. Farmers in the Murray valley will be sent individual letters since there are so few of them.
4. The letter to all commercial and DA agronomist participants will include a permission slip requesting farmers' permission to use the data for research and trial purposes
5. Trial Sites. Any key research or extension trial sites could be included if flight time available.

District Agronomists contacted growers particularly those in discussion groups to arrange participation. Farmers faxed crop locations to District Agronomists who relayed the maps to Terrabyte.

An aircraft was used to take the infrared images. Images were mailed to DA's who sent them to growers. The time delay in this process was too great as some crops were past panicle initiation (PI) before collection of the map. Hence some maps were directly emailed to growers and DA's.

2003/04 season

In the 2003/04 season a pamphlet "Rice imaging for improved crop monitoring-2003/04" was produced by Terrabyte Services, NSW DPI, and SunRice. It outlined the whole process for aerial imaging. It included the NSW Agriculture project, roles of District Agronomists and commercial agronomists, how to obtain an image, image delivery, image format change analysis and interpreting images.

This process was explained to farmers by District Agronomists at group discussion meetings in November or by farmers contacting a commercial agronomist or by contacting Terrabyte Services direct.

About 15% of the total rice area had free aerial images provided. This was to ensure there was a sample of imaged crops in each District Agronomist discussion group for farmer education and learning. Most of the free images were for Murray Valley farmers since most Murray Valley farmers were unable to grow rice in the 2002/03 season because of a very low 8% water allocation. Hence the majority of the aerial images were provided at commercial cost. In summary the plan was:

- free images 8000ha- mostly Murray Valley;
- most farmers to pay \$2.20/ha +GST per image;
- produce a leaflet “Rice imaging for improved crop monitoring”;
- NSW Agriculture District Agronomists provide an education role;
- a ground truthing study of 6 crops per District Agronomist was planned which is discussed in sub-project II; and
- retail agronomists to provide a commercial on-farm services – eg. \$12/ha for variable rate application.

The project built on the progress from 2002/03. The infra red images were taken by a satellite compared to aircraft in the first year. Images were emailed to farmers. The project supplied 40% of the images with commercial services supplying 60%. The project supplied images were used in each District Agronomist district for farmer training particularly in the Murray Valley.

2004/05 season

The project followed on from 2003/04. DPI District Agronomists continued to educate farmers in the use of images at PI meetings although many farmers were past the awareness phase. Hence the project did not provide a number of free images as in previous seasons. The project only paid for images of crops participating in sub-objective II. Most infra red aerial images were taken by a satellite with an aircraft used for isolated crops. Images were supplied at commercial rates of \$3.85/ha directly to farmers and retail agronomists by Terrabyte Services.

RESULTS

2002/03 season

Although low irrigation allocations limited rice areas particularly in the Murray Valley, each district had farmers who volunteered to participate in the project. There was good collaboration between the district and retail agronomists. Word of mouth resulted in a higher than planned number of imaged crops. Terrabyte Services from Wagga Wagga were engaged to carry out the aerial imaging.

The protocol of the identification of the crop location, taking the images, distribution of the images, education of farmers in the interpretation of the images and tissue test sampling and in targeted nitrogen topdressing was generally very successful.

Growers received a free colour image of their crop. The colour image indicated the higher, moderate and lowest biomass areas using 5 colours. This map allowed growers to target the different growth areas for their NIR tissue test sampling. The concept was well accepted and gave growers a more accurate idea of the variability within their crops.

The aerial image in Figure 1 displays a 5 colour image of crop vigour from high vigour to low vigour in the colour order red, orange, yellow, green, blue. Blue often represents holes in crops. The colours for the paddock vigour image are specific to the crop and not directly comparable to other crops. District Agronomists ensured discussion group leaders had their crop imaged. The map could be shown and interpreted for the farmers in the group and the rice crop was then monitored to assess and verify the biomass vigour zones displayed on the map.

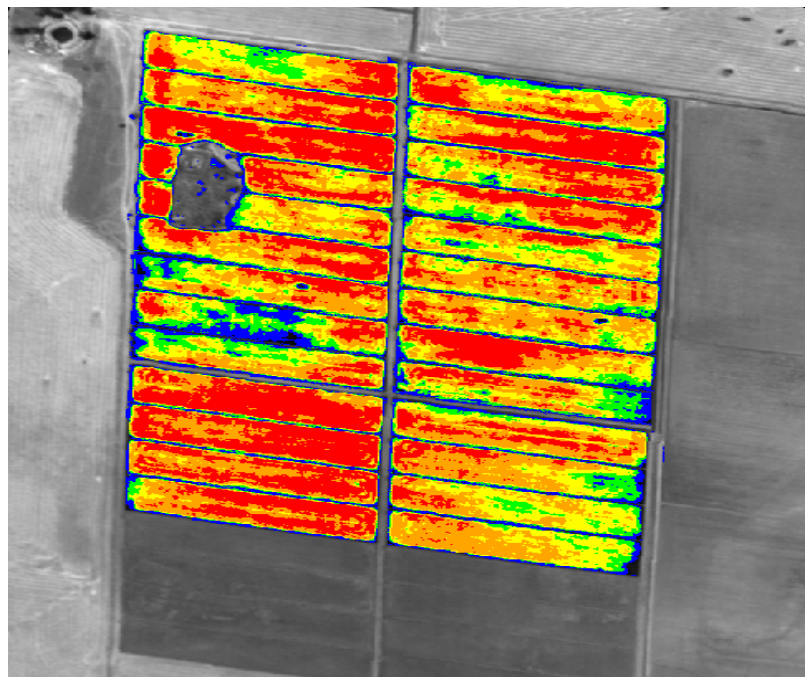


Figure1.

**Aerial Terrabyte infrared
image of a rice crop
2002/03**

There were 270 farmer participants mainly from the Murrumbidgee Valley who aerial imaged 484 crops with a total area of 14000 ha.

2003/04 season

A coloured information brochure for farmers, “Rice Imaging for Improved Crop Monitoring – 2003/2004” was the result of collaboration between Terrabyte Services, NSW Agriculture and SunRice.

Over the 2 years the number of farmer participants increased from 270 to 549, crop numbers from 484 to 834 and crop area from 14000 ha to 29500 ha.

2004/05 season

Although the 2005 rice crop area was lower at 44,000 ha compared to 65000 ha in the 2004 season 29000 ha was imaged representing 66% of the total area. This compares to 47% in 2003/04.

DISCUSSION OF RESULTS

2002/03 season

In 2002/03 the first year of the project there were minor problems. The images for some crops were too late to be of use while some crops could not be located by the aircraft. Solutions needed to be found. It was decided future images were to be emailed rather than mailed in the post. Irrigation Company maps were to be used to locate crops instead of farmer maps.

The project was evaluated at District Agronomist meetings and a meeting of the steering committee in February 2003. Feedback was excellent.

Quotes include:

“There was more crop variation than I thought”

“I was surprised by cut and fill areas showing up after 20 years”

“The aerial images are an excellent tool at PI meetings”

“The variation is often not due to nitrogen”

The maps allowed PI sampling to be targeted resulting in great time saving and more accurate sampling.

2003/04 season

There were some problems with satellite and image delivery timing and image colour differentiation which were rectified for 2004/2005.

Feedback again was associated with recognition of factors causing crop variation and most farmers accepted the use of the imaging was to better target sampling of crops at PI. Other advantages claimed were less leg work and better use of nitrogen fertilizer through application of variable rates.

Some commercial services desired earlier images to fit either early to mid December crop assessment or earlier PI crops. There was discussion as to whether the use of multiple images of a crop, i.e. 2-3 images at different stages can give different stories of the crop. Terrabyte have found the variation trends in most crops do not change. However for some crops the image pattern can change from midseason in early December to the image depicted at PI in late December.

2004/05 season

In 2003/04 there were a number of teething problems in timing of delivery of the images. In 2004/05 there were no problems. Collaborative teamwork by NSW DPI and retail

agronomists and Terrabyte resulted in aerial imaging being accepted as an essential tool for identifying sampling areas for the NIR test and for evaluating crop variability.

The relatively high (66%) adoption of imaging was a great result. At the rice retail agronomist meeting and farmer rice pre-season meetings it was pointed out the images help target PI NIR Tissue test sampling. The images show differences in rice vigour. The images do not directly measure plant nitrogen. Only the PI NIR Tissue test directly measures crop nitrogen. Some retail agronomists and farmers were using the images to subjectively assess nitrogen topdressing rates. It is believed this method gives inaccuracies.

The adoption of the NIR Tissue test at 51% of all crops was the highest on record presumably from the influence of the presentations to agronomists and farmers.

IMPLICATIONS AND RECOMMENDATIONS

All the objectives relating to this sub-program were achieved. The challenge in the next few seasons as rice areas return to normal is to maintain and improve the adoption (66%) of this technology.

The split nitrogen strategy needs to be further promoted to allow farmers to image crops at PI and apply variable nitrogen rates to enable more uniform and high yielding crops

The successful consultation and cooperation between Terrabyte Services, retail agronomists, NSW DPI District Agronomists, SunRice and farmers on the logistics of the provision of the imaging service needs to be maintained

Uniform image colours should be utilised by all service providers to reduce misunderstandings with diagnosis.

II Sub-Project: Identification of factors causing variable rice growth and crop yields”

OBJECTIVES

1. To identify the factors influencing rice crop growth variability and crop yield in the 2003/04 and 2004/05 rice seasons.
2. To assess biomass variation within each colour vigour zone.

METHODOLOGY

This sub-project builds on the progress of sub-project I from the two previous years “Targeting better NIR test sampling using aerial imagery.” In 2003/2004 besides the education of farmers in remote sensing a crop monitoring project was implemented.

The crop monitoring focussed on the factors affecting crop and yield variability. Soil and crop parameters were to be monitored. In order to prioritise and determine the parameters to be measured in 2004/05 the data from the 2003/04 crop monitoring project needed assessment. Relationships between the parameters and the 5 colours representing low to high vigour for each crop were investigated and to determine relation to yield. A key issue is whether the vigour images are directly related to nitrogen or whether other factors are involved.

The project also investigated the crop vigour and biomass variation within each colour zone to assist in the interpretation of paddock images to be utilised by farmers. There was close liaison with Terrabyte and commercial agronomists in this process.

In 2003/04 an on ground crop monitoring survey of 38 crops was conducted throughout the season to determine the factors causing crop growth and yield variability. The Rice Education Officer at Yanco and Rice Technical Officer, Finley monitored 4 to 6 crops from each District Agronomist district.

A reduced number of 20 crops were monitored in 2004/05 because the workload in 2003/04 was too high. The Rice Education Officer at Yanco and Rice Technical Officer, Finley monitored 2 to 4 crops from each District Agronomist district. In 2004/05 in contrast to 2003/04 soil samples were taken prior to rice sowing.

Each season 6-8 tomato stakes were placed at random in crops either just before or after flooding with 1 or 2 per bay. Plant counts, water depths, soil type, cut fill, salinity, N uptake, weeds and yields at each stake were assessed.

Figure 2.
Rice Education
Officer Peter
Evans sampling at
a stake site



RESULTS

The monitoring data for the 2003/04 season was assembled into excel spreadsheets. The CV (coefficient of variation %) was determined for yields for each of the stakes in each crop. Figure 3 shows the yield CV between the stakes from the lowest crop to the highest crop for 22 crops. The yield CV ranges from 4% to 76%. This shows there is large yield variability within and between crops.

Figure 3.
The yield
variability
(CV)
for each
rice crop
2003/04

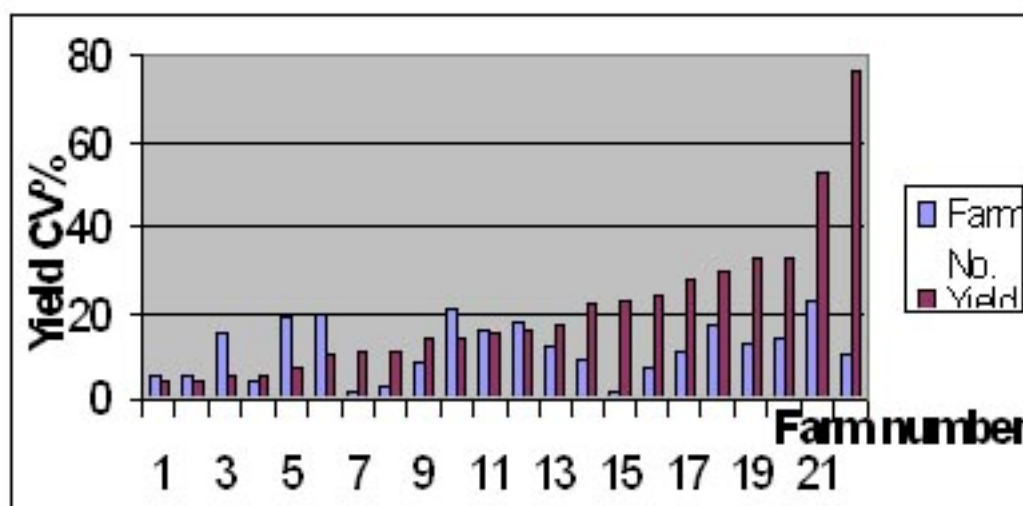


Table 1 shows the data for a crop with 5 stakes. Water 1 is the water depth (cm) at establishment, water 2 the depth at tillering, water 3 depth at panicle initiation and water 4 the water depth at the young microspore growth stage. The image colour code is 1 is blue, 2 green, 3 yellow, 4 orange and 5 red. The higher the number the higher the crop biomass and vigour. Weed number ratings range from 0 = zero to 3 = high.

Table 1 . Crop with the lowest yield CV in 2003/04

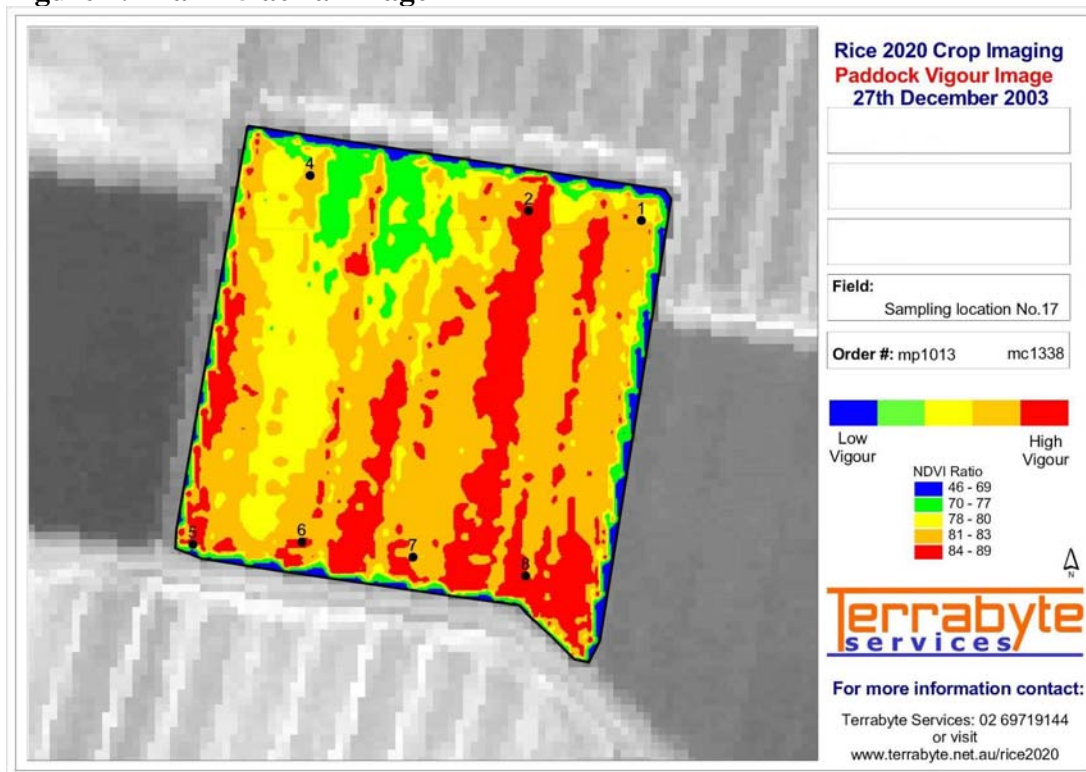
Farm 5 lowest yield variability

Stake	1	2	3	4	5
plants m2	110	130	100	60	220
Water 1	11	13	8	5	5
Water 2	12	12	12	9	6
Water 3	11	9	9	9	8
Water 4	25	27	25	25	27
N uptake	181	208	98	205	151
Fresh Wt	322	395	132	324	315
Image colour	4	5	2	4	5
NDVI	82	87	74	82	87
Weeds	0	0	0	0	0
Salinity	0.05	0.06	0.06	0.06	0.44
Yield	12.0	10.7	11.0	11.2	10.6

The data in Table 1 shows the crop with the least yield variability measured by coefficient of variation. Although the yield coefficient of variation (CV) and water 4 CV is only 4% the CV for all the other factors are higher eg nitrogen uptake was 24%. The plant number, water and nitrogen data shows no correlation with yield.

There are 2 stakes 1 and 4 with the same image orange colour implying the crop vigour is similar which would allow NIR Tissue test sampling from either area. The data shows the nitrogen uptake for stake 1 orange image is 181kgN/ha with 205kgN/ha for stake 4. Similarly the nitrogen uptake and fresh weight for the red image for stake 2 is respectively 208kgN/ha and 395 g/0.1m² compared to 151kgN/ha and 315g/m² respectively for red image stake 5.

Figure 4. Farm 5 aerial image



Contrary to Table 1 the data in Table 2 is for the third highest yield CV of 33%. There appears to be no correlation between most factors and yield. However there is a strong relationship between yield and water 4 with low water depth giving low yields.

Table 2. Crop with the third highest yield variability 2003/04

FARM 14	1	2	3	4	5	6	7	8
plants m2	180	145	215	105	210	135	85	150
Water 1	24	22	20	10	9	6	15	5
Water 2	6	7	5	0	1	1	4	0
Water 3	12	10	11	11	5	6	11	0
Water 4	21	23	30	22	6	11	11	1
N uptake	119	147	69	148	141	104	135	69
Fresh Weight	294	382	249	405	403	260	376	264
NDVI		60		71		60	73	74
Weeds	0	1	2		0	0	0	0
Salinity	0.08	0.12	0.08		0.06	0.09	0.06	0.05
Yield	11.5	8.5	14.5	14.5	5.5	10.5	9.5	5.5

Table 3 shows the farm crop with the lowest variability between the measured factors. This was assessed by the determination of the CV% for each factor measured then averaging all the CV's for the crop. The data shows there is still significant variability for each factor.

Although this crop was the most uniform and yields were relatively uniform it was not the highest yielding crop which shows there are other factors besides uniformity influencing crop yields.

Table 3. Crop with the lowest factor variability

FARM 4	1	2	3	4	5	6	7	8
plants m2	130	170	280	520	160	200	330	160
Water 1	9	9	13	10	11	11	13	10
Water 2	11	8	15	15	5	8	9	8
Water 3	10	13	21		14			8
Water 4	9	12	14	16	17	12	15	13
N uptake	158	99	120		143			138
Fresh Weight	343	285	329		324			327
Image colour		4	5		5	5		4
NDVI		78	83		83	83		78
Weeds		0	0		0	0		0
Salinity		0.04	0.04		0.04			0.04
Yield		9.0	7.9		9.5	8.3		8.7

Table 4 shows the crop with highest factor variability. The CV for establishment plant number is 44% with the CV% for water 1 at 91%. Nevertheless overall yield variability is good although the stake yields vary by a CV% of 22%.

Table 4. Crop with highest factor variability

FARM 9	1	2	3	4	5	6	7	8
plants m2	190	10	200	190	80	130	140	180
Water 1	2	4	16	11	0	15	1	4
Water 2	4	5	9	3	4	16	13	22
Water 3	5	8	14	12	4	18	27	20
Water 4	5	8	16	14	30	19	15	15
N uptake	141	238	86	74	53	85	127	119
Fresh Weight	295	398	222	225	96	190	228	245
Image colour	2	5	5		3		2	5
NDVI								
Weeds	0	0	0		0		0	0
Salinity	0.06	0.05	0.06		0.29		0.19	0.07
Yield	9.7	8.6	9.6		4.8		10.3	7.4

Other factors affecting rice crop growth and yield variability

Figure 5 shows a stake site with poor establishment which reinforces the issue crop growth variability is not only affected by nitrogen and nutrient variability.

**Figure 5.
Stake site with
poor plant
number
establishment**



2004/05 results

These results are still to be analysed and collated. There is no soil test data for 2003/04. However soil tests were taken at each stake site in 2004/05. An example of some of the soil test results for one crop is shown in Table 5. There is relatively little variability except for the P (Colwell phosphorus) soil test results.

Table 5. Soil test and yield results per stake for one rice crop 2004/05							
Peg	1	2	3	4	5	6	7
Yield	9	5.4	9.3	7.4	8	4.2	7.2
pH	6.5	6.7	6.2	6.1	5.7	6	6.4
OC%	0.6	0.7	0.9	1	1.1	1.1	0.91
S	7.7	9	8.6	7	9.1	7.9	8.7
P	11	14	23	22	60	54	25
ESP	12	12	12	13	11	12	15

DISCUSSION OF RESULTS

There were two issues relating to the results. It was difficult finding a methodology for presenting the results for each crop and comparing crops.

It was difficult finding a method for sorting the 2003/04 data into meaningful result. The second issue was that Peter Evans, Rice Education Officer and Felicity Steel, Rice Technical Officer, Finley had other key duties in addition to this project. Hence the time able to be devoted to this sub-project was shared with other duties. The Rice Education Officer resigned in January 2005 which prevented time to be given to data analysis and reporting of results from both years of the project. The remainder of the crop monitoring and yield cuts in the Murrumbidgee Valley districts for the 2004/05 crops were carried out by the Rice Farming Systems Leader, District Agronomists, Griffith Technical Assistant and assistance from research staff. Only the results from the 2003/04 season are available for this report.

This extension sub-project set out to investigate the factors affecting rice growth and yield variability. It measured a number of simple parameters including some parameters measured by farmers in the Ricecheck program. Hence the project has attempted to investigate simple relationships which can provide basic knowledge and understanding as a prelude to more complex research investigations.

The project has established there is large yield variability and large factor variability within crops and between crops. The yield CV ranged from 4% to 76%. The variation of measured parameters within the one crop eg plant number, water depth, N uptake has been surprisingly high with CV often as high as 60-80%. There is a need to gain an understanding of the reasons for this variability which will be the subject of further analysis of the data.

Further analysis of the data will assess relationships between the factors measured and rice growth and rice yields. Table 2 provided an example where young microspore water depth is correlated with two of the low yield stakes. Figure 5 shows an example of poor plant numbers having a big impact on the stake yield.

There has been an assumption each image colour or NDVI is uniform. The nitrogen uptake and fresh weight data in Table 1 shows there is some variation within these zones. This suggests the need for the narrowing of the NDVI range for the zones, more sampling of each zone, the need for more discretionary sampling and awareness that the zones are not perfectly uniform.

IMPLICATIONS AND RECOMMENDATIONS

The data from the 2003/04 and 2004/05 seasons needs to be fully collated, analysed and reported.

The data for each crop gathered so far is valuable. Opportunities to expand the data set for each crop should be investigated to enable fuller diagnosis of the variability. The farmer co-operators, contractors and irrigation supply companies may have extra information and need to be contacted. Data includes soil type, cut and fill information and EM maps.

Once all data is collated and results analysed farmer co-operators need to be consulted on their results and surveyed on what the results mean to them to assist with future project planning.

The project results should be linked to the network of researchers engaged in precision agriculture projects for rice farming systems and the recently formed Precision Agriculture for Rice and Rice Farming Systems steering committee

A research project proposal to intensively investigate and overcome the factors causing spatial variability in rice crops should be submitted to RIRDC R&D committee by September 2005.

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