Assessment of the use of degradable polymer films in early planting of aerobic rice varieties

By Dr. Melissa Nikolić (CRC-P), Dr. Bronwyn Laycock (CRC-P), Anna Jewell (RRAPL)
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Foreword

Aerobic rice varieties are known to exhibit problems due to the duration or growth period being too long. Trials using degradable polymer film seek to demonstrate that such aerobic varieties could be sown at an earlier stage (during cooler conditions) and thus still mature during the ideal environment occurring in the first months of autumn. Producers of aerobic rice and related industries are set to benefit most from this research.

There will be predominately economic and environmental benefits from this research, including:

- Safeguarding early generations of aerobic rice through early establishment and fewer weeds;
- Being able to test the varieties for performance in an aerobic situation whilst also multiplying seed, giving a double bonus to the bottom line of economic efficiency;
- Reducing the amount of time the crop will take to establish (up to 15 days);
- Polymer film can help reduce the time taken to develop varieties that use less water;
- The ability to add the aerobic rice farming system into the current farming practices for rice would allow the possibility of shorter crop rotations and easier ‘traffic ability’ of machinery before and after the rice crop.

Degradable film supplied by Integrated Packaging performed as required by breaking down within 14 days above-ground in the field. During the 2014 – 2015 trial, crops that received a film treatment had a higher germination rate and matured more rapidly, however; this was not translated into better growth over the crop season. Further trial development is required to determine the extent of any advantages to aerobic rice with the use of degradable film.

Data is too preliminary to be able to recommend what producers and policy makers should do differently to achieve better outcomes from aerobic rice farming.

The CRC for Polymers incorporates this AgriFutures Australia research project as a component of a larger project within one of three research programs. This collaborative research involves expertise in polymer chemistry, water studies, microbiology, agronomy and soil science. The Polymers, Water & Food Security program aims to develop polymer technologies that assist Australian farmers to meet the growing global demand for food, by overcoming water scarcity and improving crop yields.

This report, for the Rice R&D program, is an addition to AgriFutures Australia’s diverse range of over 2000 research publications and it forms part of our Growing Profitability arena, which aims to enhance the profitability and sustainability of our levied rural industries.

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John Harvey
Managing Director
AgriFutures Australia
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Executive Summary

What the report is about

This project has assessed the cost and benefits of a proposed new practice for producing aerobic rice using degradable film that offers the potential of sowing at an earlier stage (during cooler conditions) and reaching maturity during the ideal environment occurring in the first months of Autumn. The project has been hosted and managed by RRAPL and involved small-scale trials in the first year followed by larger scale trials conducted over the following two years. The benefits also include water savings and a reduction in crop impacts by pests, particularly locusts, and weeds.

Who is the report targeted at?

The use of polymer film with aerobic rice has undergone a proof of concept on a research scale by RRAPL. Once a proven method of use had been accepted for nursery style plots, it would be envisaged that the use of the polymer film would be tested on a slightly larger scale planting across a number of varieties to evaluate the potential of improved crop efficiency through faster and cleaner establishment.

If proven successful in this testing, the value and efficiency will be known for commercial scale adoption. The cost of the polymer film would be evaluated against the improved crop efficiency to allow farmers to assess the value of the system.

Where are the relevant industries located in Australia?

This research has focussed on the Sherpa variety grown in “Old Coree”, Jerilderie, New South Wales.

Background

Integrated Packaging has developed very thin polyethylene films for use in crop production. These ultra-thin plastic films are applied by a machine at the same time that the seed is planted to form a temporary ‘green house’ that enhances water retention and crop outcomes, and degrade in a controlled way during the growing cycle. They are used in Ireland with maize where the benefit is extension of the short growing season to ensure crop maturity at harvest. The CRC for Polymers and Integrated Packaging have established that the main potential benefits to crop producers in Australia resulting from the 4-8 weeks that the films are intact prior to degradation include: consistently high germination rates; very good establishment and early growth; elevating the soil temperature (allowing early planting); retaining soil moisture and transpired moisture (greater efficiency in water use); achieving crop maturity in shorter time frames (e.g. allowing late plantings, early harvesting, production of an extra crop); and allowing a crop to be produced in regions where climatic conditions would normally not allow this (e.g. marginal regions, land with salt contamination).

Aerobic rice varieties are known to exhibit problems due to the duration or growth period being too long. The trial using degradable polymer film would seek to demonstrate that such aerobic varieties could be sown at an earlier stage (during cooler conditions) and thus still mature during the ideal environment occurring in the first months of autumn.

Aims/objectives

The use of degradable polymer film in the early planting of aerobic rice varieties will be trialled to:
1. Evaluate the selected film formulations for their potential to aid early growth during cooler conditions.

2. Determine the best time to apply the film, and the optimal time it should remain intact prior to it degrading, so that its use achieves the best crop outcome.

3. Determine the best rice variety to use in conjunction with the film technology.

4. Assess the cost and benefits of using this technology, including assessing the water saving that can be achieved.

**Methods used**

RRAPL has hosted and managed the rice trials with polymer film. Films were provided by Integrated Packaging and laid manually by RRAPL staff at Old Coree, NSW. Aerobic nursery plots were established using the Sherpa variety.

The area of the plot size is approximately 600m$^2$. It is laid out with dripper and trickle irrigation which is ideal for aerobic rice production.

Monitoring involved the collection of data on establishment; root growth observation (which is suspected to be more vigorous during the early stage of growth due to their ability to penetrate to deeper levels and source available moisture); and yield by variety in a replicated block design.

Trials to be conducted in these years will build on and be informed by the results obtained in the first year.

**Results/key findings**

Based on the results of the trials, the film degraded within the requested time above-ground; however weather events and aerobic growing conditions of the trial and it’s subjectiveness to cold weather without ponded water that helps insulate the crop from temperature extremes, severely impacted on outcomes. Unforeseen weather events, such as heavy rainfall and strong wind delayed trials that were originally planned for a September/October to start in November/December. High atmospheric temperatures negatively impacted on the use of film over aerobic rice due to heat build-up within the headspace between the soil and film. Ideally the trial needs to start in September to avoid heat build-up in the headspace.

There were water savings by growing rice on sub surface drip irrigation; however the gross margin did not outweigh the benefits of the water saving compared to traditional ponded rice which has a greater gross margin. Additionally, crop yield was far superior in traditional ponded rice hence the greater gross margin.

Trials focussed on the Sherpa variety as it has the shortest season, is most tolerant to cold temperatures out of commercially available rice varieties and well suited to the soils at the Old Coree site.

Further trial development is required to determine the extent of any advantages to aerobic rice with the use of degradable film.

**Implications for relevant stakeholders**

**Economic Benefits**

The initial benefits are safeguarding early generations of aerobic rice through early establishment and fewer weeds. It is hard to put an exact cost on the value of establishing
nurseries for aerobic rice, but the cost of maintaining this seed alone is considerable. Being able to test the varieties for performance in an aerobic situation whilst also multiplying seed, gives a double bonus to the bottom line of economic efficiency.

The secondary economic benefit will be from reducing the amount of time the crop will take to establish. It is estimated this could reduce the total days of growth by up to 15 days, also leading to a reduced water requirement.

*Environmental Benefits*

The whole drive to reduce water use is the drive for aerobic rice. If the polymer film can help reduce the time taken to develop varieties that use less water, then the environmental benefits will flow from the commercialisation of these varieties.

If the polymer film is found to be beneficial for commercially grown aerobic or Delayed Permanent Water (DPW) Rice, then this will have an addition environmental benefit through the reduction of water used.

*Social Benefits*

It is difficult to directly relate the introduction of the polymer film to a social benefit.

Indirectly, the ability to add the aerobic rice farming system into the current farming practices for rice would allow the possibility of shorter crop rotations and easier ‘traffic ability’ of machinery before and after the rice crop.

*Recommendations*

Further trial development is required to be able to evaluate further benefits for the use of degradable film on aerobic rice production. The following recommendations can be drawn data accumulated from each trial:

- Ensure the site is animal-proof
- Film have some wind resistance as the site became very windy at times causing premature tearing of the film
- Start trials in mid to late September to reduce heat stress to the plants
- Use film laying equipment in order to avoid any lifting of the film, or bury the film edges with more soil if film laying is being performed manually;
- Investigate alternative farming practices or other crop types to successfully obtain a viable crop.
Introduction

Integrated Packaging has developed very thin polyethylene films for use in crop production. These ultra-thin plastic films are applied by a machine at the same time that the seed is planted to form a temporary ‘green house’ that enhances water retention and crop outcomes, and degrade in a controlled way during the growing cycle. They are used in Ireland with maize where the benefit is extension of the short growing season to ensure crop maturity at harvest.

The CRC for Polymers and Integrated Packaging have established that the main potential benefits to crop producers in Australia resulting from the 4-8 weeks that the films are intact prior to degradation, include:

- consistently high germination rates;
- very good establishment and early growth;
- elevating the soil temperature (allowing early planting);
- retaining soil moisture and transpired moisture (greater efficiency in water use);
- achieving crop maturity in shorter time frames (e.g. allowing late plantings, early harvesting, production of an extra crop); and
- allowing a crop to be produced in regions where climatic conditions would normally not allow this (e.g. marginal regions, land with salt contamination).

Aerobic rice varieties are known to exhibit problems due to the duration or growth period being too long. The trial using degradable polymer film would seek to demonstrate that such aerobic varieties could be sown at an earlier stage (during cooler conditions) and thus still mature during the ideal environment occurring in the first months of autumn.

The expected outcome is an assessment of the cost and benefits of a new practice for producing aerobic rice using degradable film that enables sowing at an earlier stage (during cooler conditions) and reaching maturity during the ideal environment occurring in the first months of autumn. Other anticipated advantages of early planting are the reduction in crop impact by pests, in particular locusts, and weeds.
Objectives

The use of degradable polymer film in the early planting of aerobic rice varieties will be trialled to:

1. Evaluate the selected film formulations for their potential to aid early growth during cooler conditions.

2. Determine the best time to apply the film, and the optimal time it should remain intact prior to it degrading, so that its use achieves the best crop outcome.

3. Determine the best rice variety to use in conjunction with the film technology.

4. Assess the cost and benefits of using this technology, including assessing the water saving that can be achieved.

Methodology

RRAPL has hosted and managed the rice trials with polymer film. Films were provided by Integrated Packaging and laid manually by RRAPL staff at Old Coree, NSW. Aerobic nursery plots were established using the Sherpa variety.

Small scale field trial – 2013-2014

The area of the plot size was approximately 600m². It was laid out with dripper and trickle irrigation which is ideal for aerobic rice production.

Monitoring involved the collection of data on establishment; root growth observation (which is suspected to be more vigorous during the early stage of growth due to their ability to penetrate to deeper levels and source available moisture); and yield by variety in a replicated block design.


Trials conducted in these years built on and were informed by the results obtained in the first year.
Results

Old Coree, NSW, 2013-2014

The objective of the rice trial was to assess the use of degradable polymer film in early planting of the aerobic rice variety Sherpa. The film (code “Jerilderie film”) was required to embrittle above-ground after two weeks in the field.

This degradation target was met with the film reaching embrittlement after 10 days in the field.

Table 1 summarises the main results from the field trial over the course of the study.

Key Results

The key results from the trial were that the film degrading within the above-ground target after 10 days; however the control plants (no film) caught up in size to the plants that were grown under film within the first few weeks of the trial. Nearly 40% of the plants from under the film died due to burning from the conditions of the trial; whereas plants grown in control groups (no film) grew well.

A detailed analysis of emerging rice plants was not possibly as the plants were extensively damaged by kangaroos with most plants being chewed down to less than 10 cm, rendering it impossible to perform comparison measures between the rice grown under control (no film) and film treatments.

Future Trials

Based on the results of this first trial, the following was suggested for future trials:

- Reduce the “tear susceptibility” of the film as Jerilderie’s climate is prone to strong winds;
- Have the film ready to sow by mid to late September;
- Animal-proof the site with a fence.
Table 1. A pictorial summary of the 2013-2014 aerobic rice trial with degradable film at Old Coree, NSW.

<table>
<thead>
<tr>
<th>Date</th>
<th>Film Description (clear, opaque, white, embrittled)</th>
<th>Plant monitoring (emergence date, emergence count/m, plant height)</th>
<th>Irrigation</th>
<th>Picture</th>
</tr>
</thead>
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<tr>
<td>20/12/13</td>
<td>No areas of intact film remain. All areas were torn and the plants are all exposed. Film has broken off in areas and been carried away by wind around paddock. Film is now white in colour but still tender to touch.</td>
<td>The control plants have now caught up in size to the plants under film. Nearly 40% of the plants from under the film have died due to burning. Plants in control groups are doing well.</td>
<td>40 hours irrigation</td>
<td><img src="image1.jpg" alt="Image" /></td>
</tr>
<tr>
<td>30/12/13</td>
<td>No exposed film remains. Only samples of under sections will be sent to UQ for analysis.</td>
<td>Plants growing well. Significant areas (30-40%) of the under film areas have no plants left (Eastern side of trial). These deaths were due to burning of the growing tip.</td>
<td>Irrigated 27 and 28th of December for 40 hours</td>
<td><img src="image2.jpg" alt="Image" /></td>
</tr>
<tr>
<td>6/01/14</td>
<td>Under soil plastic still intact.</td>
<td>Control plants are now the same height or taller than plants that were under film. Significantly less weeds in film areas compared to control, although some weeds still present.</td>
<td>Irrigated for 30 hours on Friday. Every Friday the watering will now come on for 30 hours.</td>
<td><img src="image3.jpg" alt="Image" /></td>
</tr>
<tr>
<td>28/01/14</td>
<td>No plastic remains</td>
<td>Extensive damage from kangaroos. Most plants have been chewed down to less than 10 cm. This is a common issue in aerobically grown rice.</td>
<td>Still being watered every Friday for 30 hours</td>
<td><img src="image4.jpg" alt="Image" /></td>
</tr>
</tbody>
</table>
Old Coree, NSW, 2014-2015

In the following year, two film types of different expected lifetimes (codes TR114019 and TR626), were trialled to assess their impact on plant germination and survival post film degradation above-ground. Film TR114019 was of the same formulation as the film used in the 2013-2014 trial, therefore it was expected to reach embrittlement within the above-ground degradation target of 2 weeks. TR626 contained half the concentration of prodegradant compared to TR114019. The site was also “animal proofed” to avoid disruption from wildlife (Figure 1) and the same rice variety, Sherpa, was used as the previous trial.

This trial started on the 9th of October 2014 (spring); however issues were encountered with the film early in the trial due to strong wind. On the first Sunday of the trial (12th of October 2014) two rows of film lifted and drifted and it was not possible to secure these rows again due to the mud from watering. One row could be laid back down on Wednesday the 15th of October 2014 but the other could not. The trial continued regardless of these issues.

Figure 1. Image of the rice field trial on the day the films were laid (October 9, 2014).

Film Degradation

The above-ground degradation target was met with film TR114019, where embrittlement was observed after 15 days above-ground. The embrittlement of film TR626 was slower (39 days) as expected due to a lower concentration of prodegradant within the film.
Crop performance

Table 2 summarizes the different stages of film degradation above-ground and the subsequent crop growth at Old Coree, NSW. After 20 days in the ground, the plants that had grown under film were at a 3 leaf stage whereas plants that were not grown under were only at 2 leaf stage. There was also a significantly higher plant population where the film was applied compared to the control area (no film). The crops that received a film treatment had a higher germination rate and matured more rapidly but this was not translated into better growth over the crop season.

Unfortunately, crop growth and development throughout the season was poor, resulting in sterility in the rice crop and crop failure due to low temperatures after crop emergence. Aerobic conditions exposed the crop to the low overnight temperatures; significantly more than in anaerobic rice growing conditions, which have an insulating layer of water of up to 25 cm deep that protects plants from the cold conditions. This resulted in reduced tillering, sterility of the spikelets, spikelet abortion and therefore delayed, incomplete and no grain maturation. Along with sterility in the rice crop, inadequate water supply and competition from weeds also decreased the crop production. Due to the significant crop failure, it was not harvested. Differences in plant germination and survival could not be observed between film treatments TR626 and TR110419 as these results have been overshadowed by poor conditions of the trial.

Table 2. A pictorial summary of the 2014-2015 aerobic rice trial with degradable film at Old Coree, NSW.
Summary

Crops that were grown under film matured more rapidly and with a higher germination rate, but this was not translated into better growth over the crop season. Overall, the season was poor which resulted in reduced tillering, sterile/abortion of spikelets, low temperatures overnight and inadequate water supply. For these reasons, the trial was not harvested.

Future Trials

Suggestions to consider for future trials are:

- Use film laying equipment in order to avoid any lifting of the film, or bury the film edges under more soil if film laying is being performed manually;
- Investigate alternative farming practices or other crop types to successfully obtain a viable crop.

Old Coree, NSW, 2015-2016

The objective of this rice trial was to assess the use of degradable polymer film in early planting of the Sherpa aerobic rice variety; using three film types:

- TR626 (about 10 m – not perforated)
- T2014 (about 4 m – not perforated)
- A biodegradable/oxodegradable blend (perforated every 5 cm).

The biodegradable/oxodegradable blend was perforated with the aim of releasing heat build-up within the headspace.

The rice was sowed on the 16th of November 2015, however due to heavy rain it was not possible to lay the film at the same time was laid on the 30th of November 2015. Three replicates for the perforated film were laid and one replicate for films TR626 and T2014 (not perforated). The site was watered after films were laid.

The investigation of the benefit of using a small bank up around the trial at about the 4 leaf stage with the aim to hold in more water later in the season and also retain some heat was assessed. Figure 2 shows part of the trial setup.
Crop performance

High temperatures and sweating occurred under the polymer film treatments resulting in reduced crop establishment and low plant populations (Figure 3). Despite having a perforated film there was still a hostile environment for rice under the film. Daytime temperatures would have been reaching 35°C outside of the film and much higher levels under the film. The environment under the film would have been almost anaerobic, even though the aim was to have an aerobic environment for the growing season.
Figure 3. Demonstrating high temperatures and sweating that occurred under polymer film. (A) T2014 (not perforated), (B) TR626 (not perforated) and the biodegradable/oxidodegradable film (perforated) on the 18th of November 2015, resulting in reduced crop establishment and low plant populations.

Figure 4 illustrates the status of the trial on the 5th of January 2016. Under the perforated film, some rice survived that emerged through a perforated hole, however a large amount or rice had perished before the film broke down. Larger perforations are required to adequately release heat build-up from the headspace. There was minimal rice present in areas covered by polymer film (all types) and consequently it is not expected that there will be an advantage in yield with the use of film. This is mainly due to the aerobic growing conditions of the trial and it’s subjectiveness to cold weather without ponded water that helps insulate the crop from temperature extremes, not due to failure of the film. These conditions impacted on the panicle initiation (PI) and microspore stage during reproduction. Low temperatures at this stage disrupt the movement of sugars into the microspores, reducing the number of viable pollen produced and leading to floret sterility.
Figure 4. Status of the trial on the 5th of January 2016 (after 1.5 months in the field).
Film TR626 has disintegrated and the perforated film is intact. Minimal rice growth under perforated film (A) and no rice germination was evident under film TR626.

The trial is still being watered consistently, however is struggling to fill many grains. An attempt at harvesting will be made at the end of April to evaluate differences in polymer film (perforation versus non-perforated) and control (no film).

Summary

Based on the results from each of the trials, the non-perforated films TR626 and T2014, degraded within the requested time above-ground; however weather events and aerobic growing conditions of the trial and it’s subjectiveness to cold weather without ponded water that helps insulate the crop from temperature extremes, severely impacted on outcomes. Unforeseen weather events, such as heavy rainfall and strong wind delayed trials that were originally planned for a September/October to November/December. High atmospheric temperatures negatively impacted on the use of film over aerobic rice due to heat build-up within the headspace between the soil and film. For the perforated film treatment, larger perforations are required to adequately release heat build-up from the headspace. Ideally the trial needs to start in September as mentioned throughout the report to avoid heat build-up in the headspace.

Further trial development under optimal trial conditions is required to determine the extent of any advantages to aerobic rice with the use of degradable film.
Key Findings

Based on the results of the trials, the film degraded within the requested time above-ground; however weather events and aerobic growing conditions of the trial and it’s subjectiveness to cold weather without ponded water that helps insulate the crop from temperature extremes, severely impacted on outcomes. Unforeseen weather events, such as heavy rainfall and strong wind delayed trials that were originally planned for a September/October to start in November/December. High atmospheric temperatures negatively impacted on the use of film over aerobic rice due to heat build-up within the headspace between the soil and film. Ideally the trial needs to start in September to avoid heat build-up in the headspace.

There were water savings by growing rice on sub surface drip irrigation; however the gross margin did not outweigh the benefits of the water saving compared to traditional ponded rice which has a greater gross margin and crop yield was far superior in traditional ponded rice hence the greater gross margin.

Trials focussed on the Sherpa variety as it has the shortest season, is most tolerant to cold temperatures out of commercially available rice varieties and well suited to the soils at the Old Coree site.

Further trial development is required to determine the extent of any advantages to aerobic rice with the use of degradable film.
**Implications and Recommendations**

**Benefits**

**Economic**

At this point the difficulties with the timing of the trials mean that it is not possible to establish the potential economic benefits; the use of the film did result in better establishment but this did not translate into a yield advantage.

**Environmental**

The whole drive to reduce water use is the drive for aerobic rice. If the polymer film can help reduce the time taken to develop varieties that use less water, then the environmental benefits will flow from the commercialisation of these varieties. However, at this point, given the timing of the trials, it has not been possible to establish any benefit to the use of the film. Earlier planting may deliver a benefit, but to date this has not been trialled.

**Social**

It is difficult to directly relate the introduction of the polymer film to a social benefit. Indirectly, the ability to add the aerobic rice farming system into the current farming practices for rice would allow the possibility of shorter crop rotations and easier ‘traffic ability’ of machinery before and after the rice crop.

**Recommendations**

The following are recommendations derived from the trial data:

- Ensure the site is animal-proof;
- Ensure that the sites have some wind resistance as the site used became very windy at times causing premature tearing of the film;
- Start trials in mid to late September to reduce heat stress to the plants;
- Use film laying equipment in order to avoid any lifting of the film, or bury the film edges with more soil if film laying is being performed manually; and
- Investigate alternative farming practices or other crop types to successfully obtain a viable crop.
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