Evaluation of degradable polyethylene film for potato production

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RDS Partners Pty Ltd

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Final Report (May 2009)

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Purpose

The purpose of this final report is to summarise the project HG06152, Evaluation of degradable polyethylene film for potato production, which ran from April 2007 – April 2009.

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June 2009

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Media summary

Polyethylene film mulch was used on a commercial processing 'Ranger Russett' potato crops in North West Tasmania in the 2007/08 and 2008/09 seasons.

The aim of the project was to assess the impact of the film on potato plant growth and development; in particular to assess yield and tuber quality in early planted potato crops.

In the first trial (initiated September 2007), four weeks after planting, crop percentage emergence was significantly less in film treatments compared with the control. The film increased soil temperature such that the potato stems were burned or "solarised" as they emerged. This dramatic effect led to a re-thinking of both the usage timing and the thermal characteristics of the film. The trial in the second season therefore focused on earlier planting and films were investigated where light reflecting properties changed with film age.

In the second trial (initiated August 2008), emergence was earlier in the film treatments compared with the control, by about two weeks. This indicated that earlier crop emergence, particularly in early planted crops, can be achieved with use of film. Earlier emergence may increase the length of the growing season, and potentially increase yields, in early harvested crops.

Tuber development began earlier under the film treatments compared with the control. In treatments where film remained after emergence, tuber development was more advanced compared with treatments where the film was removed at emergence. This indicated that the impact of the film on king tuber size was post emergence.

Results indicated that the use of film may alter yield structure, with fewer small potatoes (<75g) from under the film treatments. In some instances this may increase the "processing yield" of potatoes.

Observations through the life of the crop indicate that there is better utilisation of existing water resources particularly through decreasing evaporative losses early in the life of the crop. In addition to this, under film, there is potentially an increase in usable soil volume available to the potato plant (due to more extensive root system in warmer soil under the film).

Leaf nitrogen and potassium levels were observed to be higher in the early and later tuber bulking stages. This indicates higher utilisation and/or reduced leaching of nitrogen and potassium.

Final yield data was inconclusive. This was due to a range of unintended non treatment factors such as weed burden and possibly moisture stress impacting on the trial site.

Experience from the above trials provides us with excellent direction for undertaking further research into commercialisation of this film technology. Further research on the impact of film on potato crop development, yield and yield structure is warranted. An estimated yield increase of 0.5t/ha (from use of film) is required to break even and cover film costs. Further assessments should also

include examination of the effects on crop nitrogen utilisation, and soil moisture dynamics, as the technology has the potential for nitrogen and irrigation savings. Further research should include identifying appropriate pre-emergent weed technology to be used in conjunction with the film; and also evaluation of optimum time for film degradation, such that any negative impact of intact film later in the life of the crop can be avoided.

Technical summary

Year one trial:

Degradable polyethylene film (Manufactured by Integrated Packaging Pty Ltd) was used on a potato (*Solanum tuberosum* L.) (‘Ranger Russett’) crop, at Leith Tasmania.

Five treatments were intended, including removal of film at four and eight weeks after 50% emergence:

1. Film A “Envirocare”covered for 4 weeks after 50% emergence
2. Film A “Envirocare”covered for 8 weeks after 50% emergence
3. Film B “Xtend”, covered for 4 weeks after 50% emergence
4. Film B “Xtend”, covered for 8 weeks after 50% emergence
5. Control (no film)

The aim of the trial was to assess the impact of the film on the potato plant growth and development, and in particular to assess the impact on yield, tuber quality and time to harvest of early planted potato crops. Soil moisture and soil temperature were also assessed.

The film had a significant effect on soil temperature. Soil temperatures were greater under the film, and as expected this difference was greater, closer to the soil surface.

Four weeks after planting, crop percentage emergence was significantly less in film treatments compared with the control. High soil temperatures in the film treatments had a “solarising effect”, and necrosis of the stems was observed at 20-30mm below the soil surface.

Holes were made in the film to reduce soil temperatures and facilitate emergence. Consequently, the film was not removed as originally planned, and film was left in place. Therefore there were three treatments:

1. Film A “Envirocare”
2. Film B “Extend”
3. Control

Harvest results indicated that use of film may alter yield structure, with fewer small potatoes (<75g). This could result in an increase in yield suitable for processing. It was unclear however, how the yield structure of the year one trial was influenced by the initial set back from the high temperatures.

The trial aimed to evaluate time of removal of film. This was problematic, and the need to make holes in the plastic, meant that plastic was not removed as originally planned.

Soil moisture under the film treatment was more uniform through the profile, particularly early in the season. However, as crop water usage increased later in the season, soil moisture at 20cm declined. In the control, soil moisture increased with depth, and this relationship continued throughout the season.

Results from the year one trial indicated that the film may be beneficial for use in even earlier planted crops. In earlier planted crops, the time of removal, or degradation of the centre of the film may be important.

Year two trial:

Degradable polyethylene film (Manufactured by Integrated Packaging Pty Ltd) was used on a potato (*Solanum tuberosum* L.) ('Ranger Russett') crop, at Wesley Vale, North West Tasmania. There were four treatments:

1. Film removed at emergence (October 3) (approx. 5 weeks with film) (T1)
2. Film removed at canopy closure (November 11) (approx 11 weeks with film) (T2)
3. Film not removed (approx. 20 weeks with film) (T3)
4. Control (no film) (T4)

Results from the first trial (initiated September 2007) indicated that the film may be useful for early planted crops because of the observed damage resulting from the effects of overheating of the plants under the film. Therefore, the aim of the second trial (initiated August 2008) was to assess the impact of the film on potato plant growth and development; in particular to assess yield and tuber quality in early planted potato crops.

Later in the season (as crop water use increased) there was greater fluctuation in soil moisture at 20cm in T3 (film not removed). There was however evidence that irrigation resulted in some lateral movement of water into the potato hills as soil moisture at 40cm was maintained with irrigation, and there was re-wetting of the soil at 20cm. The soil moisture stress later in the season (in treatments where the film was not removed) may have had an impact on total yield. The soil at the site was a Ferrosol, however in sandy soils there would be little lateral movement of water.

Emergence was earlier in the film treatments compared with the control, by about two weeks.

Tuber development was also more advanced in the film treatments compared with the control. The length of the king tuber was measured 10 weeks after planting and again at 15 weeks after planting. In treatments where film remained after emergence, tuber development was more advanced compared with treatments where the film was removed at emergence. This indicated that the impact of the film on king tuber size was post emergence.

Total yield data was unfortunately inconclusive, since only significant differences between treatments were observed where differences in weed control (not an intended factor in this experiment) occurred. The very heavy weed burden at the site may have impacted on final yield results. Where film was not removed (T3), this afforded some weed control. Where film was laid and then removed later (T1 and T2), weed control was less effective. Treatments T1 and T2 were still covered when the knockdown herbicide was applied on 2^{nd} October. The weed control was subsequently uninhibited upon film removal in these treatments. Where the film remained (T3), soil moisture stress later in the season, may also have affected total yield.

Further assessment of the impact of film on potato crop development, yield and yield structure is warranted. An estimated yield increase of 0.5t/ha (from use of film) is required to break even and cover film costs. Further assessments should also include examination of the effects on crop nitrogen utilisation, and soil moisture dynamics, as the technology has the potential for nitrogen and irrigation savings. Further research should include identifying appropriate pre-emergent weed technology to be used in conjunction with the film; and also identifying optimum time for film degradation, such that any negative impact of intact film later in the life of the crop can be avoided.

Introduction

The purpose of this section is to provide historical background to the project, why it was undertaken, its significance for industry and the aims of the project.

Historical background to project

In 1997 Integrated Packaging Pty Ltd (IP) filed "X-Tend Crop System" patents in America. X-Tend film is an ultra-thin, clear, photo-degradable film used to enhance field crop production. X-Tend has been proven to increase dry matter and harvestable yield, protect early crop growth from frost and overall, reduce cost per tonne for a range of crops including maize, sorghum and various other cereals.

In 2005 IP became a participant in the CRC for Polymers (CRC). The CRC for polymers is engaged in the project D*egradable polyolefin films for agricultural production* as part of its "Polymers for Sustainability" Program. The CRC's project's objective is to develop polyolefin films for use in agricultural production that will degrade in a controlled way during, or at the completion of, the growing cycle and so enhance water retention and crop outcomes. Agricultural films have been laid on a range of crops during or after planting as a way of retaining moisture and acting as a form of 'greenhouse' to improve plant growth. The principal benefits include higher, and more reliable, crop yields and soil moisture conservation. Additionally, crops can be planted earlier and thus grown in colder and/or lower rainfall areas with better weed control.

Why it was undertaken

Photo-degradable polyethylene films have the potential to provide substantial benefits and transform broad-acre production of crops such as potatoes other vegetable crops, maize, cotton and sunflower.

For this to occur, technologies need to be developed to control and adjust the rate of degradation of the film so that this can be tailored for specific crops and regional differences in climatic conditions. There are currently no commercially available degradation systems for polyethylene films that provide the control necessary for widespread use of these degradable films.

Tasmania's potato industry is the largest sector of the state's vegetable industry, making up approximately 70% of the total value. About 80% of potatoes are grown for processing, with the industry focusing on frozen french fry production. Most potatoes are sourced from the northern half of the state. The main processing variety grown is Russet Burbank. Smaller quantities of Kennebec, Shepody and Ranger Russet are grown to allow for early season production.

There was an opportunity to examine the efficacy of the film for potato production in Tasmania. Most Tasmanian potato growers also grow other vegetable crops. Therefore, demonstration of benefits in potatoes also provides opportunities to a) demonstrate potential benefits in other vegetable crops; and b) identify other opportunities for use of the technology in other vegetable crops.

Significance for industry

a) Early harvest:

In Tasmania, early planted crops are generally planted into cooler soil which limits emergence rate. Earlier emergence, through increased soil temperatures, may:

1. Possibly extend the growing season of early planted crops (and therefore potentially increase yields); and
2. Increase the area of early plantings, therefore improving utilisation of infrastructure

b) Water efficiency:
This technology has the potential to significantly reduce the evaporative water losses during the first third of the life of the crop, thereby reducing the number of irrigations that the crop requires. It is now becoming evident, that water rather than land is a key factor limiting farm viability. Water budgeting at a farm level is becoming a major issue for primary producers.

c) Nitrogen efficiency:
A large amount of nitrogen is commonly used in potato crops, which makes it an expensive crop input; and the loss of nitrogen from a potato production site through the soil is a known to be a significant source of environmental pollution. An important contributor to the wastage and pollution associated with nitrogen in potato crops is thought to be due to poor utilisation and loss of nitrogen applied with the band placed, basal fertiliser at planting. The loss of this nitrogen is due to nitrogen's solubility and mobility in water. The film will protect the fertiliser from being washed through the soil profile before it can be utilised by the plant.

d) Increased yields:
Yields in Tasmanian potato crops vary considerably (HAL, PT05027 *A potato crop management service to promote new technology in Tasmania*), and there is potential to increase average yields. Earlier planting increases yield *potential*, but crops often do not reach potential yield. The use of film technology may increase yields by extending the growing season, through earlier emergence.

Summary of literature reviewed:

Polyethylene film mulch increases soil temperature, especially early in the season (prior to canopy closure and effect of shading). For potatoes, optimum temperature for emergence was 22-24^{o}C, but after emergence, tuber initiation was promoted by low temperature (Sale, 1979).

There have been varying results regarding the effects of film on yields. Some studies have found no marketable increase in yield (Henninger et al, 1977; Ruiz et al, 1999); others have found an increase in yield (e.g. Ruiz et al, 1999). However, the effect on yield may depend on cultivar, climate, type of film and other factors such as planting and harvest time (Hensel, 1968). It is therefore difficult to draw conclusions from the literature, regarding the possible effect on yields in Tasmania.

The use of film can result in earlier emergence. However, it is unclear if this in turn results in earlier maturity, or a longer time available for tuber bulking. Longer effective growing seasons can increase potential yield (Temmerman et al., 2002). These effects are probably cultivar dependant.

Some studies have found that increased soil temperature and/or use of film mulch can affect tuber specific gravity (SG) (Henninger et al, 1977; Yamaguchi et al. 1964). However, the timing and duration of increased temperatures may be important (Epstein, 1966), and therefore timing of film degradation may be important.

Monitoring of the effect on tuber SG is warranted in processing potatoes, as this is especially important for processing quality in potatoes for the french fry industry.

The use of polyethylene mulch in potato increased the efficiency of nitrogen utilisation (Ruiz et al, 1999). Soil temperature is one of the factors influencing root absorption of nitrate. However, the authors concluded that the soil temperatures in the film treatments were optimal for *metabolism* of N. Henninger et al (1977) found that more N was available under potatoes mulched with slitted polyethylene mulch, compared with unmulched. The authors suggested that this was due to less leaching under the film mulch.

This increased N use efficiency is interesting, given the recent escalation in N fertiliser costs, and the increasing interest in reducing N leaching. Improvements in N use efficiency would provide substantial benefits in the Tasmanian industry.

It is difficult to draw conclusions from studies undertaken overseas, due to different climates, soils and other environmental conditions, compared with Tasmanian potato production areas. For example, in semi-tropical and tropical conditions soil temperatures are well above optimal, and cooling the soil can be beneficial. However, in temperate regions soil temperatures (especially early in the season) are below optimal for emergence and sprout extension.

In Tasmania, film mulch may provide a benefit by increasing soil temperature around the time of emergence, especially in early planted crops. However, timing of film degradation may be important, to avoid supra-optimal temperatures. Planting time may also be critical to success of the technology.

In Tasmania, there may be interest in earlier harvest; however other benefits for the Tasmanian processing potato industry would include decreased input costs, and in particular increased yields. Earlier harvest may also be of interest for fresh market potatoes, where market advantages are gained from early harvest.

The technology has the potential to increase yields, reduce inputs, and reduce environmental impact (through reduced leaching of N).

Should the film prove effective in increasing yields and/or reducing inputs, other factors such as economics, plastic in the environment, and any potential negative effects on tuber disease levels (e.g. soft rot) also require investigating.

Project aims

The aims of the project included:

- Identification of known key opportunities and problems with the use of mulches in potato crops
- Assessment of the impact of a degradable film on plant growth and development, soil moisture, plant nitrogen status, tuber yield and tuber quality
- Demonstration of the efficacy of the technology
- Communication of project strategy and outcomes to relevant stakeholders

The project was designed to provide a preliminary investigation and demonstrations, and was expected to lead to further research and development in potatoes and other crops.

Materials & methods

Reference Group

A project Reference Group was established to provide strategic guidance on the project. The Reference Group included representatives from Integrated Packaging Pty Ltd, the CRC for Polymers, Simplot Australia Pty Ltd, HAL and Rural Development Services. Reference Group meetings were held via teleconference.

Literature review

A literature review was undertaken to inform trial design. This included an examination of potato growth and development (including temperature requirements); the Tasmanian potato industry (including yields and climate); and the effects of mulch on temperature, soil moisture, potato growth and development, tuber yield, tuber quality and nitrogen utilisation.

Trials (one trial per year)

1. **Year one trial:**

An early processing ‘Ranger Russett’ potato crop was planted on 18th September 2007, at Leith, North West Tasmania (41^{o} S, 146^{o}E). Film treatments were laid one day after planting on 19th September.

There were five intended treatments:

1. Film A “Envirocare”covered for 4 weeks after 50% emergence
2. Film A “Envirocare”covered for 8 weeks after 50% emergence
3. Film B “Xtend”, covered for 4 weeks after 50% emergence
4. Film B “Xtend”, covered for 8 weeks after 50% emergence
5. Control (no film)

The trial was set up as a randomized complete block design, each plot consisted of one bed *17 metres. One bed acted as a buffer between blocks.

Removal of the film was problematic. It became necessary to make holes in the film to facilitate emergence, and the film was not removed as initially planned. Data was therefore pooled, and the time of film removal was not assessed. As a result there were three treatments 1) film A; 2) film B; and 3) control.

Measurements included:

- Soil temperature (one day after planting; one week after planting; and five weeks after planting)
- Soil moisture (GreenLight-RedLight capacitance probes at 10, 20, 30 and 50cm from the top of potato hills) (one plot selected per treatment)
- Percentage emergence (four weeks after planting and five and a half weeks after planting)
- Yield (total yield and tuber size distribution)
- Tuber quality (specific gravity and tuber rejects)

2. **Year two trial:**

An early processing ‘Ranger Russet’ potato crop was planted on 19th August 2008 (week 0), at Wesley Vale, North West Tasmania. The target plant spacing was 300 mm. Fertiliser was applied as:

1. Pre-spread 250 kg/ha Urea + 250 kg/ha muriate of potash;
2. At planting 1,750 kg/ha single superphosphate

There were four treatments:

5. Film removed at emergence (October 3) (T1)
6. Film removed at canopy closure (November 11) (T2)
7. Film not removed (T3)
8. Control (no film) (T4)

Film treatments were laid on 28th August 2008. Pre- emergent herbicide, Lexone, was applied under the film.

The paddock was sprayed with Sprayseed on 2nd October 2009.

The trial was set up as a completely random design, with four replicates. Each plot consisted of one bed x15 m. There was a buffer of 3m between plots (within each bed), and one bed acted as a buffer between rows. The site was closely monitored around the time of emergence, and holes were made in the film to facilitate emergence.

Measurements included:

- Soil temperature
- Soil moisture (GreenLight-RedLight capacitance probes at 20, 40, 60 and 80cm from the top of potato hills) (one plot selected per treatment)
- Percentage emergence
- Plant and tuber development
- Yield (total yield and tuber size distribution)
- Tuber quality (specific gravity and tuber rejects)
- Leaf sap nitrate, % Brix (to provide preliminary data on crop N utilisation; a more detailed investigation was not possible within the project budget)

Demonstration sites

In year one (initiated in 2007) a wide range of films of different thicknesses and treated in a range of ways were evaluated by the manufacturer. The above and below ground, rates of deterioration varied between different film types. The temperatures under different treatments varied significantly and the ease of stem sprouts breaking through the various films varied. These sites demonstrated to field officers and other interested industry stakeholders that there were significant opportunities to modify films to suit the requirements for potato production and in particular potato production in Tasmania.

In the second year (initiated in 2008) focus moved to the more promising films evaluated in the preceding year. Films of particular interest were those that became increasingly white and brittle upon exposure to light. These changes not only influenced the thermal properties of the film, but also the capacity of the film to allow the potato plants to emerge through the film. Film was sampled from these demonstrations, and analysed by the CRC for polymers to determine the time to degradation, both above the ground and also under ground where the edge of the film was buried under soil.

Results

Soil temperature

As expected, the film had a significant effect on soil temperature. Soil temperature at seed depth (approx 250mm below surface from the top of the mold), was typically two degrees warmer under the film, compared with the control. At shallower depth the temperature differential was greater, and temperatures in year one reached above 40^{o}C under the film (at 10mm below the surface).

Soil moisture

In year one, soil moisture under the film treatment was more uniform through the profile, particularly early in the season. However, as crop water usage increased later in the season, soil moisture at 20cm declined. In the control, soil moisture increased with depth, and this relationship continued throughout the season.

In year two, later in the season (as crop water use increased) there was greater fluctuation in soil moisture at 20cm in T3 (film not removed) compared with the control (no film). There was however evidence that irrigation resulted in some lateral movement of water into the potato hills as soil moisture at 40cm was maintained with irrigation, and there was re-wetting of the soil at 20cm.

Emergence

In year one, four weeks after planting the % emergence of plants under the plastic was profoundly less than in the controls (Figure 1). Digging up the un-emerged seed pieces under the film revealed that when the stems reached a zone 20-30 mm below the soil surface a necrosis was observed (Figure 2, Figure 3). Examination of temperature at 10mm soil depth under the plastic revealed that temperatures were very high (above 40oC).

Following the discovery that high temperatures were having a “solarising impact” on the emerging plants, holes were made in the films along the ridge at the top of the mold. The expected impact of this was to firstly reduce the temperature for the emerging potato plants, and secondly to facilitate the emerged potato plants in “breaking through” the film.

In year two, the crop was planted earlier than the year one trial, to avoid the damage that occurred in year one. Emergence was significantly earlier in the film treatments compared with the control, by about two weeks.

Figure 1: Differences in emergence among film and control treatments

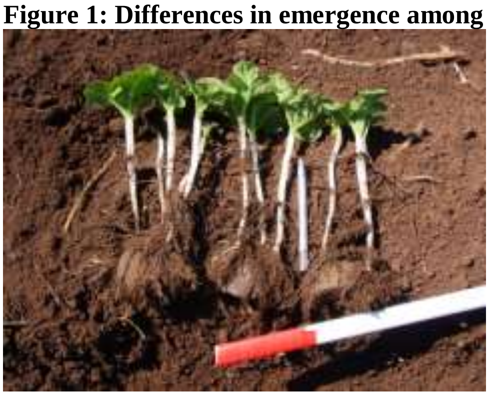

Figure 2: Control, healthy, emerged potato stems (year one trial)
Figure 3: Heat effected stems from film treatment (year one trial)

Plant and tuber development

Film treatments had no significant effects on final percentage emergence, plants per metre or stems per metre.

In year two, at 10 weeks after planting, tuber development was more advanced in the film treatments than the control (Figure 4, Figure 5). In film treatments, length of the king tuber averaged 25mm, while in the control some king tubers were still at the hooking stage.

Later, 15 weeks after planting, king tuber length was measured again.
Data from "film removed at canopy closure" (T2) and "film not removed" (T3) were pooled (because these two treatments were the same at this point in time). The length of the king tuber was greater in the T2 & T3, compared with T1 & T4 (at P=0.05).

Figure 4 Overview comparing film with untreated (24 October 2008)

Figure 5 Tuber development in control (right) compared to film treatment (left) as at 24th October 2008

Yield and yield structure

In year one, total yield was significantly greater in the control compared with the two film treatments (Table 1). It was not clear however, if this related to the initial setback due to high temperature, moisture stress (due to exclusion of water by film), or another effect of the film.

In year one, in film A, there were significantly ($P<0.05$) fewer small potatoes (kg/plot in tubers <75g), compared with both film B and the control.

Treatment	total yield (kg/plot)	cooks (% of total yield)	<75g (kg/plot)	75-250g (kg/plot)	250-850g (kg/plot)	850-1000g (kg/plot)
Control (no film)	26.09	82.50	1.17	12.26	12.16	0.50
Film A (Envirocare 437)	20.83	95.00	0.06	7.06	13.71	0.00
Film B (Xtend)	21.67	81.25	1.07	9.20	11.40	0.00
L.S.D.	4.83	13.35	0.68	2.55	ns	0.36

Table 1: Yield, % cooks, and yield structure for year one

In year two, yields from T1 and T2 were less than yields from T3 and T4 (Table 2). There was also a significant ($P<0.01$) treatment effect on percentage of yield in tubers less than 250g.

Treatment	Yield / 5m(kg)	Tubers <250g (kg)	Tubers ≥250g (kg)	Tubers<250g (% of yield)
Film removed at emergence (T1)	11.2	9.5	1.6	48
Film removed at canopy closure (T2)	12.9	7.9	5.0	63
Film not removed (T3)	18.6	8.3	10.2	44
No film (control) (T4)	20.0	9.6	10.4	48
L.S.D.	4.2			16

Table 2: Yield and yield structure for year two

Tuber quality

In both trials (i.e. in both years) there were no significant effects on tuber specific gravity (SG) or individual tuber reject categories. Mean SG was 1.089 and 1.077 in year one and year two trials respectively.

Effect of time of removal of film

In year one, the trial aimed to evaluate time of removal of film. This was problematic, and the need to make holes in the plastic meant that plastic was not removed as originally planned.

For year two, the effect of film removal time, on soil temperature, soil moisture, plant and tuber development, yield, yield structure, and quality are discussed in the relative sub-sections.

Leaf sap nitrate

In year two, sap nitrate was greater in treatments with film remaining (i.e. treatment 4) than the control at both sampling dates (11th November and 27th November) (Table 3).

Treatment	Nitrate (ppm)		Brix (%)		K (ppm)
	11/11	27/11	11/11	27/11	27/11
Film (T2 & T3)	5,616	5,750	2.8	2.1	14,000
Control (T4)	4,791	4,750	2.2	2.2	11,590

Table 3: Leaf sap nitrate; % Brix; and potassium (year two)

Discussion

The film significantly increased soil temperature. In year one, the high temperatures at shallow depth caused damage to emerging stems. In year two (planted earlier than year one), this damage did not occur and emergence was about two weeks earlier than the control. Therefore the use of film should be restricted to early (or very early) planted crops. Once intra-row canopy closure occurs, the risk of damage from high temperatures diminishes due to shading of any remaining or in-tact plastic.

For potato production, soil moisture at 20 and 30cm would be of most interest in relation to water management. Potato has a relatively shallow root system, with most of the roots in the surface 30cm.

Early in the season, moisture was retained in the film treatments. This would be due to a reduction in evaporative losses from the bare soil.

During the later part of the season (around December and January), the soil become drier in treatments where film remained (particularly 20cm below the surface). This can be explained by an expected increase in crop water usage at that time. Irrigation maintained soil moisture in the control, but the film excluded water. This exclusion of irrigation may have limited crop yield. Therefore, the timing of film degradation should be considered in designing the film.

There was however, some evidence of lateral movement of water into the mold. The soils at both trial sites were Ferrosols; in sandy soils there would be little lateral movement of water.

Further evaluation of soil moisture is warranted, using films that degrade after emergence. Further evaluation should aim to estimate irrigation savings (savings through a reduction in evaporative losses early in the season).

Generally, early planted crops have a higher **potential** yield than later planted crops. Earlier emergence, using film mulch may potentially increase yields by extending the growing season.

In year one, yields were significantly lower in the film treatments compared with the control. This may have been due to the initial set back (due to supra-optimal soil temperatures), or possible moisture stress.

In year two, yield results were unfortunately affected by weed competition. In the treatments where the film was removed (at emergence, T2; and at canopy closure, T3), yields were most likely affected by weed competition. Pre emergent herbicide (Lexone) was applied under the film. Later, the site was sprayed with a non-selective knockdown herbicide (Sprayseed), while the film was still in place (i.e. the film prevented penetration by the herbicide). Later, when the film was removed from T2 and T3, weeds germinated and grew. Where the film was not removed, the film provided some weed control. The yield data was non-conclusive and future trials should ensure that weeds are more carefully managed.

Results indicate that the film may influence yield structure, with a greater percentage of the harvest meeting target specifications. In year one, the yield of tubers <75g was less in film A compared with both film B and the control. It was unclear why the two films differed. It was also unclear how the initial set back (due to supra-optimal soil temperature) affected yield structure.

In year two there was a significant treatment effect on yield structure. However it is unclear whether weed competition influenced results. Where the film was not removed, the yield structure was not significantly different to the control (no film). In treatment two (film removed at canopy closure) the percentage of the total yield represented by tubers <250g, was different to treatment three (film not removed). This could relate to weed competition.

The film had no significant effect on tuber quality. There was no significant effect on tuber SG. There were no differences in tuber diseases (e.g. rot).

In year two, leaf sap nitrate was greater in the film treatments than the control at both sampling dates. This may relate to less leaching of N from the soil in film treatments and improved N utilisation. Results indicated a greater uptake of N by plants in film treatments. These results provide evidence that the technology with respect to N utilisation is worthy of further investigation, and has the potential to reduce the amount of N fertiliser required by the crop.

The trials demonstrated potential environmental benefits through reduced fertiliser leaching, and reduced crop inputs (fertiliser and water).

Economic benefits to growers include reduced input costs (through a reduction in fertiliser and water requirements), and possible increased yields. Potential yield increases through the use of film technology, requires further investigation.

A cost benefit analysis was undertaken (Table 4), based on potato crop gross margins for Tasmania (DPIW, 2008) with updated fertiliser costs (Impact Fertiliser price list as at 28th February 2009). The film costs approximately $350/ha. Reduced irrigation of three applications (total saving of 0.75ML/ha) have been demonstrated, which would reduce the number of irrigation by 15%. A reduction of three irrigations would increase grower gross margins by $60 - $120/ha (based on water costs of $40/ML from dams and rivers to $140/ML from current irrigation schemes (pers. comm. Sue Hinton)).

However, water costs under some new irrigation schemes will be higher, with water prices suggested to be $200/ML (pers. comm Simplot Potato Business Grower Group meeting July 2008). A reduction of three irrigations would save $190/ha based on a water price of $200/ML.

Reduced requirements for nitrogen fertiliser have not been quantified (due to the limited budget in the present study). However, an estimated reduction of 50kg urea/ha would increase grower gross margins by $60/ha (based on current urea price of $1,112/t). The analysis shown in Table 4Table 4: Cost benefit analysis and break even yield increase for cost of illustrates that a break even yield increase (yield increase from use of film) of 0.5t/ha would be required, to cover the cost of film. In an average 60t/ha crop, this would represent a yield increase of less than 1%. Greater yield increases would provide substantial benefits to growers. For example a yield increase from 60t/ha to 63t/ha (5% increase) together with savings of 3 irrigations (@ $40/ML) plus savings of 50kg/ha urea, would increase grower gross margins from $10,650/ha to $11,630/ha.

		$/ha
Cost:		
Film		350
Benefits:		
Reduced water use of 0.75ML/ha (average of $60-120/ha) Note benefit would be greater with higher water costs under new irrigation schemes	90	
Labour savings from reduced irrigations (1h/ha)	30	
Reduced nitrogen fertiliser costs (assume 50kg urea)	60	
Total benefits		180
Increased income required to cover net cost of film		$170/ha

Price $/t	$350/t
Break even yield increase required to cover cost of film	0.5t/ha

Table 4: Cost benefit analysis and break even yield increase for cost of film

This analysis suggests that film technology in Tasmanian processing potatoes would be economic for growers where 1) a consistent yield benefit can be demonstrated of at least 0.5t/ha; 2) on farms with higher water costs; and/or 3) where greater nitrogen savings can be demonstrated.

The opportunity cost of using the saved irrigation water on other high margin crops has not been included in our analysis.

Potential benefits for industry include better utilisation of infrastructure (through an increase in earlier plantings), risk management and also more uniform tuber size. The film could be used to reduce the risk of crop loss through seed set decay, especially in some regions and soil types such as the Northern Midlands. The effect on tuber size requires further evaluation; including evaluation of the effect on grower payments (growers received bonus payments for tubers within processing size).

Problems associated with weeds in the year two trial highlight the need for a specific weed control program for use with film technology.

The film should be designed to allow the crop to break through at emergence, while remaining intact. This can be achieved by designing films which become brittle at around the time of emergence. Films with thermal properties which change with deterioration are currently being designed. These films become increasingly whitened (and therefore reflect more light), and reduce the heat load under the film, by the time of tuber initiation. Results from year two have informed film design and timing of whitening and embrittlement. Above ground film degradation would also allow entry of irrigation and rainfall into the mold.

Planting equipment should also be developed which integrates fertiliser, seed planting, film application and pre-emergent herbicide in one pass.

Technology transfer

Activities undertaken during the project included the following:

- Reference Group meetings included representatives from the major processor in Tasmania, Simplot Australia Pty. Ltd.
- Several phone link discussions with Simplot Australia Pty Ltd, including the Agricultural Manager and Senior Agronomist, to provide updates on trial results and progress.
- Field visits to trial site, including the Agricultural Manager, Senior Agronomist and field officers
- Awareness of the project was raised at three industry workshops in 2007, "potato futures 2007" (information was included in a presentation on new projects, at each workshop held in the major Tasmanian potato growing regions: Scottsdale, Longford and Ulverstone)
- Results to date were included in poster sessions (poster outlining results from a range of research and development projects) at three industry workshops in 2008, "potato futures 2008" (poster sessions were held at each workshop held in the major Tasmanian potato growing regions: Scottsdale, Longford and Ulverstone).
- Dr David Fulton attended a meeting in Melbourne in December 2008. This meeting provided a strategic approach to the research and development efforts associated with commercialisation of the technology in potato crops (e.g. discussion of film specifications suitable for use in processing potatoes in Tasmania).
- A meeting was held in Hobart in May 2009 to review trial results for the 2008/09 season, to inform draft trial designs and resource requirements for a continuing project in 2009/10. This meeting included representatives from Integrated Packaging Pty Ltd, CSIRO, TIAR (Tasmanian Institute of Agricultural Research) and RDS. CSIRO have agreed to supply in-kind support to the continuing project, including crop modelling, support from a senior consultant, and a potential PhD scholarship.
- Andrew Makin, Agricultural Division Sales Manager, Integrated Packaging has meet with Simplot representatives on several trips to Tasmania, to discuss industry needs and trial results.

The target audience for this project was Simplot Australia and its growers. The project aimed to *demonstrate* the efficacy of the technology, and continuation projects should include a strategy for knowledge transfer and industry adoption.

Critical success factors in relation to industry adoption are

a) Further demonstration of efficacy of the technology, and return on investment
b) Film design to allow plants to break through the film at emergence,
c) Film design to allow film degradation at optimal timing,
d) Development of protocol for weed management under the film
e) Development of technology for potato planting equipment which will allow integration of fertiliser application, seed planting, film application and pre-emergent herbicide application in one pass

Recommendations – scientific and industry

1. Undertake further investigations to assess value of film technology on early crops (therefore taking advantage of the "already demonstrated" benefits of the technology on emergence time and advanced plant development). Assessment should include:
    a. Yield
    b. Quality
    c. Nitrogen utilisation
    d. Water utilisation

2. Demonstrate the production, economic and environmental benefits of the film in processing potato crops in Tasmania.

3. Undertake trials investigating the benefits of films with the following characteristics:
    a. Changing thermal properties – giving an initial high soil heating capacity, then reducing prior to emergence
    b. Increased brittleness (and timing of brittleness) of the film such that potato stems are able to emerge through the film with little resistance
    c. Near complete loss of structural integrity of the film by the time of full canopy closure (to allow adequate moisture to enter the mold, preventing any possibility of moisture stress due to the film, during this time.)
    d. Near to complete deterioration of the film, both above and underground, by the end of crop growth.

4. Develop technology for potato planting equipment which will allow integration of fertiliser application, seed planting, film application and pre-emergent herbicide application in one pass.

5. Develop a robust protocol for weed control under film.

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