# $CO_2$ Exchange

**'Examination of the effectiveness of recycled tractor exhaust for use on dryland cropping soils on yield and grain quality and soil health'**

## FINAL REPORT

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## 1.0 Executive summary

Mallee Sustainable Farming Inc. (MSF) was commissioned by the Lower Murray Darling Catchment Management Authority (LMD CMA) to administer, examine and report on a project that investigated the effectiveness of carbon dioxide ($CO_2$) exchange on plant growth and sustainable agricultural production. This is the first time the technology has been trialled in Australia and under Mallee-like conditions.

Results from this preliminary demonstration activity indicated that there was no net positive or negative consequence for the use of this technology. It can be viewed in a number of different ways, including the short-term benefit of reduced input costs and an overall savings in the cost of production. However, the long term viability and effectiveness of this technology is still unknown, and thus soil auditing should be conducted and conventional products applied until the results of further experimentation confirm the proposed benefits.

Mallee Sustainable Farming Inc. therefore recommends the following;

1. Further financial investment should be secured to examine this technology on an annual basis for a minimum period of 5 years. This will ensure that the results are plausible and accurate.
2. MSF believes that experimental works should be completed on one property only to validate the equipment and technology. By introducing onto other properties, increases the amount of variability (namely environmental).
3. Complete soil analysis be conducted on the trial site to assess changes to the soil nutrient balance.
4. Endorse technology through an incentive scheme, only after stringent scientific experimentation confirms the benefits of the technology.
5. Research should at best evaluate whether tractor exhaust can be retained by soils and the form carbon is converted to when in the soil.
6. At the current time, MSF and the LMD CMA should tread cautiously in promotion of this technology and should be seen as supporting products that support three principles, a) registered products, b) critically examination and assessment of the product claims and c) valuation of products based on nutrient composition.

## 2.0 Introduction

Gary Lewis (founder of N/C Quest Inc.) claims that for optimal microbial stimulation, a carbon:nitrogen (C:N) ratio of 30:1 is required. One way to achieve this is to utilise exhaust emission from traditional tractor activities by converting machinery that allows for the exhaust emissions to be recycled and injected into the soil (referred to as BioAgtive Emissions; BAE). As important is the nitrogen levels are to the crop, the $CO_2$ processed is just as important to the biology of the soil.

The actual chemical composition of tractor exhaust emissions is determined by the thermal efficiency of the engine (dependent on type of fuel, engine speed, engine load, injection settings and operating temperature). This BAE technology captures 100% of machinery diesel exhaust, and processes it into a soil-injectable nutrient gas for agricultural use.

Combined, the BAE system with the addition of fuel additives adjusts exhaust composition which in turn enhances the biochemical interactions with the soil and plant to maximize plant production.

The Bio-Agtive Emission system is proposed to increase the availability of nitrogen compounds in several ways;

1. Increased soil $CO_2$ level stimulates free-living nitrogen-fixing bacteria which produce amino acids (a food source for soil biota).
2. Plants have a preference to use nitrogen in the form of nitrate ($NO_3$), the BAE technology is twice as efficient at sequestering $CO_2$ as when ammonium (traditional form) is used. The surplus $CO_2$ continues to stimulate the nitrogen-fixing bacteria, setting up a positive feedback loop which keeps the nitrogen cycle going longer.

According to Lewis, the exhaust should not be compared to traditional fertilisers, but rather as a catalyst for nature to trigger biological influence of plant growth.

This technology has been used with mixed results internationally. It was developed in Canada, and has been used in farming systems in Europe and the United Kingdom. It has been used on crops other than cereals, including corn. It is important to note that these trials sites have used this technology in environments very different to the Mallee, where a wet soil profile or irrigated crops are grown and may influence the outcomes reported.

This report provides insight whether this technology is suited to the Mallee environment based on dryland cropping practices engaged. Experiential anecdotes by the participating farmer will feature in the report.

## 3.0 About the case study landholder and farm

The case study landholder decided to trial this technology because they were experiencing problems with nutrient availability, in particular phosphorus (P) and calcium (Ca) lock-up. They were also concerned about the sustainability of their soils and the crop's ability to access stored soil moisture. The landholders were hoping that the use of this technology would assist in unlocking these abovementioned elements and making them more available to the plants. In addition, it is hoped that soil biological activity will be promoted.

The previous management of the trial site comprised of continuous cropping principles for the past 10 years with seeding rate at 25kg/ha and di-ammonium nitrate (DAP) applied at a rate of 60 kg/ha. The landholder will continue to conduct soil audits (testing for macro and micronutrient levels) and will apply specific conventional products on a needs basis based on the soil test results.

## 4.0 About the equipment

The technology utilises the existing seeding and cultivation bar. The major modifications include the transfer of the exhaust gas from the engine to the sowing knife without any interruption to the fundamental air-seeder functionality. A large heat exchanger (fans) is mounted onto the seeding machine behind the tractor and additional hoses are required to be connected to and fro the heat exchanger into the seedbox. In addition, simple mounting brackets, fittings and flexible connectors were all that were required to make the conversion. The importance of the heat exchanger is to ensure that the exhaust is at an optimum temperature that does not cause detriment to the seed. The temperature is altered from approximately 400°C (at engine) to approximately 30°C (at seed boot). Plates 1-3 depict the equipment and special features for this machinery conversion.

**Plate 1.** Participant landholder, Mr Ian Linklater describing the mechanical changes to his seeding rig at a field day in 2008.

**Plate 2.** MSF Extension Coordinator Dr. Nicole Dimos presenting results of the trial in NSW.

**Plate 3. E**quipment used.
Note the large fans behind the tractor and the piping that connects to all parts of the seeding equipment ensuring no exhaust is emitted until after the seedbox.

## 5.0 Aims

The project aims;

1. To provide assistance to one participatory farmer to convert existing farm equipment that promotes sustainable agricultural production.
2. To assess the effectiveness of $CO_2$ exchange (recycling diesel exhaust) by measuring changes to soil characters to treated and untreated agricultural soils used in dryland cropping activities.

## 6.0 Methods

The demonstration trial was set up investigating the new technology "recycled tractor (diesel) exhaust" against conventional agricultural practices in the Mallee.

The four treatments consisted;

1. Double exhaust pass – whereby the first pass injected exhaust and the second pass injected exhaust and seed into the soil

2. Single exhaust pass – where the seed and exhaust was injected in one pass only
3. Control – seed only sown
4. Conventional practice – Nitrogen (in the form of DAP) and seed.

Soil samples were collected twice throughout the growing season. This includes at sowing (May 19th, 2008) and 4 weeks post-sowing (18th June, 2008). Plant analysis was conducted twice (4 weeks post sowing; 18th June, 2008 and 16 weeks post sowing; 8th September, 2008). Samples were harvested (24th November, 2008) and analysed for yield and quality parameters.

Samples or replicates were collected in six metre strips, i.e. each treatment was 18 metres wide, and thus, five replicates were six metres apart, with a three metre buffer on either side of the sampling area. Each replicate strip comprised of eight samples combined.

Soil was collected using an auger of 55cm diameter to a depth of 10cms. The samples were collected pre-sowing, and post-sowing (within 30 minutes of sowing).

Soils were placed into labelled zip lock bags and stored on ice bricks. The samples were taken to the Department of Primary Industries (Irymple) where the soils were weighed into tared oven trays and dried for approximately five days (or until a consistent reading was made). The samples were then freighted to CSIRO Adelaide for laboratory analysis. The samples were measured for total soil carbon content (% soil mass).

At four weeks post sowing, soil sampling was conducted as described above. Soils were kept cold, and sent same day to CSIRO Adelaide for analysis of dissolved organic carbon (µg C g/soil) and for microbial biomass (µg C g/soil).

At this time, the plants were visually assessed for any deficiencies (discolouring) and any disease symptoms. Five plants per treatment were also dug out to assess root growth. This was then repeated at 16 weeks post sowing. Plant counts were also conducted. This was achieved by randomly throwing a pasture transect and counting the number of individual plants in the transect.

At harvest, the landholder header was used to strip the crop within each treatment area. The header drove through the middle of each treatment to avoid any error or cross-over from aligning treatments. The header travelled 1200m. The stripped grain was then augured into a weigh bin where the weight (kg) was recorded. A sub-sample of the grain was collected and taken to the Graincorp delivery site (Yelta) for assessment of grain quality.

## 7.0 Results and Discussion

### *7.1 Total soil carbon content*

Mean soil total carbon content was 0.67 (% soil mass) pre-sowing and altered after sowing was conducted. In the double exhaust and nitrogen applied treatments, total carbon content decreased from pre-sowing, however, increased in the other two treatments (**Figure 1**). Soil total carbon content was lowest in the nitrogen applied treatment, but comparable with the double exhaust treatment. The control treatment yielded the highest soil total carbon content, however, this was not different to the single exhaust treatment. It is unclear why the levels responded the way they did, and it is possible that the double exhaust treatment was lower due to the twice knifing of the soil and hence disturbing the levels in a negative way that released the carbon that was previously trapped in the soil.

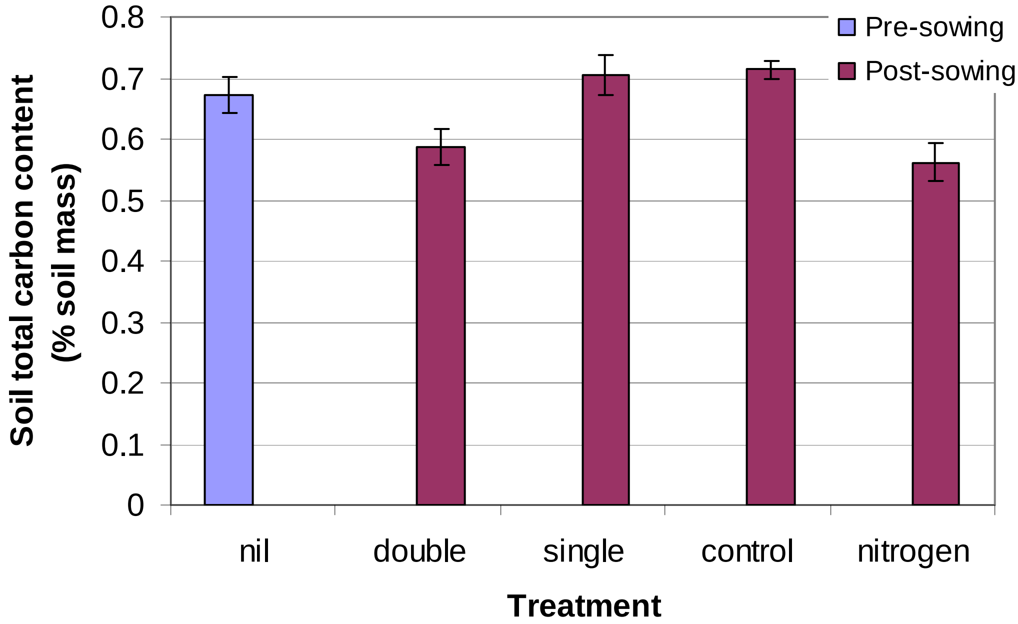


**Figure 1.** Mean soil total carbon content (% soil mass) at time of sowing.
The purple bar indicates sampling collected prior to the seeding, whereas the maroon bars indicate samples taken 30 minutes post sowing.

### *7.2 Extractable C – Dissolved organic carbon*

There was large variation in dissolved organic carbon (DOC) four weeks post sowing. The greater the value of DOC, the greater the benefit for soil microbiology (**Figure 2**). Dissolved organic carbon is the form that carbon is measured that is readily available for bugs. In this demonstration, the exhaust treatments report increased carbon available for microbiota.

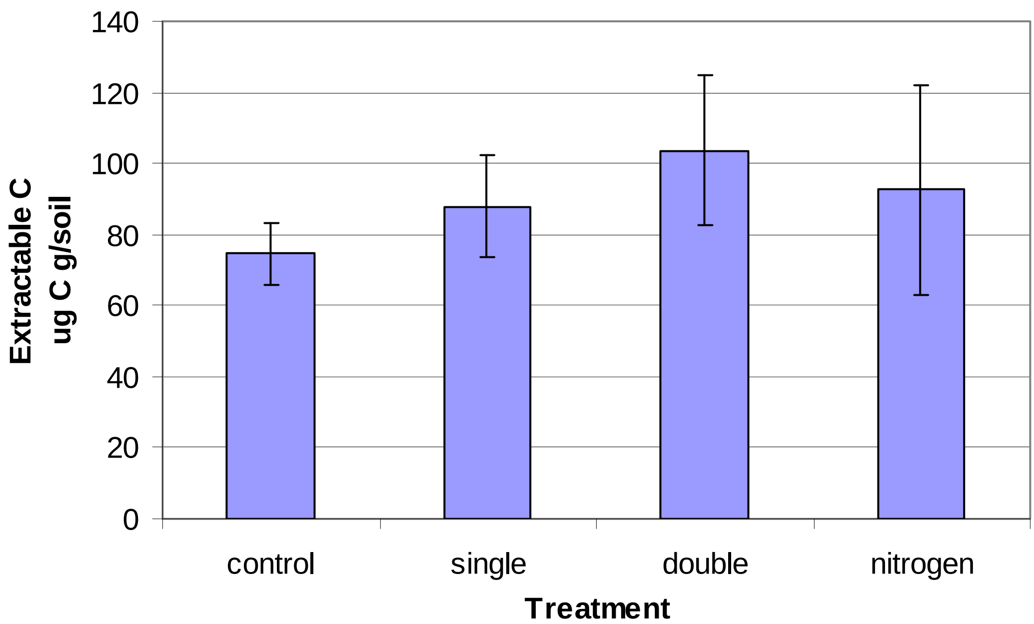


**Figure 2.** Mean extractable carbon (µg C/g soil) at 12 weeks post sowing.

### *7.3 Microbial Biomass Carbon*

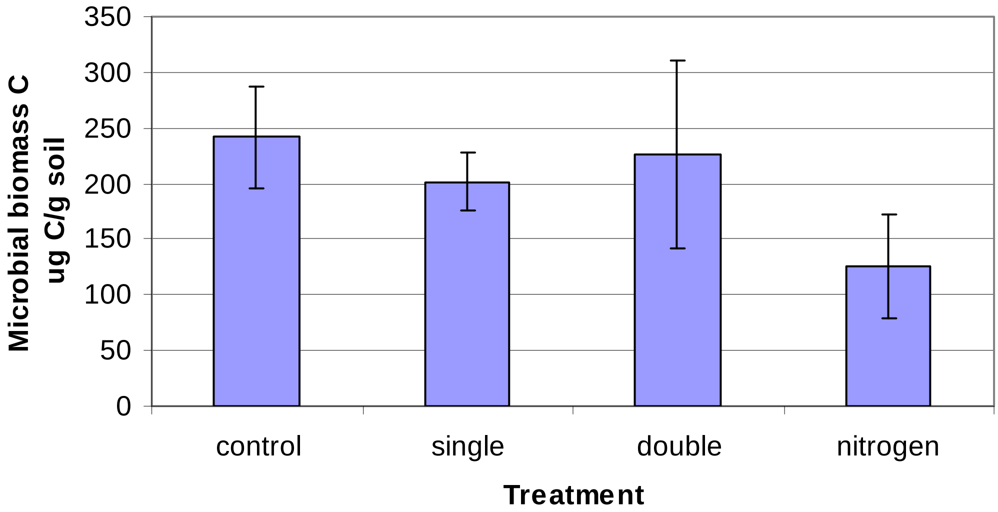


**Figure 3.** Microbial biomass carbon (µg C/ g soil) at 12 weeks post sowing.

Microbial biomass was highest again for the double exhaust treatment, but was not different to any other treatments (**Figure 3**). For good microbial function in the soil, microbiologists aim for levels between 200-400ug C/ g soil. This was achieved in all but the nitrogen applied treatment. It is likely that the reason for the reduced microbial biomass levels in the nitrogen treatment is a result of the microbes being consumed by the nitrogen fertiliser.

### *7.4 Plant Counts*

Plant counts varied across the exhaust treatment and the non-exhaust treatments (**Figure 4**). A principle factor may be due to the seeding rate that was used in the control and nitrogen treatments was sown at 25kg/ha compared to 29kg/ha. Regardless of sowing rates, there was no obvious between treatments.

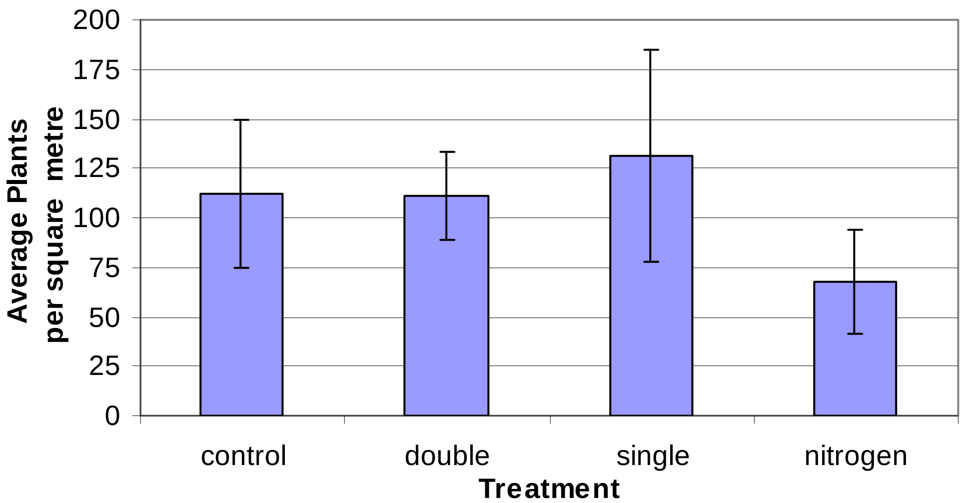


**Figure 4.** Average plant counts.

Please note, this trial was for demonstration purposes only, and no statistical analysis was conducted. The error bars on each of the above figures is to highlight the variation reported in the sampling only and no level of significance can be determined.

*7.5 Visual assessments*

The images (**Plate 4**) below show that the plants at four weeks post sowing have a more vigorous primary root system in the nitrogen applied treatment, however the exhaust treatments have more lateral roots system however, at 16 weeks post sowing, there was no discernible difference both above and below ground. The plants appeared healthy with consistent green colour on the plants.


**Plate 4.** Plant visuals at 4 weeks post sowing (above) and 16 weeks (post sowing) below.

The landholder noted that lower seed mortality was observed in the exhaust treatment and that strip rust was more prevalent across the areas where fertilizer was not used.

*7.6 Harvest*

At harvest, there were no differences in the quality components of the assessments collected (**Table 1**). There were differences in yield with the exhaust treatments yielding the least, and the conventional practice with nitrogen producing the greatest amount of crop. As there is only one sample, no statistical analysis has been conducted to assess for significance.

**Table 1.** Yield and quality results at harvest of the effectiveness of recycled tractor exhaust applied to agricultural soils.

| | Control | Double | Single | Nitrogen |
|---|---|---|---|---|
| Test weight | 80 | 79 | 79 | 80 |
| Moisture content | 10.4 | 10.6 | 10.6 | 10.4 |
| Protein | 14.1 | 14.2 | 13.2 | 13.5 |
| Screening | 3.0 | 2.4 | 2.1 | 2.4 |
| Yield (t/ha) | 1.45 | 1.30 | 1.40 | 1.49 |

Interestingly, yield was highest in the non-exhaust treatments which as mentioned above were sown at lower sowing densities, although these differences were not reportable in the test weights of the grain. Protein levels were acceptable as were screenings which would not result in a penalty to the landholder.

*7.7 Growing season rainfall*

Rainfall on the trial paddock was collected for the growing season (1 April – 31 October). A total of 117.25mm was recorded (**Figure 5**). April saw only one rain event of 16mm on the 26th April and a second significant rain event on the 5th July with 17mm recorded. The majority of rain fell November (55mm) during the harvesting period.

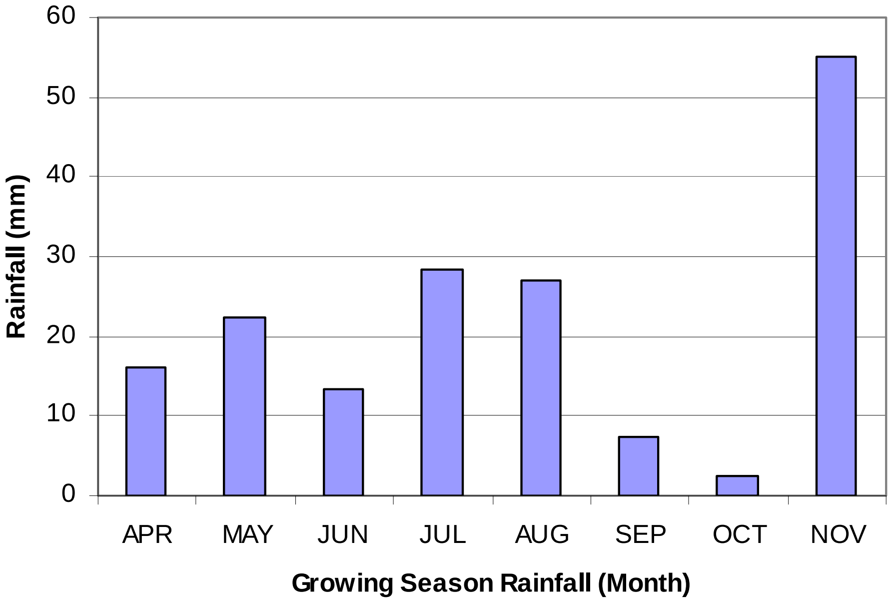


**Figure 5.** Growing season rainfall at the trial paddock.

## 8.0 Community awareness

The project has been disseminated broadly to the local Mallee community and within major rural news print media. The landholder family has also had a number of enquiries and visitors inspecting the equipment on occasions separate to the main event held in September 2008. The following is the communications and publicity list from the project.

*8.1 Media and communications*

a. ABC Rural report 18th September "Using tractor exhaust fumes to grow wheat"
b. Weekly Times 28th May 2008 "Ian makes carbon his friend"
c. Weekly Times 29th October 2008 "Exhausting all the grain possibilities"
d. Weekly Times 29th October 2008 "Mallee group puts revolutionary method to the test"

*8.2 Communications*

a. MSF RDE meeting 13th August – presentation delivered by Dr Nicole Dimos to 30 participants.

b. Healthy Soils team meeting 27th August – presentation delivered by Dr Nicole Dimos to 12 participants.
c. Kerribee Crop Walk/ Soil Biology day 17th September - presentation delivered by Dr Nicole Dimos and Mr Ian Linklater to approximately 50 participants (**Plate 5**).
d. Mallee Research Station Open day 3rd October – presentation delivered by Dr Nicole Dimos to approximately 100 participants.

**Plate 5.** Participants at an industry field day inspecting the converted equipment proposed to improve sustainability in dryland cropping activities.

## 9.0 Conclusions

This study has investigated the effectiveness of recycling tractor exhaust and applying to Mallee cropping soils. The outcomes from this study has revealed inconsistent results with positive effects observed in the soil measurements with regards to microbiota and carbon levels as the season progressed, however, these benefits were not transferred into final harvested yield benefits. As there is no statistical analysis of harvest data, there is no apparent disadvantage for the use of this technology in the short term. This can therefore be seen as a positive effect as cost savings may be significant in farming systems in the Mallee. Longer term studies and the continuation of soil chemical auditing is a process to that should be continued to assess the longevity for use of this technology.

## 10.0 Recommendations

Mallee Sustainable Farming Inc. therefore recommends the following;

1. Further financial investment should be secured to examine this technology on an annual basis for a minimum period of 5 years. This will ensure that the results are plausible and accurate.
2. MSF believes that experimental works should be completed on one property only to validate the equipment and technology. By introducing onto other properties, increases the amount of variability (namely environmental).
3. Complete soil analysis be conducted on the trial site to assess changes to the soil nutrient balance.

4. Endorse technology through an incentive scheme, only after stringent scientific experimentation confirms the benefits of the technology.
5. Research should at best evaluate whether tractor exhaust can be retained by soils and the form carbon is converted to when in the soil.
6. At the current time, MSF and the LMD CMA should tread cautiously in promotion of this technology and should be seen as supporting products that support three principles, a) registered products, b) critically examination and assessment of the product claims and c) valuation of products based on nutrient composition.

## 11.0 Acknowledgement

MSF gratefully acknowledges the support and contributions from;

- LMD CMA for financial assistance in completing the experimental component of this project.
- NSW DPI, especially Anthony Baird and Susan Walla for technical assistance in the field work.
- Gupta Vadakattua (CSIRO) for the laboratory analysis of dissolved organic carbon and microbial biomass.
- Jeff Baldock (CSIRO) for the laboratory analysis of total soil carbon content.
- Victorian DPI for laboratory and drying oven use.
- Mick Connelly (Graincorp) for the harvest quality assessments.
- Ian, Daniel and David Linklater for their cooperation, assistance and participation in this project.