Comparison of biodegradable mulch products to polyethylene in irrigated vegetable, tomato and melon crops

Sarah Limpus
The Department of Agriculture, Fisheries and Forestry, QLD

Project Number: MT09068

MT09068

This report is published by Horticulture Australia Ltd to pass on information concerning horticultural research and development undertaken for vegetables, melon and tomatoes

The research contained in this report was funded by Horticulture Australia Ltd with the financial support of The Department of Agriculture, Fisheries and Forestry, QLD.

ISBN 0 7341 2920 3

Published and distributed by:
Horticulture Australia Ltd
Level 7
179 Elizabeth Street
Sydney NSW 2000
Telephone: (02) 8295 2300
Fax: (02) 8295 2399

Horticulture Australia

FINAL REPORT

HAL Project MT09068

Comparison of biodegradable mulch products to polyethylene in irrigated vegetable, tomato and melon crops

May 2012




Limpus, S. *et al*.

Horticulture and Forestry Science

Queensland Department of Agriculture, Fisheries and Forestry

HAL project MT09068

Comparison of biodegradable mulch products to polyethylene in irrigated vegetable, tomato and melon crops

Project Leader: Ms Sarah Limpus
Development Horticulturist
Agri-Science Queensland
Queensland Department of Agriculture, Fisheries and Forestry
Bowen Research Facility, 45 Warwick Road, Bowen Q 4805
Telephone: 07 4761 4000 Fax: 07 4785 2427
Email: sarah.limpus@qld.gov.au

Key Personnel:
Sue Heisswolf (project leader 2009-2010), Senior Horticulturist, Bowen Research, Facility Queensland Department of Agriculture, Fisheries and Forestry (DAFF)
Denise Kreymborg, Industry Development Manager, Bowen-Gumlu Growers Association
Ross Wright, Bowen Research Facility, DAFF
Warwick Hall, Australia and New Zealand Consultant for Novamont
Sara Guerrini, Agricultural Sales Specialist for Novamont, Italy

Purpose: This final report 'Comparison of biodegradable mulch products to polyethylene in irrigated vegetable, tomato and melon crops' summaries the research and extension into evaluating biodegradable mulch film products for irrigated horticulture and accelerating the uptake of suitable products by Queensland vegetable growers.

Funding sources: This project has been funded by HAL using voluntary contributions from the Bowen-Gumlu Growers Association, Novamont and the Queensland Government with matched funding from the Australian Government.

Date: 23 April 2012

Cover photographs, clockwise from left: Rolled polyethylene mulch film ready for disposal, Photograph by S. Limpus; a tomato crop planted into biodegradable mulch film, by S. Heisswolf; below soil biodegradation of films, by S. Limpus; and polyethylene, (left and middle bed) and biodegradable (right bed) mulch film laying operations, by S. Heisswolf.

Table of Contents

Media Summary

Vegetable growers in the Dry Tropics of Queensland have been using drip irrigation and fertigation systems, in combination with polyethylene mulch film and seedling transplant technology for many years. Polyethylene mulch conserves water, suppress weeds and improve crop yields and product quality. However, the disposal of polyethylene mulch at the end of its useful life remains an intractable problem for growers and is considered a major environmental issue by the Industry. Options for mulch disposal are becoming increasingly untenable around Australia, with municipal authorities rejecting, restricting or increasing the costs of dealing with plastic mulch at their waste management facilities.

There have been many proposed solutions trialled over the last two decades, with varying levels of success, but very low adoption. In an effort to solve the agricultural plastic waste dilemma, Bowen and Gumlu vegetable, tomato and melon growers have been trialling biodegradable mulch film products alongside Queensland Department of Agriculture, Fisheries and Forestry researchers.

The project, funded by Bowen-Gumlu Growers Association, Horticulture Australia, mulch manufacturers and the Queensland Government, aimed to identify replacements for traditional polyethylene films and accelerate grower uptake of practical solutions.

A number of products have been evaluated during this project, to identify potential replacements for polyethylene mulch films in irrigated vegetable production. These replacement films need to have the same desirable traits, with the benefits of no disposal issues and costs.

Mater-Bi®, a biodegradable product produced by Novamont and marketed by Australian Bio-Plastics, has been the most successful product to date. Mater-Bi® complies with Australian Standard AS 4736 "*Biodegradable plastics suitable for composting and other microbial treatment"* and was evaluated against traditional plastic products with admirable results. Yields of honeydew melon, rock melon, capsicum, tomato, eggplant and chilli transplanted into Mater-Bi® were comparable with those grown in polyethylene films and provided good weed suppression for the life of the crop.

The handling and laying of biodegradable products is slightly different to traditional plastic products. To keep costs down, 12 and 15 micron thicknesses are used, instead of 20 to 25 micron in polyethylene. It is important to handle these thinner films with care and use as soon as practicable. Thicker biodegradable films may be more suited to stony or cloddy soils.

Technical Summary

Vegetable growers in the Dry Tropics of Queensland have been using drip irrigation and fertigation systems, with polyethylene mulch film and seedling transplant technology, for many years.

Polyethylene conserves water, suppresses weeds and improves crop yields and product quality. However, the disposal of polyethylene mulch at the end of its useful life remains an intractable problem for growers and is considered a major environmental issue by vegetable growers. Options for disposal of polyethylene mulch films are becoming increasingly untenable around Australia, with municipal authorities rejecting, restricting or increasing the costs of dealing with plastic mulch at their waste management facilities.

Research over the last 10 years has highlighted the potential of renewable products to replace non-renewable materials such as traditional polyethylene. Recent research has included living mulches (Rogers et al., 2006), paper barriers, biodegradable mulch films and non-renewable products such as oxo-degradable plastics that break down in sunlight.

In 1998, the biodegradable mulch films Mater-Bi® (Novamont, Italy) and Bionolle (Showa, Japan) and a paper product (Gromulch, UK) were trialled at the Bowen and Gatton Research Facilities (Rutgers, 2006). In 1999, DAFF researchers assessed a range of organic mulches (hessian, sugarcane trash, sawdust), brown paper film (Growmulch, UK) and Mater-Bi® against white on black polyethylene at the Bundaberg Research Facility (Olsen and Gounder 2001).

During 2002/03, a project led by Rutgers (2003) focused on developing biodegradable mulch based on novel biopolymer nano-composites. Field tests of imported Chinese mulches and paper mulch were also conducted during this time.

Queensland growers are utilising few of these methods today. Living mulch systems have found some success in the southern states. In North Queensland, the impact of a warmer climate on living mulch options and weed growth has curtailed progress in this area, with only a few exceptions. All other products either failed the biodegradability test, by being photodegradable, could not be laid with standard commercial equipment, or their price was prohibitive.

Biodegradable mulch is converted into water, carbon and biomass by microbes, leaving no toxic residues or plastics to accumulate in the soil. There are several different regulations and standards pertaining to plastics, however certification to European EN 13432 “compostable and biodegradable” standard and Australian Standard AS 4736-2006 “*Biodegradable plastics suitable for composting and other microbial treatment”* appear to be the most relevant at present. However, there are still a number of questions to be answered regarding the performance of biodegradable mulch films and their role in commercial vegetable production.

Evaluations of biodegradable mulch film on the Bowen Research Facility as part of MT09068, targeted specific research data on film performance arising from previous work. These were:

- Rate of mulch degradation below ground
- Longevity of mulch cover and integrity above ground,
- Retention of desirable characteristics such as flexibility, elasticity and strength,
- Adequate suppression of weed growth, and
- Maintenance of yields comparable to polyethylene mulch film production.

To evaluate these parameters, replicated field trials were performed on the Bowen Research Facility from 2009 to 2011. In 2009, two grades of Mater-Bi® were tested. NF803/P Mater-Bi® was produced in Australia from imported resin while the new generation, CF04/P could only be manufactured in Italy (at that time). In 2010, problems manufacturing CF04/P in the Australian plant led to a project extension until the 30 May 2012. In 2012, the new generation CF04/P was successfully manufactured in Australia and could be evaluated that season on the Bowen Research Facility and local farms. The bulk of the evaluations focused on the Mater-Bi® products, but other products that we considered had potential through the screening trials were also tested. Unfortunately, none of the products screened in 2009 and 2010 met the project's criteria.

Mater-Bi® maintained excellent bed coverage throughout the cropping cycle. Early losses in bed coverage (as a direct result of laying or planting operation or animals) can dramatically accelerate bed cover losses later in the season. Using biodegradable mulch that is more than six months old, or is exposed to extended periods of photodegradation before planting the crop, will also accelerate biodegradation and lead to bed cover losses and increased weed density. The loss of bed cover tended to lead to more weeds in the Mater-Bi® treatments than the polyethylene, especially where mulch had been damaged early on (through difficult soil, or the laying and planting operations). These differences in weed population were not substantial and seemed to reduce as the crop matured.

Biodegradable mulch films should be stored in a dark, dry place and used as quickly as possible, to prevent accelerated photodegradation after exposure to sunlight. For best performance, biodegradable mulches should be used within six months of manufacture. It is preferable to lay films no more than four weeks prior to transplanting. Thicker gauges (15 to 25 micron) of biodegradable mulch film will be better suited to soils that are cloddy or have sharp gravel or stones. Mater-Bi® biodegradable mulch films are capable of being laid using commercial equipment with no or little adjustment to equipment or speed during laying.

At the time of writing this Final Report, biodegradable mulch film costs were $160 more expensive per roll than the cost of using and disposing of polyethylene. However, prices are likely to fluctuating with the exchange rate, while the resin continues to be imported from Italy. The cost of polyethylene removal and disposal can vary widely depending on labour costs associated with lifting and removing mulch from the field, cost of transport to and fees charged by the disposal site.

Growers have noticed a definite improvement in biodegradable mulch technology over the years of this project and those previous. The quality and desirable traits of biodegradable mulch will continue to be enhanced as this technology and techniques of manufacture are perfected. A small and slowly increasing proportion of growers have decided the up front cost of biodegradable mulch film is offset by the benefits of using a product with no end of crop disposal issues and lower end of crop costs.

Introduction

The project sought to accelerate the development and uptake of practical solutions to the issues around polyethylene mulch disposal. The evaluation of biodegradable mulch products against the standard black and the white on black polyethylene mulch films investigated products with the potential to replace those films currently used by the vegetable, tomato and melon industry.

Biodegradable films were targeted because they can be incorporated into soils after harvest, biodegrading into natural materials and leaving no toxic waste. The key desirable characteristics in biodegradable mulch are:

- No disposal issues – mulch can be incorporated into the soil after harvest leaving no toxic residues or build up of toxins or plastics over time
- Ability to be handled with current commercial equipment and systems with only minor, if any, adjustments needed
- Weed suppression, water retention, crop quality and yields comparable to those currently provided by standard polyethylene mulch film
- Adequate bed coverage throughout the life of the crop including a period of at least four weeks exposure to photo-degradation prior to the crop being planted
- Economic viability

Over the past five years, significant advances have been made in biodegradable plastics technology. An improved version of Mater-Bi® (NF803/P) from Novamont, Italy, was evaluated in screening trials at the Bowen Research Facility, and on local farms, with very promising results during 2006 to 2008. The mulch was laid with commercial mulch laying equipment, with only minor adjustments needed. The mulch was also capable of being planted through with standard equipment.

The majority of this project focused on evaluating the Mater-Bi® product produced by Novamont through on-farm and Bowen Research Facility trials. Results from this work were used by the manufacturer and developer to improve the product. This resulted in the development and manufacture of a new generation of the mulch film CF04/P in an Australian manufacturing plant.

Mater-Bi® continues to be improved, with technology allowing the continual increase of the starch content of the product and improvements in manufacturing technique. During the writing o this report, the production of yet another generation of Mater-Bi® and the pursuit of producing a white biodegradable mulch film is occurring.

The cost of these products is still the main impediment to widespread adoption of the technology, despite manufacture of films from imported resin in Australia. At the time of writing this report, 15 micron Mater-Bi® was at least 30% more than the cost of polyethylene mulch (when retrieval and disposal costs are factored into the equation).

Other products identified in previous work and during the course of the project were also screened for their potential as replacements, before progressing to in-depth evaluations on the research facility, to gain an understanding how the product meets the required characteristics previously outlined.

The focus was to evaluate biodegradable mulch films manufactured from starch and biodegradable polymers with scope in the project to screen and assess other products. The work program was based on three inter-related sets of trials:

- Screening of potential mulch products at the Bowen Research Facility
- In-depth trial work at the Bowen Research Facility to answer specific research questions raised during earlier trial work reported in projects by Olsen (2001), Olsen and Grounder (2001), Rogers et al. (2006) and Rutgers (2003)
- Evaluation of promising replacement products under commercial conditions on local farms

By involving growers early in the evaluation process, through an extensive on-farm trial program, promising products were assessed under commercial conditions. This involved a wide range of crops and soils, using various laying, planting and incorporation techniques, within a variety of farming systems. This added rigour to the evaluation process and enhanced adoption and commercialisation of replacement mulch products.

Screening

Throughout the life of the project, we constantly sought products that could be tested for their viability as a biodegradable mulch film in commercial vegetable farms. This occurred during the evaluations of Mater-Bi® over the life of the project, with small additional plots incorporated into these evaluations. As we were looking for specific traits in biodegradable products (outlined previously), these plots were on a much smaller scale and not replicated. This was done to determine their potential before costly, full scale replicated trials were performed.

Screening also provided an opportunity for manufacturers to have their products tested in near-commercial conditions in the intended location of distribution. The information the screening trials provided could then contribute to the improvement of existing technology in biodegradable mulch films, or help manufactures to develop new products and technology.

During this project, three biodegradable and one degradable product that had potential for incorporation into commercial vegetable production were screened. These were:

- Ecocrop – manufactured by Ecocover
- BioPak – manufactured by Natureworks Ingeo PLA
- White Mater-Bi® 15 micron – manufactured by Novamont
- Weed Gunnel

The paper mulch Ecocrop was supplied by the New Zealand company, Ecocover. This paper/glue laminate product is made from waste paper. Some grades of Ecocover are already in use in the landscaping, road edge stabilisation and forestry industries. The experimental product, Ecocrop, is designed for use in the fruit and vegetable industry however to our knowledge has not yet been trialled widely in this industry. At that time, all Ecocrop product was hand laid.

The BioPak films are certified to EN13432 and Australian Standards 4736 for biodegradability and compostability. They are produced by Natureworks Ingeo PLA a starch (corn) derived plastic.

The white Mater-Bi® product manufactured by Novamont complies with Australian Standard 4736-2006 for biodegradability and compostability. It is inherently the same product as the black Mater-Bi®, already thoroughly tested during this project, without the addition of carbon to make it opaque and black. The film contains an additive to give it a semi-opaque, white colour.

Weed Gunnel is degradable polypropylene, non-woven fabric weed matting. The company describes it as being permeable and degradable with ultraviolet light stabilisers to extend the life to 3 to 4 years in full sunlight. Weed Gunnel is certified with the Biological Farmers of Australia under A1-452. According to the Weed Gunnel website, www.weedgunnel.com.au, this product can be used in organic production systems as a registered, allowed input. The manufacturer indicated that the polymer chains of the fabric degrades into carbon dioxide and water and will not be a source of heavy metal or toxic chemical contamination. Weed Gunnel is generally used as weed matting in gardens, nurseries, orchards and revegetation areas.

Degradation in degradable plastic products occurs when a series of chemical reactions take place that break-up the polyethylene or polypropylene chains into shorter lengths. These reactions are promoted by exposure to oxygen, ultraviolet light and/or heat. Degradation time is manipulated by increasing or decreasing the quantity of additives (in polyethylene products) depending on the requirements. Currently, it is unclear if the products biodegrade under normal field conditions and further studies are required to answer these questions.

Once we were satisfied that the screened product had potential in commercial vegetable production, the product could progress to more in-depth assessments and on-farm trials. However, the only product that passed the screening trials was the BioPak product. Unfortunately, the manufacturer, at that stage could not produce an improved film (using the results from these screening trials) for in-depth replicated evaluations. The results of these screening trials have not been detailed here.

Chapter 1: Bowen Research Facility Evaluations

Introduction

Evaluations of biodegradable mulch film on the Bowen Research Facility as part of MT09068, targeted specific research data on film performance arising from previous work. These were:

- Rate of mulch degradation below ground
- Longevity of mulch cover and integrity above ground,
- Retention of desirable characteristics such as flexibility, elasticity and strength,
- Adequate suppression of weed growth, and
- Maintenance of yields comparable to polyethylene mulch film production.

To evaluate these parameters, replicated field trials were performed on the Bowen Research Facility from 2009 to 2011. In 2009, two grades of Mater-Bi® were tested, NF803/P Mater-Bi® was produced in Australia from imported resin while the new generation, CF04/P could only be manufactured in Italy at that time. In 2010, problems manufacturing CF04/P in the Australian plant led to a project extension until the 30 May 2012. In 2012, the new generation CF04/P was successfully manufactured in Australia and could be evaluated that season on the Bowen Research Facility and local farms. The bulk of the evaluations focused on the Mater-Bi® products but other products that we considered had potential through the screening trials could also be tested. Unfortunately, none of the products screened in 2009 and 2010 met the project's criteria.

Once we were confident that a product appeared to provide comparative performance to polyethylene and degraded below ground (through screening and Bowen Research Facility trials), growers were approached to trial products under commercial conditions on farm. This extensive on farm work helped to provide a clearer picture of the costs and savings made with biodegradable mulch, when compared to polyethylene mulch, across a range of farming operations and crops.

2009 Bowen Research Facility Evaluations

Material and methods

During winter and spring 2009, two grades and two thicknesses of black Mater-Bi® mulch film were assessed against the current standard polyethylene mulch, on a light alluvial soil at the Bowen Research Facility. Mater-Bi® is a starch/biodegradable polyester product. The materials used in the 2009 trial were manufactured in Australia by Australian Bio-plastics from resin imported from Novamont, Italy (Grade NF803/P) and rolls imported directly from Novamont (Grade CF04/P). This new material, CF04/P, was characterised by a higher content of renewable resources in its composition than the previous generation, NF803/P.

The Mater-Bi® trial block consisted of eight beds of 80 m length, each on 1.6 m wide beds. The experimental design was a randomised block, with each treatment replicated six times. Plot sizes were 14 m long by 1.6 m wide. There were 2 m sections of buffer crop at either end of the trial and guard beds of double row capsicum on either side of the trial block.

Treatments were:

1. 25 micron polyethylene standard
2. 12 micron Mater-Bi® NF803/P (12 micron Australian manufacture)
3. 15 micron Mater-Bi® NF803/P (15 micron Australian manufacture)
4. 15 micron Mater-Bi® CF04/P (15 micron Italian manufacture)

The block was divided into two sections. The first section comprised a replicated trial block cropped with double rows of capsicum (Mater-Bi® replicated trial). An uncropped section of the replicated beds was included to observe mulch performance subsequent to exposure to full sunlight and other environmental factors, in the absence of a crop, see Figure 1 for trial layout.

A 6 m area of each plot was reserved for collecting non-destructive data on mulch integrity above ground, percentage bed cover, weed growth, crop growth and green fruit yields. Destructive sampling (relative brittleness/tear strength, degradation of buried mulch film) and red fruit yield were harvested from 3 m sections of crop at either end of each plot.

Beds were made with a conventional bed-former, while drip tape and mulch films were laid with commercial equipment in one operation after bed formation, see Figure 2. Mulch was laid on 4 June at a speed of around 2 km/hr. Six-week old capsicum, *Capsicum annuum* L., seedlings variety "Warlock" were obtained from a local commercial nursery and transplanted into the Mater-Bi® replicated trial six weeks later, using a standard water-wheel planter, see Figure 3. Double rows of capsicum seedlings were transplanted on 1.6 m centres, with 39 cm between plants in the row. Standard irrigation, fertigation, pest and disease management regimes were performed.

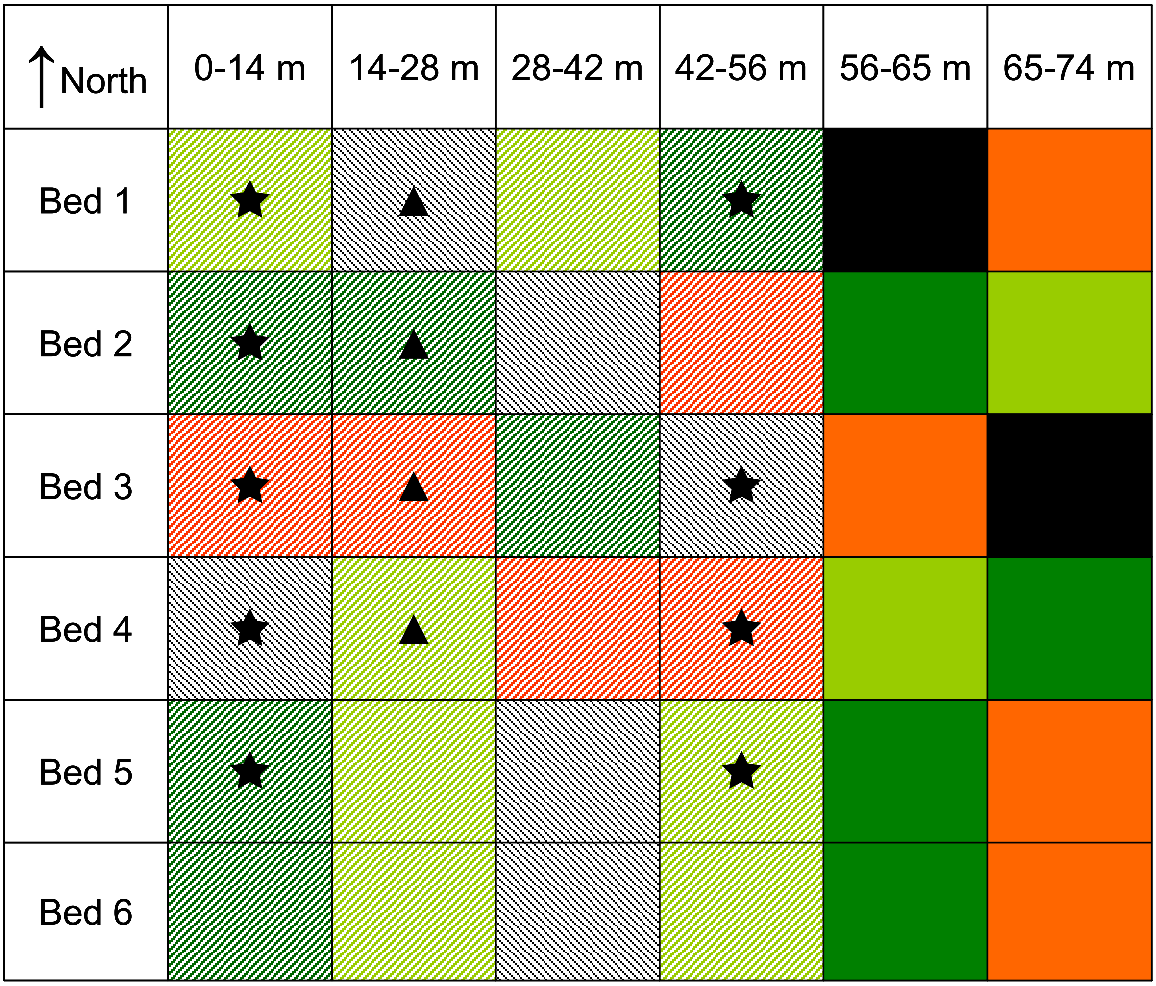


Figure 1: 2009 Bowen Research Facility evaluation layout; plots shaded: green = 12 micron Mater-Bi® NF803/P, dark green = 15 micron Mater-Bi® NF803/P, orange = 15 micron Mater-Bi® CF04/P (imported from Italy) and black = polyethylene. Diagonal lines indicate areas cropped with capsicums while solid colours are uncropped.
★ = indicate tensiometer placement while ▲ = soil temperature probe placement.

Soil temperature probes were installed 3 weeks after laying mulch films, at 5 cm (surface) and 12 cm (root zone) depths in one plot of each treatment. Soil temperature was electronically logged at one hour intervals for the duration of the trial. Air temperature and rainfall data were taken from Bowen Research Facility weather records.

Tensiometers were installed 9 weeks after laying mulch films. Two pairs of tensiometers (shallow at 15 cm depth, deep at 40 cm depth) per bed were installed. Each treatment was represented twice in tensiometer placement, to obtain data along beds as well as across treatments.

Harvesting capsicums commenced 17 weeks after laying, with two green fruit harvests from each plot. Red fruit was harvested from an adjacent section in each plot. The crop was slashed, mulch lifted, polyethylene mulch and drip tape rolled up prior to discing in crop residues with biodegradable mulch on 29 October, 21 weeks after laying mulch films.

Figure 2: laying mulch films with standard commercial equipment on the Bowen Research Facility (S. Heisswolf), and Figure 3: Transplanting capsicum seedlings into pre-laid mulch films using standard equipment (S. Heisswolf).

Harvesting capsicums commenced 17 weeks after laying, with two green fruit harvests from each plot. Red fruit was harvested from an adjacent section in each plot. The crop was slashed, mulch lifted, polyethylene mulch and drip tape rolled up prior to discing in crop residues with biodegradable mulch on 29 October, 21 weeks after laying mulch films.

Mulch assessments

Assessments of bed coverage consisted of a visual estimate of the amount of bed coverage mulch film provided in the datum section of each plot, from 100% to <1%, with 5% intervals. For example, if a plot scored a relative integrity rating of 10 then a 100% bed cover was assumed; if it scored an integrity rating of 9.9 then bed cover reduced to 99% and remained at 99% even if the relative integrity rating decreased until we were reasonably confident that at least 5% of bed cover had been lost. The plot then scored 95% for bed coverage. Plant holes were not factored into the rating.

Measurements of relative integrity consisted of a visual estimate of the amount of damage to above ground section of mulch film. The rating scale was 10 for fully intact with no rips or tears or holes through to 1 for no mulch remaining intact above ground. Mulch scored a 9.9 as soon as it was no longer perfectly intact, for example, if a tiny hole or rip was detected. This small loss of integrity became more difficult to detect as mulch aged, became covered in dust, and as the crop canopy closed. Damage caused by animals, for example wallabies, emus, or dogs, was included in the integrity rating, as degree of damage was an expression of mulch strength and flexibility. Original plant holes were not included in the integrity assessment.

A destructive assessment to evaluate relative brittleness and tear strength was performed by tapping outstretched fingers of one hand, with more or less consistent force, five times. This subjectively gauged changes in mulch elasticity, brittleness and tear strength over time. We used the 3 m sections at the ends of each plot for this assessment, taking care to avoid areas where mulch had ripped. The rating consisted of 10 for very strong (no rips or tears occurring, elastic and strong feel) through to 1 for extremely brittle (large rips occur each time mulch is tapped). This was a very subjective assessment that was affected by temperature, soil moisture, soil condition (stones, clods) and evenness of the bed under the mulch.

Weed growth assessments consisted of a visual estimate of weed growth in the datum section, including any weed growth visible under the mulch. Weeds growing out of plant holes were excluded. The ratings scale used was 1 for no weeds visible under or growing through mulch, to 10 for very high weed growth, if the whole datum section covered by weeds.

Two short sections of buried edge (one on each side of the bed) were inspected for biodegradability in each plot, to check for signs of mulch deterioration below soil level. The assumption was that loss of integrity below ground indicated biodegradability. Each buried edge was rated from 1 for a fully intact piece of mulch to 10 for completely disintegrated. The ratings of the two sides of the bed were averaged for each plot. As assessments were destructive; they were made in the 3 m sections at either end of the plot, taking care to remain consistent across plots in the section of edge inspected at each assessment. The aim was to inspect a different part of buried mulch edge each subsequent assessment.

These assessments of relative integrity, percentage bed cover, relative brittleness, weed and crop growth were made fortnightly, until the first signs of brittleness were detected. Following that occurrence, assessments were made on a weekly basis. Buried mulch edges were inspected every four weeks, for the first two months. As mulch showed signs of degradation, frequency of inspection was increased to fortnightly for the following two months, then weekly for the last month of the trial.

Crop and yield assessments

A visual estimate of crop growth was performed during the trial. A rating of 10 denotes no observable difference when compared with the polyethylene standard. Specific growth stages were also noted for example, first flower buds, first flowers, fruit size.

The aim of the red fruit harvest was to check on a quality issue that had been observed in the previous year's screening trial. This consisted of small pieces of Mater-Bi® adhering to the bottom of red fruit as they matured. The fruit exerted pressure on the mulch, see Figure 4. The extent of this potential quality problem was assessed in subsequent on-farm and research facility trials.

Green through to red mature fruit was taken at each harvest with immature green left on the bush. Harvested fruit was sorted into several categories prior to weighing according to Woolworths produce specifications.

The Genstat® statistical program was used to conduct statistical analysis of yields. All yield analysis were one way Analysis of Variance (ANOVA) in randomised block design. Treatment means were compared and separated using Fisher's Least Significant Difference Test (LSD).

Figure 4: Quality problem observed during 2008 trial work: Mater-Bi® mulch adhering to the bottom of red fruit (right) and the indentation and splitting of mulch as fruit matured (left). S. Heisswolf

Results and Discussion

Layout and planting

All three Mater-Bi® treatments laid well with conventional equipment. As noted in earlier work, the product initially looks and feels less substantial than the standard polyethylene mulch, as it is much thinner.

A portion of mulch had to be discarded from the rolls of the NF803/P produced in Australia, as they were damaged during transport or at manufacture. Figure 5 is an example of the type of damage caused by handling and bumping Mater-Bi® mulch films; here the layer can stick together and cause tearing during laying attempts. Despite this precaution, some slight damage was evident in the first plots laid with these two treatments. The Italian-sourced 15 micron product arrived at Bowen Research Facility in good order, however a mistake in matching treatment with plot location meant that two plots needed to be re-laid, resulting in some slight damage to these plots. This slight initial loss in integrity was recorded as part of the first relative integrity assessment.

While there were no major problems with punching planting holes and planting capsicum seedlings, variable amounts of damage did occur through pressure of the planting wheel on the mulch in all Mater-Bi® treatments. Figure 6 is an example of the type of damaged caused by the planting wheel pressing hard, sharp soil clods into 12 micron Mater-Bi® mulch film.

Figure 5, Left: Damage to Mater-Bi® roll from rough handling causing holes and underlying layers sticking together leading to tearing during laying (S. Limpus), and Figure 6, Right: Damage caused to mulch films from transplanting equipment pressing on sharp or rough soil below the film (S. Heisswolf).

There was a difference in the size of plant holes between treatments. Polyethylene showed the smallest plant holes (average rating of 1 out of 5), plant holes for the new generation Mater-Bi® CF04/P, produced in Italy, were slightly larger (average rating of 3.2) while the Australian produced 12 and 15 micron NF803/P Mater-Bi® had the largest plant holes (average rating of 4.4 and 4.6 respectively), see Figure 7.

Estimated bed coverage

The polyethylene mulch maintained 99% bed coverage throughout the trial. Animal damage caused a slight decline in mean bed coverage percentage towards the end of the trial for the polyethylene mulch film treatment, see Figure 8.

All three Mater-Bi® treatments provided excellent bed coverage until quite late in the trial. The 15 micron Mater-Bi® CF04/P retained the highest percentage of bed cover at 95% of the Mater-Bi® treatments. This loss in bed coverage did not significantly impact on crop yields or weed populations, as it occurred very late in the trial, after harvesting had commenced at 17 weeks after laying. Bed coverage of 12 and 15 micron Mater-Bi® NF803/P treatment fell to 88% and 94% respectively by harvest. See Figure 7 for treatment bed cover percentages.

Relative brittleness and tear strength

There was a general downward trend in Mater-Bi® strength and flexibility by 12 weeks, see Figure 9, with mulch becoming increasingly brittle and prone to tearing as time progressed.

As for bed coverage, mulch integrity and biodegradability, the 15 micron Mater-Bi® CF04/P grade appeared to be somewhat more robust than the 12 and 15 micron Mater-Bi® NF803/P grade Mater-Bi®. Polyethylene scored a rating of 10 throughout the trial for brittleness.

Figure 7: Difference between plant holes formed in mulch treatments, clockwise from top left: 15 micron Mater-Bi® MF803/P, 12 micron Mater-Bi® NF803/P, 15 micron Mater-Bi® CF04/P imported from Italy and 25 micron Polyethylene. (S. Heisswolf)

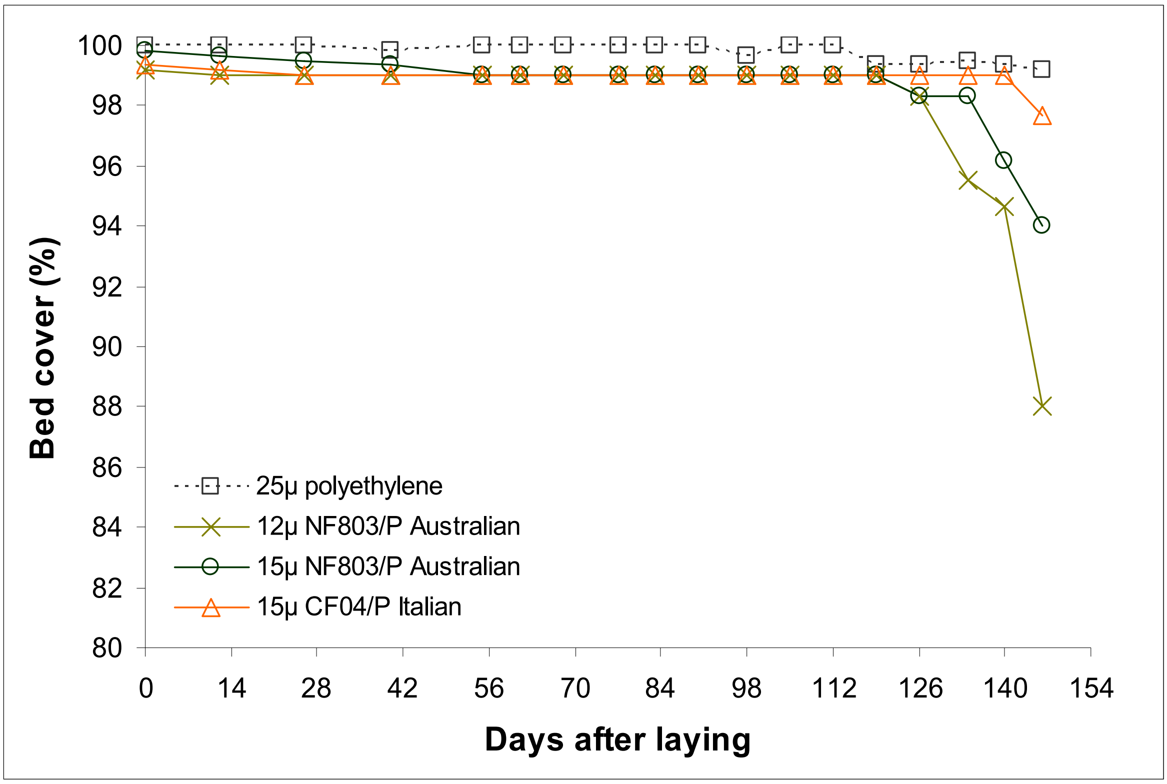


Figure 8: Bed cover of mulch film treatments over time.

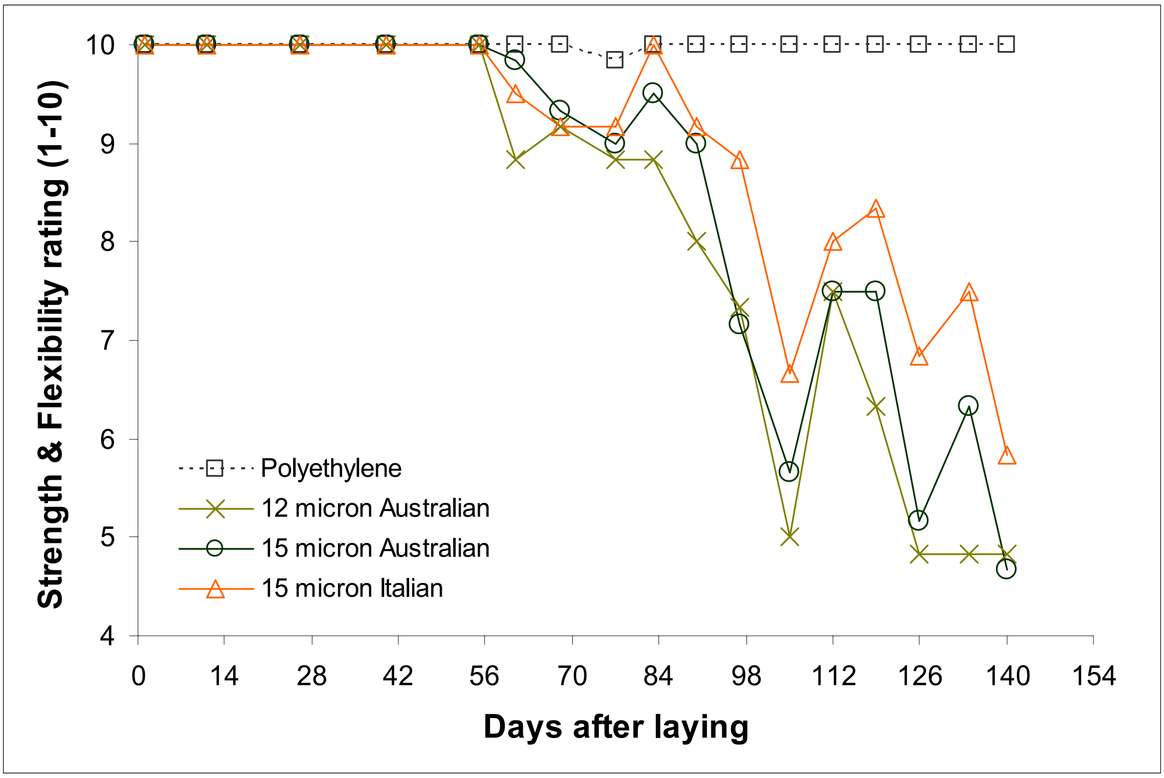


Figure 9: Strength and brittleness rating of mulch film treatments over time on a scale of 1-10, a rating of 1 = very brittle with low strength and 10 = very strong and flexible (compared to polyethylene).

Weed growth

Differences in weed growth between the four treatments were very low overall. Grass seedlings emerged through small holes and rips in plots that had been slightly damaged by the laying operation. They were controlled with light hand weeding at 5 and 6 weeks after laying. Ten weeks after laying mulch, a second germination of mainly grass weeds was controlled with an application of Fusilade® (fluazifop-P) on 18 August. No further weed control was required or applied in the cropped section of the trial.

Biodegradability

All Mater-Bi® treatments showed signs of biodegradation early in the trial. The first evidence of mulch deterioration in Mater-Bi® treatments occurred at the assessment at 8 weeks after laying. Buried edges of mulch became increasingly brittle to touch with tears, fractures and holes appearing. This tendency to fracture and disintegrate when disturbed made it increasingly difficult to confidently rate the degree of loss of integrity. Brushing away soil tended to shatter the buried film; this explains some of the variability between plots and over time, see Figures 10.

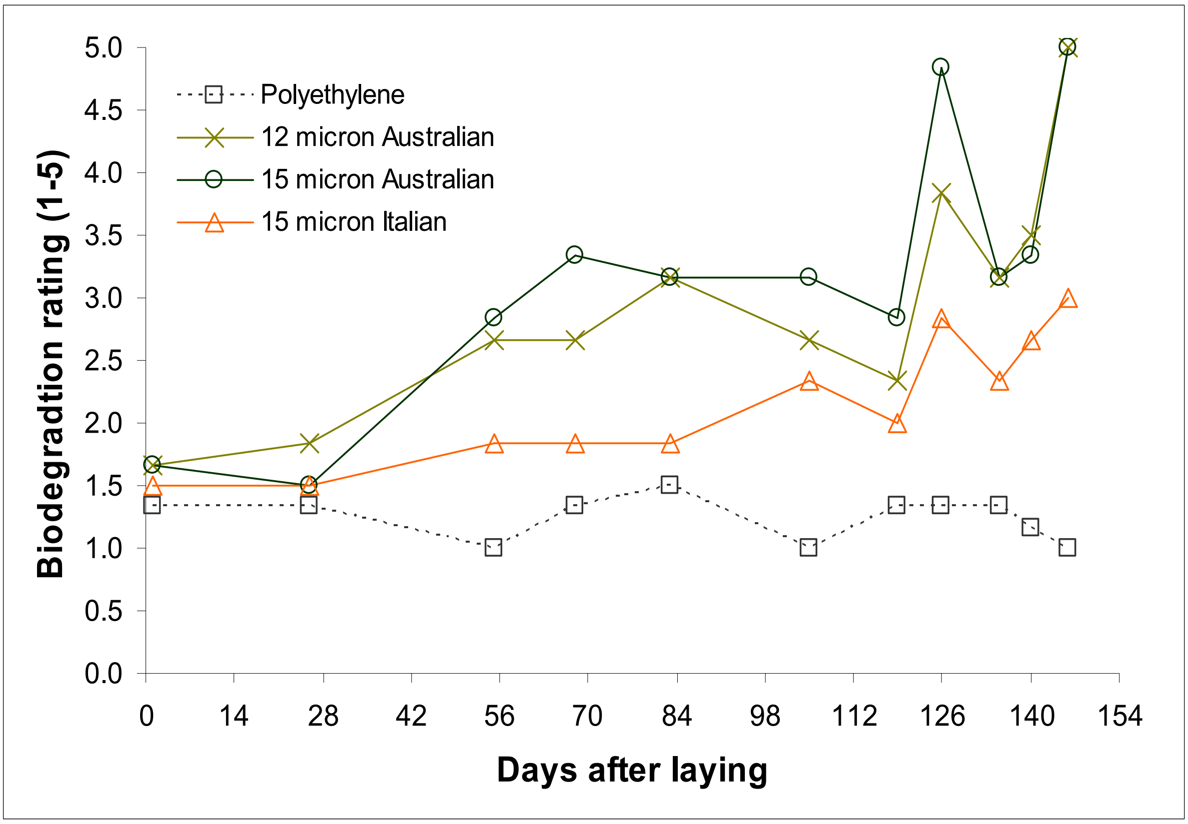


Figure 10: Strength and brittleness rating of mulch film treatments over time on a scale of 1-10, a rating of 1 = very brittle with low strength and 10 = very strong and flexible (compared to polyethylene).

Crop growth

Plants established well in all treatments and only a few transplants failed to grow. Regular observations of crop growth did not show any discernible differences between treatments. Just, prior to first harvest (17 weeks after laying) the crop in some plots appeared paler, shorter and sparser in foliage, with symptoms increasing with time. Observations were not consistent between treatments or beds and did not cause yield differences.

Yields

To determine yields, ten plants from the datum section of each plot were harvested at 17 and 18 weeks after laying, to obtain green harvest yields. A red fruit harvest was taken from plants outside the datum section at 20 weeks after laying (from 8 plants in the southern 3 m section of each plot). Green fruit harvest determined if mulch treatments impacted on crop yields.

There were no significant treatment effects on weight or number of fruit harvested per plot in either green or red fruit harvests. Treatment means of marketable and total yields for the green fruit harvest are summarised in Table 1.

Table 1: Mean marketable and total green fruit yields for the Mater-Bi® replicated cropped trial.

Treatment	Marketable yields		Total yields	
	Fruit weight per plant (kg)	Number of fruit per plant	Fruit weight per plant (kg)	Number of fruit per plant
Polyethylene control	0.597	2.733	0.877	4.483
12 micron Mater-Bi® Australian	0.630	2.867	0.841	4.217
15 micron Mater-B® Australian	0.598	2.850	0.819	4.300
15 micron Mater-Bi® Italian	0.642	3.050	0.866	4.550
L.s.d (P=0.05)	0.1154	0.4747	0.0763	0.4152

A high percentage of red fruit harvested were affected by tomato spotted wilt virus and sunburn. This impacted on marketable yields and variability of yields between plots.

Biodegradable mulch film was found to stick to the fruit that rested on the surfaces of mulch. This problem may cause quality issues if fruit starts to rot when in contact with soil. Another issue may be soil microbes causing problems in the packing shed when soil is not washed off during normal operations. This was recognised as an issue in earlier work, however here the problem was confined to a small percentage of fruit. Mulch sticking to fruit was observed on the on-farm trials and future trials on the research station and on-farm addressed the severity of this quality issue. Plant cultivar and seasonal conditions are likely to impact the height of fruit set and the subsequent risk of this problem occurring.

Soil temperature

The slightly higher mean temperatures under the polyethylene standard at both 5 and 12 cm were likely due to the maintenance of integrity and consequent bed cover of this mulch throughout the life of the trial. The Mater-Bi® treatments lost some integrity, which may have slowed the build-up of higher temperature air under the mulch cover. Temperature minimums, maximums and means over the season are displayed in Figure 11.

Temperature at 5 cm under the polyethylene treatment recorded the highest maximum temperature (data not shown) near the end of the trial during the hottest weather period. This confirms that hot air tended to build up where mulch integrity and bed cover were maintained. Studies indicate that night soil temperatures below 20°C and prolonged day temperatures above 32°C at 5 cm deep are detrimental to capsicum yields (Olsen and Gounder, 2001, Dodd et al., 2000, Meurant et al, 1999). Low temperatures restrict root and shoot development Dodd et al., 2000) while high temperatures reduce pollination resulting in deformed or small fruit (Meurant et al. 1999). Black coloured mulches can increase heat accumulation in the root zone, while the film prevents the loss of this heat through evaporative cooling. As we did not see any yield effects as a result of mulch film treatments, the root zone temperature difference between treatments was not a limiting factor.

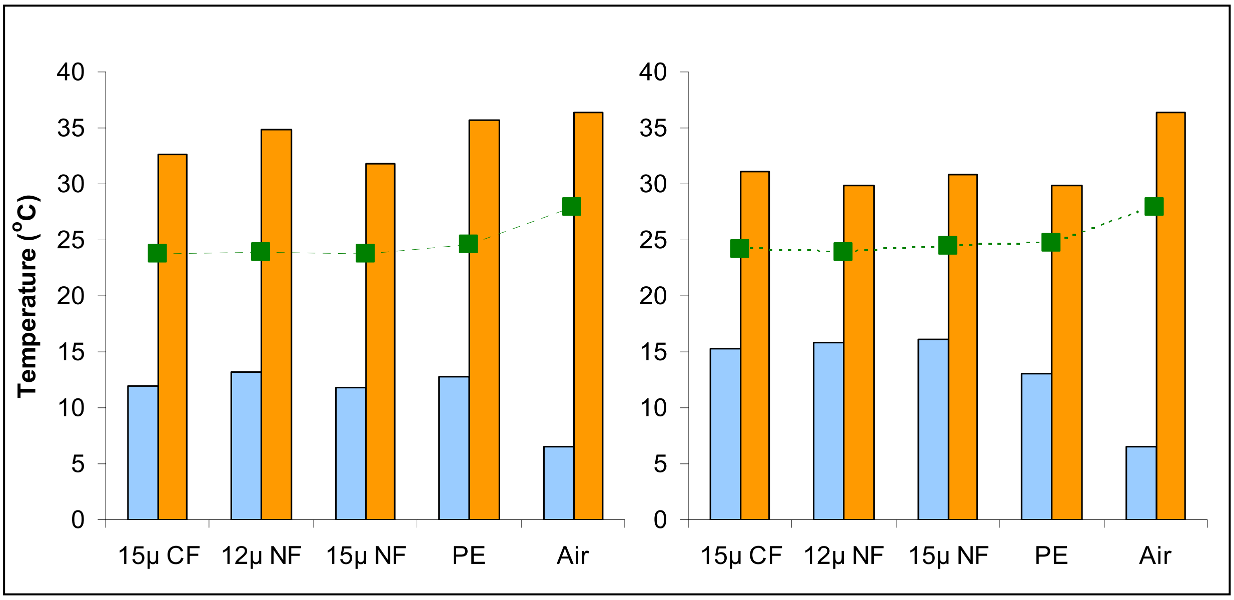


Figure 11: Minimum (blue bars), maximum (orange bars) and mean (green dotted line) temperature at 5 cm (left), and 12 cm (right) of mulch film treatments 15µ CF (Mater-Bi® CF04/P imported from Italy), 12 and 15µ NF (Mater-Bi® NF803/P manufactured in Australia), PE (Black polyethylene mulch film) and air temperature.

Soil moisture

Tensiometers were used to identify variation in water availability under the treatments rather than for irrigation scheduling purposes. By early fruit set, 7 weeks after laying, soil moisture tension of deep tensiometers, at 40 cm, began increasing, to reach 75 kPa at 11 weeks after laying. These levels remained high for the reminder of the trial. All shallow tensiometers at 15 cm, responded rapidly to irrigation however, variation in soil moisture is attributed to natural soil variation across the site and not treatment effects (data not shown). There were no agronomically important differences in water balances between the different mulch treatments.

Crop incorporation and mulch breakdown

The crop was slashed at 21 weeks and initially laying the mulches. Mulch in all plots was then first lifted to loosen polyethylene treatments before tying polyethylene mulch to the drip tape to roll it up together with the tape in one operation.

There were no problems pulling drip tape up through Mater-Bi® treatments when rolling up the drip tape. This showed the Mater-Bi® had deteriorated and weakened sufficiently by trial end to allow easy drip tape retrieval. Figure 12 shows a section of bed after crop had been slashed and drip tape had been pulled up through the Mater-Bi® mulch film. Once drip tape and polyethylene had been removed, the trial site was disced to incorporate Mater-Bi® and crop residues into the soil, see Figure 12, right.

By 1 June 2010, 12 months after the initial laying of the mulch films on the Bowen Research Facility, small pieces of Mater-Bi® was still visible in the block between the remains of a summer crop of forage sorghum stubble. These pieces of mulch were small (most 30 mm square, a few > 50 mm long)

and very brittle. By this time mulch film had been exposed to the elements for 12 months and had been incorporated into the soil for over six months.

While growers might expect to see no mulch residues in the soil after this length of time, these small remnants do not pose a problem for working the ground or replanting. As Mater-Bi® is accredited as biodegradable and compostable, it is assumed that all residues will be metabolised by soil organisms over time.

Conclusions

All treatments of Mater-Bi® were 100% biodegradable and few problems during laying and transplanting were encountered. The biodegradable mulch film is less robust than polyethylene and can be easily damaged by rough handling and animals. Plant holes are prone to tearing as time progresses. Bed coverage and weed suppression are comparable to polyethylene, while biodegradation begins early in the crop cycle. Investigation of the quality issue relating to mulch films sticking to low-set capsicum fruit (and potentially other fruits) was to be investigated in future work.

With yields, soil temperature and moisture availability in the Mater-Bi® equivalent to standard mulch films, these initial studies demonstrated the biodegradable films were ideal replacement products for traditional polyethylene plastic mulch films in Queensland’s drip irrigated vegetable industries.

2011 Bowen Research Facility Evaluations

Material and methods

Evaluations of the new generation of Mater-Bi® biodegradable mulch film CF04/P, manufactured in Australia, were performed using a replicated field trial on the Bowen Research Facility. Previously, this new product could only be imported from Italy for evaluations, due to the manufacturer's inability to extrude a 12 micron CF04/P film of suitable quality in Australia. These issues were corrected in early 2011. The replicated evaluation consisted of four treatments: 12 and 15 micron CF04/P Mater-Bi® (made in Australia) film, black and white-on-black polyethylene mulch films.

Each treatment bed was 20 m long and 1.6 m wide, see Figure 13. Mulch films were laid with standard equipment on the 24 August. Prior to laying operations, the rollers of the laying implement were rubbed lightly with fine sandpaper to remove any rust and soil particles that could damage biodegradable mulch films during laying. In previous work, this was identified as a risk management procedure promoting the longevity of the mulch films. All plots were irrigated prior to transplanting. Seedlings were sourced from a local nursery. Ten meters of the bed was transplanted with double rows of Warlock capsicum seedlings the next day, to a population of 41,000 plants/hectare.

A subsequently unplanted section was to be transplanted with rockmelons; however the seedlings suffered in unseasonal wet weather and succumbed to fungal diseases. These uncropped sections were used as an indicator of differences between canopy shading and full sun on the resilience of mulch films.

Soil temperature probes were installed (2 weeks after laying mulch films) at 5 cm depth in two plots of each treatment. Electronic loggers recorded soil temperature at one-hour intervals for the duration of the trial.

Sprayseed® (paraquat/diquat mixture) was applied to knock down inter-row weeds prior to planting crop. Grass seedlings emerged through plant holes were controlled with light hand weeding. Grass was controlled with application of Fusilade® (fluazifop-P) at three and ten weeks after laying. Standard agronomic, irrigation and pest control practices were used to grow the crop by facility staff.

Mulch film assessments were carried out as previously described in the 2009 Bowen Research Facility evaluations, see Pages 8-10. Destructive and visual mulch assessments were performed in separate locations, to prevent destructive evaluations influencing visual estimates of bed coverage. Mulch film assessments were concentrated in the four-meter area buffering the harvest datum sections on either end of the 10 m cropped plot and in 5 m sections of the unplanted plots, see Figure 14.

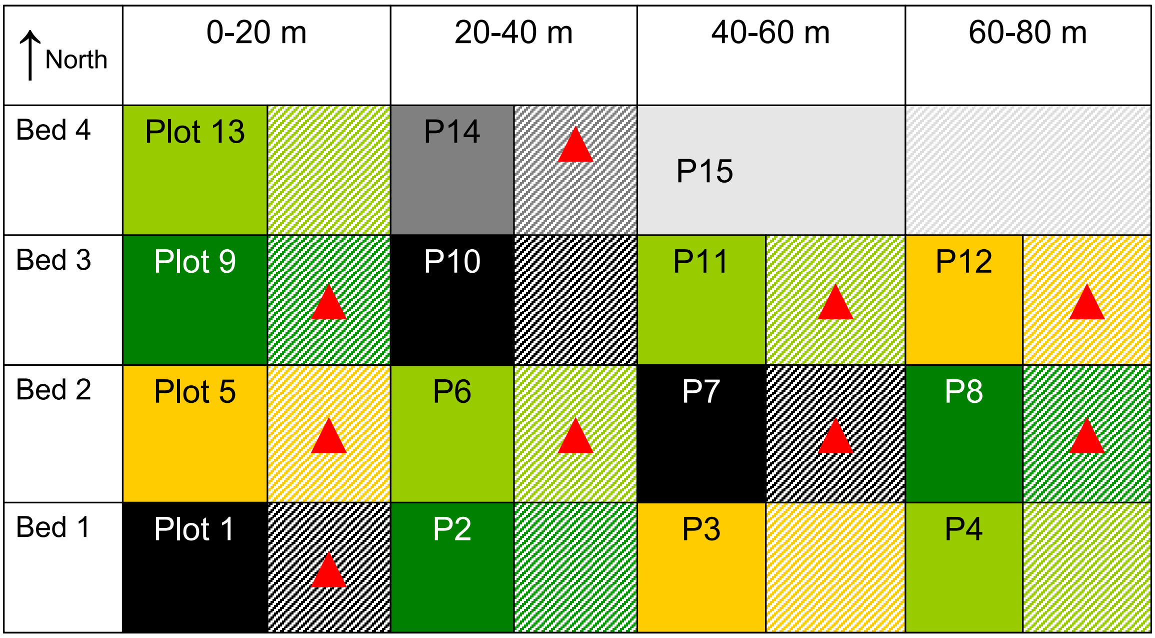


Figure 13: Bowen Research Station mulch film evaluation layout. Light green = 12 micron Mater-Bi® CF04/P, dark green = 15 micron Mater-Bi® CF04/P, Black = black polyethylene, Gold = White on black polyethylene. Plots shaded with diagonal lines = cropped sections of the replication while solid colour plots indicate uncropped sections of the replications and ▲ (red triangle) = 5 cm temperature probe placement.
NOTE: Included here are the screening plots for Weed Gunnel (dark grey) and white Mater-Bi® CF04/P (light grey), which will be discussed in Chapter 3.

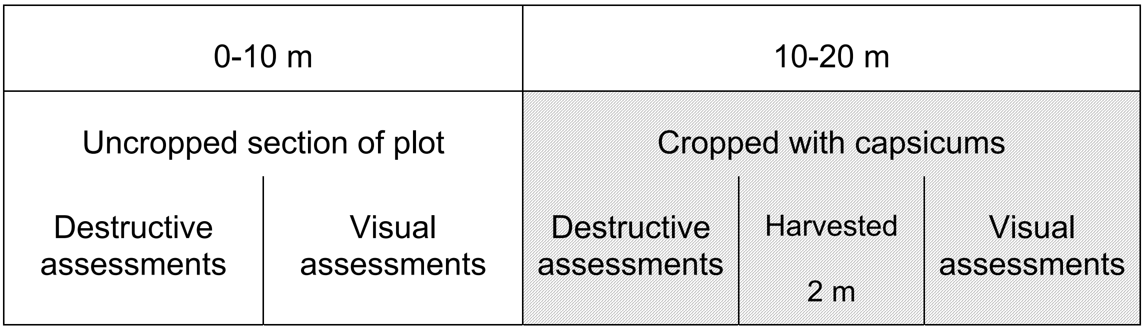


Figure 14: Bowen Research Station mulch film evaluation layout identifying areas allocated to crop harvest, destructive and visual assessments of mulch films.

Fruit from 2 m of bed were harvested at 13 weeks after laying. Due to lack of available staff, only partially red and red fruit were harvested. These fruit were graded to Woolworths' produce specifications regarding size and quality. Fruit was classed as marketable if equal to or larger than 90 mm long (from top or stem end to the blossom end of the fruit). Fruit less than 90 mm long but more than 50 mm long were recorded separately. Any fruit with structural damage including rots and sunburn, as well as fruit less than 50 mm long, were rejected as unmarketable.

Results

Layout and planting

Australian made Mater-Bi® CF04/P laid well with standard equipment. Irrigating prior to transplanting prevented damage from soil clods pressing into the mulch film as the water-wheel punched holes, as occurred in 2009 evaluations. As noted in previous observations, plant holes were larger in the Mater-Bi® treatments, with some tearing in 12 micron treatments.

Estimated bed cover

The majority of the loss of bed coverage was attributed to tearing at the plant holes and splitting where small clods of soil rubbed against the biodegradable mulch films, see Figure 15. All treatments retained at least 95% bed coverage until 8 weeks after laying, when 12 micron treatments dropped to an average of 92.5%. Two weeks later, the 15 micron treatment dropped to 93.5%, while 12 micron bed coverage continued to drop steadily. By harvest at 13 weeks, 15 and 12 micron bed coverage was recorded at below 90% and 80% respectively. Both black and white-on-black polyethylene had retained at least 97% bed coverage at harvest, see Figure 16.

Animals caused severe damage to the uncropped sections of all Mater-Bi® treatments at seven weeks. These quickly lost bed coverage as a result. Bed coverage of these sections was less than 20% at harvest, See Figure 17.

Figure 15: Splitting caused by sharp soil clods under the surface of the mulch, left, caused tearing during windy conditions, right (S. Limpus).

Other assessments

Both 15 and 12 micron Mater-Bi® retained good flexibility and strength up to harvest, with ratings of 8 and 7.3 respectively. Weed pressure increased to a rating of 1.7 and 2 in 15 and 12 micron treatments respectively at 10 weeks after laying, when bed coverage dropped. At this time, biodegradability of below ground film accelerated and at harvest was given a rating of 1.7 and 2 for 15 and 12 micron respectively. Biodegradability of buried film was slower on the Bowen Research Facility than that observed on farm; see Chapter 2 for detail. Table 2 records changes in flexibility and strength, weed pressure and biodegradability ratings over the life of the crop.

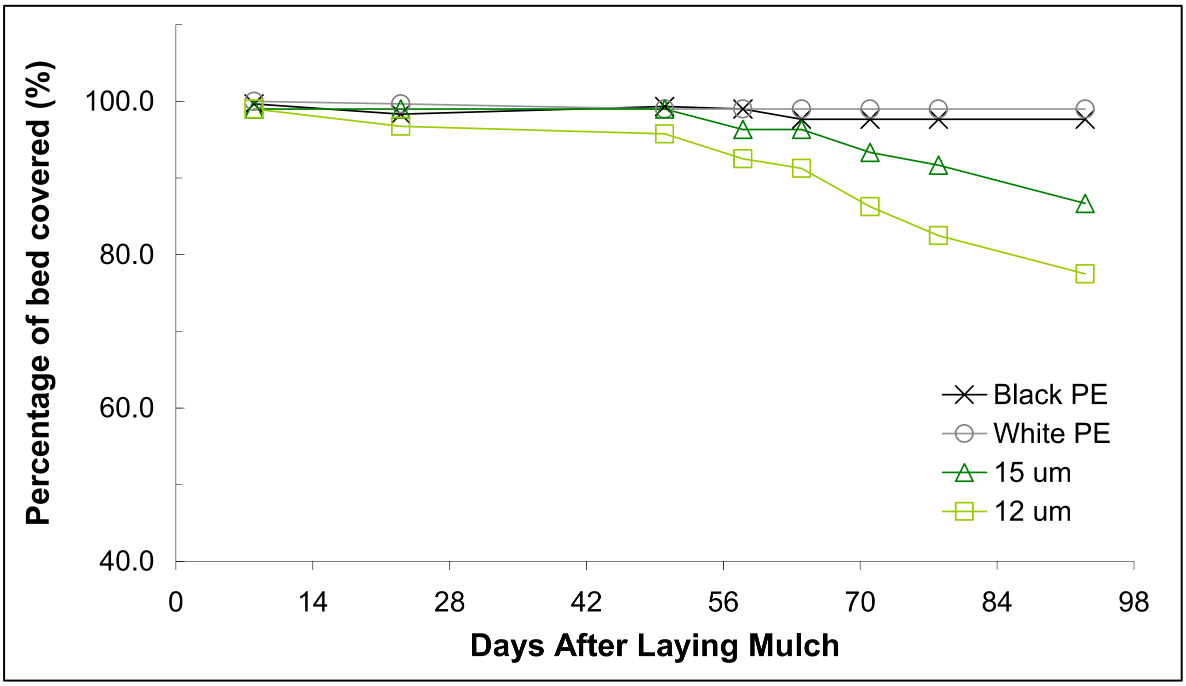


Figure 16: Percentage bed cover of treatments (*n* = 3) on the Bowen Research Facility

Figure 17: Damage to uncropped sections caused by animals moving across the surface of the mulch films. Although animals also walked on polyethylene films, these were able to withstand the pressure and no losses in bed cover were observed (S. Limpus).

Table 2: Rating of treatments for flexibility and strength, weed pressure and biodegradability recorded after laying mulch films

		Week 1	Week 3	Week 7	Week 8	Week 9	Week 10	Week 11	Week 13
Brittleness	Black PE	10	10	10	10	10	10	10	10
	White PE	10	10	10	10	10	10	10	10
	15 µm	10	10	10	10	9.3	8.3	8.3	8.0
	12 µm	10	10	10	10	9.5	8.8	8.5	7.3
Weed pressure	Black PE	1	1	1	1	1	1	1	1
	White PE	1	1	1	1	1	1.3	1	1
	15 µm	1	1.3	1	1	1	1.7	1	1
	12 µm	1	1.5	1	1	1	2	1	1
Biodegradation	Black PE	1	1	1	1	1	1	1	1
	White PE	1	1	1	1	1	1	1	1
	15 µm	1	1	1	1	1	1.7	1.7	2
	12 µm	1	1	1	1	1	2	2.3	2.5

Crop growth and yield

Due to the delay in the arrival of biodegradable mulch film, transplanting was delayed. As a result, crop growth suffered and yields were well below local averages, at 27 t/ha packed fruit over all treatments. A significant amount of fruit was sunburnt and up to 52% was graded unmarketable by Woolworths' specifications (less than 90 mm long). Up to 33% of total fruit harvested from each treatment was rejected with sunburn, see Figure 18. This may be due to reduced canopy development, exposing fruit to excess sunlight and heat during warmer than average temperatures during the growing season. See Figure 19 for air temperature data for the Bowen region during the trial period.

Air temperatures above 32°C at flowering and fruit development can cause pollination and pollen viability problems and affect the growth and shape of capsicum fruit (Meurant, 1999).These hotter conditions were also reflected in the short time to harvest. The crop was harvested at 13 weeks after transplanting, compared to the 16 weeks generally expected of capsicum crops. Statistical analysis of fruit weights indicate there were no significant differences between the treatments, see Table 3.

We found no instances of biodegradable mulch films sticking to low-set capsicum fruit. This was identified as a quality concern in previous work, including the 2009 Bowen Research Facility evaluations of Mater-Bi®. This is despite crop growth being affected by delays in transplanting and resulting in a smaller, shorter plant overall.

Soil temperature

Soil temperature probe results did not indicate any significant differences between treatments, data not shown.

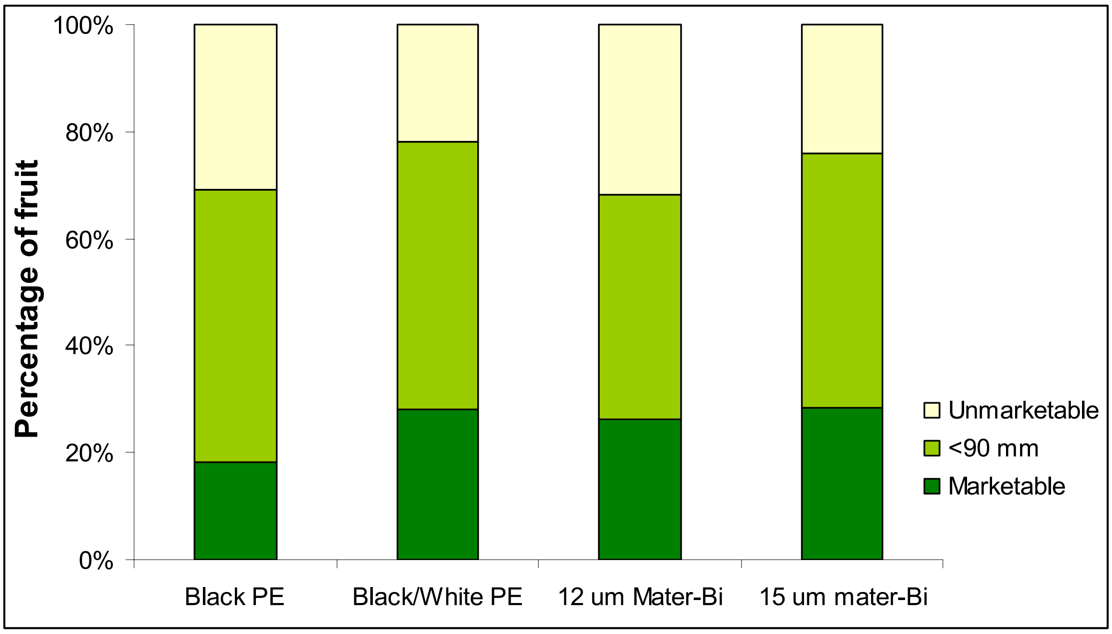


Figure 18: Percentage of yield categorised as unmarketable, marketable and less than 90 mm (potentially marketable depending on market situations.

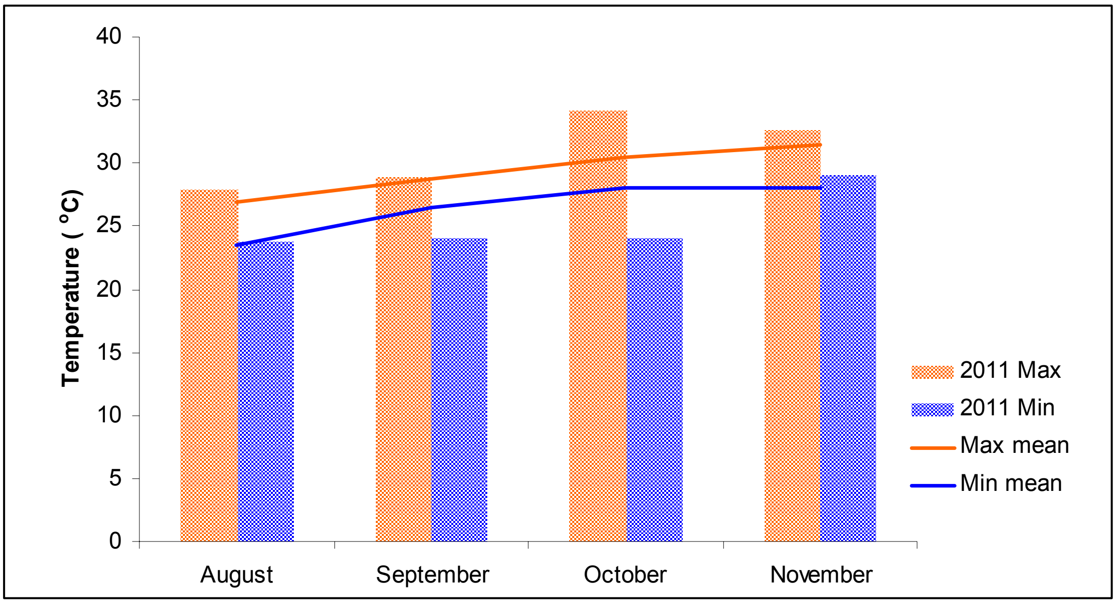


Figure 19: Minimum and maximum temperatures at Bowen during the trial period from August to November 2011 with showing minimum and maximum averages for those months over all years since 1986 to 2011. (Source Bureau of Meteorology)

Table 3: Average fruit yield per plant (*n* = 3)

Treatment	Marketable (kg/plant)	<90 mm (kg/plant	Unmarketable (kg/plant)
Black PE	0.066	0.184	0.112
Black/White PE	0.102	0.182	0.080
12 um Mater-Bi®	0.086	0.137	0.104
15 um Mater-Bi®	0.103	0.172	0.087
L.s.d (P = 0.05)	0.063	0.074	0.064

Conclusions

Despite the crop's low yield, this was consistent across all treatments. The new generation CF04/P Mater-Bi® performed well over the season, with no major differences compared to polyethylene. Brittleness and biodegradation declined over time as expected, while small losses of bed cover in the Mater-Bi® treatments did not affect yields or weed growth significantly. We found no instances of biodegradable mulch films sticking to low-set capsicum fruit, which was indicated in previous work as potentially causing a quality issue.

Mater-Bi® CF04/P, has a higher content of renewable resources than its predecessor and no visible traces remained in the field six months after being disced into soil. Being manufactured in Australia, the new generation Mater-Bi® is an ideal alternative for polyethylene replacement, keeping costs low. Compared to NF803/P (no longer manufactured in Australia), the new generation CF04/P product has enhanced qualities of flexibility, strength and biodegradation.

Chapter 2: On-Farm Evaluations

Introduction

In addition to the detailed research evaluations of biodegradable mulch, assessment of the products on-farm helped to both add value to the data, and to increase awareness and adoption of the technology in Queensland vegetable industries.

Once we were confident that a product appeared to provide comparative performance to polyethylene and degraded below ground, we approached growers to evaluate product under commercial conditions on farm. In the Bowen and Gumlu districts, these demonstrations were assessed and monitored by DAFF staff. In collaboration with Bowen District Growers Association, the sites enhanced awareness of the biodegradable mulch film benefits to local growers, through individual grower interaction and group field days. This extensive on farm work helped to provide a clearer picture of the costs and savings made with biodegradable mulch, when compared to polyethylene mulch, across a range of farming operations and crops.

In 2009 and 2010, the objective of the farm trials was to test the performance of 12 micron and 15 micron Mater-Bi® NF803/P product manufactured in Australia across a range of vegetable crops, soil types and farming systems in the Bowen and Gumlu districts. In 2011, the new generation CF04/P Mater-Bi® product manufactured in Australia from imported resin was available for on-farm evaluations. As Mater-Bi® was the only product that both passed the Bowen Research Facility trials and was commercially available; it was the only product used on-farm in these years as part of this project.

For all the on-farm trials, the mulch assessment methods were the same as used for the detailed experiments at Bowen Research Facility, see Pages 8-10 for details. The mulch films were monitored for barrier and physical properties at regular intervals, when observations on weed and crop growth were also made. Photographs were taken regularly to document subjective ratings; observations during laying were also recorded. Logistics of on-farm work, as well as constant movement of workers on-farm, prevented the use of soil temperature and tensiometer probes, and as previous results indicate, no agronomically significant differences were observed in soil temperature and moisture. As a result, only one farm was monitored for soil temperature.

Summary of Grower Experiences

During the course of the on-farm evaluations we constantly sought the opinions of growers on how they thought the mulch films performed and if they had any concerns. These thoughts/concerns are listed here:

- On properties with high nutgrass populations, which will grow through polyethylene, breaking it up into small pieces during lifting, biodegradable mulch films are a great benefit, as there is no need to employ labourers to collect these small pieces.

- It was reported that biodegradable mulch films don’t get as hot a black polyethylene films, which sometimes cause burning to the stems and shoots of transplants.
- Animals cause much more damage to biodegradable mulch films like Mater-Bi® than they do in polyethylene, as it is thinner and more fragile. Cropping soon after laying can prevent and deter some animals from moving across beds, reducing damage.
- In some cases where fruit rests on the surface of the mulch, pieces can break off and stick to the fruit. It was reported that this was not a major quality issue for commercial vegetable growers as it brushes or washes off easily.
- Fruit resting on the surface of mulch films can also cause splitting of the film under the pressure of the growing fruit. This commonly occurred in melons and eggfruit, but growers reported that it was not a widespread issue, with little to no quality repercussions.
- Where fruit punctures the biodegradable mulch films and contacts the soil, fruit can rot. Growers report that this only happens occasionally where the first set of fruit like chillies are located low on the plant and is not a major issue.
- Biodegradable mulch films more than six months old (since date of manufacture) increase the risk of loss of bed cover before harvest operations. It is best to purchase fresh mulch and stagger shipments over the season to ensure excellent quality mulch film.
- In some cases, biodegradable mulch film can take several months to a year to breakdown. Growers who have used these products for a number of seasons have recognised this but report that they are not concerned as by the next season, biodegradation speeds up under irrigated conditions.

During this project, all biodegradable mulch films that produced excellent or comparable bed cover and weed suppression were black. Standard grower practice in the Bowen – Gumlu regions is to use white on black plastic films to reduce the risk of heat damage to seedlings, particularly for early season crops. Growers have observed heat damage on seedling stems soon after transplanting when using black polyethylene mulch films. While white mulch is traditionally used on early planted autumn crops (March to May), an increasing number of growers are using white mulch throughout the season, reducing the risks from ‘unseasonal’ warm periods on the crop, during the mild autumns and winters experienced in the dry tropics. Although growers commented that they have not observed heat problems in black biodegradable mulch films, they would still prefer to use a white film during early season plantings, to minimise the risk of seedling damage.

Other comments arose during the biodegradable mulch film forum, and these have not been repeated here. See Chapter 4 for Forum report.

2009 On – Farm Evaluations

Farm 1 – Tomato and Cucumber

Tomato

A commercial sized block, see Figure 20, of 20 hectares of 15 micron Mater-Bi® (NF803/P) was laid on an alluvial loam soil from mid April through to late July 2009, for 15 staggered plantings of tomatoes. Another block of 4 beds of 12 micron Mater-Bi® (NF803/P) mulch was laid on 29 June and 1 July 2009, using product with a late April manufacture date. The tomato, *Solanum lycopersicum* L. crop was planted several days later in the 4 beds of 12 micron product, which were regularly assessed against 15 micron product in the commercial block of Mater-Bi®. The last harvest for these plantings occurred on 9 October (15 micron) and 13 October 2009 (12 micron).

The 15 micron Mater-Bi® provided good bed coverage in tomato crops for all but the late July plantings, when some splitting occurred after laying, see Figure 21. This damage may have been caused by grit on the rollers weakening the mulch during laying, so making it more prone to splitting.

The first plantings of crop were slashed, see Figure 22, and mulch incorporated in late August. The last of the staggered plantings in 15 micron Mater-Bi® were harvested in late October.

While there were no difficulties pulling up drip tape and incorporating mulch, the grower noted that the mulch seemed to be less brittle than the previous year's biodegradable mulch film. He also noted that it biodegraded more slowly than expected.

Crop shading may have had an impact on the degree of photo-degradation of mulch as tomato crops on this farm tended to be planted soon after mulch had been laid, particularly for the early season plantings. An inspection of the site on 20 May 2010 showed that small pieces of Mater-Bi® were still visible in the soil, indicated by the arrow in Figure 23, almost a year after mulch had been laid, and at least six months after it had been incorporated into the soil. Soil had been cultivated several times over this period.

Both 12 and 15 micron Mater-Bi® provided excellent bed coverage throughout the season. The harvesting operation caused some damage along the edges of beds and the mulch showed some brittleness above ground at 14 weeks after mulch had been laid. The buried edges of mulch showed first signs of biodegradation after 8 weeks in the field.

Figures 20 to 23: (Clockwise from top) Figure 20: A commercial sized block of Mater-Bi® transplanted with tomato, Figure 21: Late July plantings showing loss of bed coverage,, Figure 22: Bed coverage after final harvest and slashing of the tomato crop and Figure 23: Mater-Bi® mulch film six months after discing (S. Heisswolf)

When compared to results at the Bowen Research Facility, the time to first signs of biodegradation was very similar at around 8 weeks after laying. However, the rate of breakdown from that point on appears to be a little slower on Farm 1 than at the Bowen Research Facility. In contrast, loss of mulch bed cover seemed to occur a little earlier on farm, due to damage from farming operations. This damage did not cause any significant loss of bed cover, which remained at or above 95% bed coverage throughout. Figure 24 shows 12 micron Mater-Bi® after 8 weeks in the field.

Cucumber

Four beds of 15 micron Mater-Bi® (NF803/P) were laid alongside standard polyethylene mulch in a red soil high in quartz, ironstone and young granite, see Figure 24 (with insert) and planted with cucumbers, *Cucumis sativus* L. The quartz and sharp stones caused damage to the Mater-Bi® mulch during laying, with only minimal damage observed in the polyethylene comparison. This damage and loss of bed coverage in the four beds of 15 micron Mater-Bi® shown in Figure 25, occurred after only 4 weeks in the field. Polyethylene mulch beds are visible in the background.

Figure 24, left: After 8 weeks in the field, 12 micron Mater-Bi® NF803/P provided good bed coverage in tomato, while Figure 25, right, shows the effect of sharp stones and rough soils (inset) on 15 micron Mater-Bi® NF803/P 4 weeks after laying in cucumbers (S. Heisswolf).

Farm 2 – Cucumber and Capsicum

Cucumber

Two beds each of 12 and 15 micron Mater-Bi® (NF803/P) were laid on 5 June 2009 on a sandy alluvial soil and planted with cucumber a week later.

The crop was harvested from mid to late August, and subsequently slashed down in early September. Drip tape was pulled up a week later and mulch incorporated by the end of September. Mater-Bi® provided excellent bed coverage up until harvest, comparing favourably with polyethylene (Brand name: Amcor 25 micron). By harvest time, pressure of maturing fruit on Mater-Bi® caused some splitting of the mulch but this was not a major issue.

The Mater-Bi® beds planted to cucumber biodegraded earlier and more quickly and mulch was also substantially more brittle at the end of the trial than what would be predicted from results at the Bowen Research Facility. Relative integrity and bed coverage results were similar to those at the Bowen Research Facility.

Capsicum

On the same farm, two beds of 15 micron Mater-Bi® (NF803/P) were laid on 21 June 2009 and planted with capsicum 5 weeks later. Mater-Bi® provided adequate bed coverage right up until harvest, however Mater-Bi® beds displayed more damage and a higher population of nutgrass (*Cyperus rotundus*) than adjacent Growmulch (brand name) polyethylene beds. Some of this loss of integrity was due to animals, which impacted more on Mater-Bi® than polyethylene. Harvesting started in mid October. As some fruit matured and coloured, they tended to exert downward pressure on Mater-Bi® causing splitting of mulch and some mulch to adhere to the bottom of fruit. The severity of this potential quality issue however was much less than what was observed in the 2008 trial at Bowen Research Facility (described in more detail on Page 9).

Results for Mater-Bi® beds planted to capsicum were similar to those of the cropped Bowen Research Facility trials. While relative mulch integrity decreased more rapidly on the farm than in the research facility trial, this result was confounded by the animal damage. Mulch brittleness started a definite downward trend a week or two earlier than was predicted from results at the research facility. The first signs of biodegradability appeared slightly earlier then when compared to those recorded at the Bowen Research Facility.

Farm 3 – Lebanese Eggplant and Yellow Chilli

Lebanese eggplant

Beds of 12 and 15 micron Mater-Bi® (NF803/P) were laid on 28 May 2009 with Lebanese eggplant, *Solanum melongena* L. planted about 10 days later on 15 micron Mater-Bi®.

Despite the extensive damage caused by the laying operation (roller with rough surface pressing mulch onto dry soil) to both Mater-Bi®, see Figure 26, and polyethylene mulches provided good bed coverage until late August. After 16 weeks in the field however, Mater-Bi® had deteriorated significantly, when compared to polyethylene, with bed coverage ranging from 30% to 60%. This was earlier than expected. Damage caused during the laying operation probably contributed to this result, by weakening the mulch early in the season.

Maturing eggfruit often split the Mater-Bi® mulch as they exerted downward pressure, which could cause quality concerns.

Figure 26, left: An example of the damage caused to both 12 and 15 micron thicknesses of Mater-Bi® during laying operations (S. Heisswolf).

Yellow chilli

Yellow chilli, *Capsicum spp*, was planted 8 weeks after the Lebanese eggplant on 24 July 2009 on 12 and 15 micron Mater-Bi® (NF803/P). Both crops were harvested in October.

Mater-Bi® had deteriorated significantly when compared to polyethylene with bed coverage ranging 55% to 75% in chilli, for the same reasons as reported for Lebanese eggplant. The tips of first set chilli fruit tended to push through the mulch as they matured with some tips rotting when in direct contact with moist soil.

There was slightly more weed growth in the Mater-Bi® beds and a noticeable difference in plant colour and growth in the chilli crop. This is probably due to water stress at fruit fill rather than earlier weed competition. Buried edges of mulch did not show consistent signs of brittleness and biodegradation by trial end. This is likely due to the relatively dry condition of the soil in contact with Mater-Bi®. Soil under polyethylene was noticeably moister.

Farm 4 – Tomato

On 2 June 2009 a bed of 15 micron Mater-Bi® (NF803/P) was laid amongst a block of white on black polyethylene beds (manufactured by Polyam). The block was planted with tomato on 28 July after 8 weeks full sun exposure. At time of planting, Mater-Bi® still provided good bed coverage, however photo-degradation appeared to have weakened the product and this resulted in larger plant holes (Figure 27), compared to the polyethylene (Figure 28). This difference in plant-hole size has been noted in other trials, where mulch had been laid some time prior to planting the crop, including the 2009 season's Bowen Research Facility trial, see Chapter 1 for detail.

Figure 27, left: Plant holes of 15 micron Mater-Bi® compared to Figure 28, right: Plant holes of white on black polyethylene (S. Heisswolf).

Despite some early animal damage, Mater-Bi® provided good bed coverage for the first three months in the field, however damage from tractors and labourers (pruning) had resulted in significant damage and loss of bed coverage by time of harvest at 18 weeks. After 17 weeks in the field, the Mater-Bi® bed had slightly higher weed populations than polyethylene and had lost about 15% of its bed cover. By the end of harvest at 20 weeks, bed cover reduced to 40%.

Buried mulch edges first showed signs of biodegradation after 4 weeks in the field and by 9 weeks had biodegraded substantially. This trend however did not apply to both sides of the bed (rows running east west). By the time of the last assessment at 20 weeks after laying, the buried, northern (sunnier, drier) edge was significantly more intact than the southern (shaded, moister) edge. This trend was reversed on above ground mulch surfaces, where the northern, sun exposed side had lost significant bed coverage compared to the southern, shaded side.

Soil temperature probes and data loggers were installed at the site to compare soil temperatures between the black Mater-Bi® and white on black polyethylene mulches. These were used to monitor soil temperature at 5 cm in the 15 micron Mater-Bi® and white on black polyethylene. The black side of the white on black mulch film faced the soil, exposing the white upper surface to hypothetically reflect sunlight and therefore heat from the mulch surface early in the crop's life. This is standard grower practice particularly for early season crops. Growers have observed reduced risk of heat damage on seedling stems soon after transplanting when using the white on black polyethylene mulch films. While this practice is traditionally used on early planted autumn crops (March to May), an increasing number of growers are using white mulch throughout the season, reducing the risks from 'unseasonal' warm periods on the crop during the mild autumns and winters experienced in the dry tropics.

The temperature data indicated that while the minimum temperature reached for the white on black polyethylene was slightly lower than that for the black 15 micron Mater-Bi®, the mean and maximum temperatures for the polyethylene were higher; results shown in Table 4. This was unexpected, as it is assumed the white surface reflects heat, resulting in lower temperatures than those recorded for the black Mater-Bi® mulch. However, as observed on the research facility trials, Mater-Bi® started to loose integrity and significant bed coverage in the second half of the trial, when temperatures started to rise. This loss of mulch integrity and bed cover was likely to have prevented the build up of high temperatures under the Mater-Bi® mulch.

Table 4 Soil temperature at 5 cm on Farm 4 in white on black polyethylene and Mater-Bi® (*n* = 1)

Mulch film type	Minimum (°C)	Maximum (°C)	Mean (°C)
White on black polyethylene	16.2	33.5	25.7
15μ Mater-Bi® NF803/P	16.8	32.6	24.6

Farm 5 – Honeydew Melon

Five beds of 12 micron Mater-Bi® (NF803/P) were laid on 2 June 2009 alongside a 20 micron pre-stretched polyethylene product from Integrated Packaging using three roll , mulch laying equipment, see Figure 29, on light alluvial soil. Beds were pre-irrigated to germinate weed seeds, then planted with honeydew melons, *Cucumis melo spp*, three weeks later on 20 June.

Mater-Bi® provided excellent bed coverage and comparative performance to polyethylene. Figure 30 shows mulch after seven weeks in the field, with three beds of Mater-Bi® in the foreground, polyethylene at the rear. As melons matured and exerted pressure on the mulch, they started to split the mulch (see Figure 31), however no mulch adhered to the fruits.

The buried edges of Mater-Bi® mulch showed signs of biodegradation after four weeks in the ground and became increasingly brittle as time progressed. Figure 32 shows a section of mulch edge after 7 weeks in the field.



Figure 29, top: Three bed, commercial mulch film laying equipment, Figure 30, bottom right: honeydew melon 7 weeks after laying and, Figure 31, bottom left: Biodegradable mulch film where growing melon has rested and split the mulch film (S. Heisswolf).


Figure 32, left: Biodegradation of buried edge of mulch film 7 weeks after being laid, and Figure 33, right: Mulch film condition after slashing showing good coverage (S. Heisswolf).

The crop was harvested in early September, when mulch had been in the field for almost 14 weeks. The crop was slashed on 11 September 2009, drip tape (and polyethylene mulch) pulled up on 14 September.

Crop residues and Mater-Bi® mulch were rotary hoed then bedded up on 18 September 2009. No problems were encountered during any of these operations. Figure 33 shows mulch after the crop had been slashed (polyethylene to the left and Mater-Bi® on the right).

Incorporated mulch continued to decompose and break down in the soil over the summer. The grower did not have any concerns about the speed of mulch breakdown, reporting that no mulch was visible in the block when contacted in early June 2010.

Farm 6 – Capsicum

A short section of 15 micron Mater-Bi® (NF803/P) was laid in late June on heavy grey clay soil with sharp clods. The cloddy soil caused extensive damage to Mater-Bi®, as Figure 34 illustrates. Damage to polyethylene (Polyam advanced white on black) was negligible, although it is interesting to note that press wheels caused more damage to the buried edge of polyethylene during the laying operation than Mater-Bi®. The crop was planted 4 weeks later (end July) and harvested in early through to mid October, 14 weeks after laying.

Very little additional loss of integrity occurred after the original damage caused during laying operations. Mater-Bi® showed signs of biodegradation after 11 weeks in the field. The above ground portions of mulch showed signs of brittleness at the final assessment after 14 weeks in the field. Mater-Bi® provided reasonable bed coverage when compared to polyethylene, until trial end, with no obvious differences observed in crop growth. Some weeds were observed in the Mater-Bi® section, whereas the assessed section of polyethylene remained weed free.

Figure 34, left: Damage to 15 micron Mater-Bi® mulch film as a result of hard, cloddy soils being pressed into the film from below during laying operations, and Figure 35, right: An example of damage caused to 12 and 15 Mater-Bi® films from tractors in tomato, see 2010 On-farm Evaluations (S. Heisswolf).

2010 On – Farm Evaluations

Farm 1 – Tomato

Two beds each of 12 and 15 micron Mater-Bi® (NF803/P) were laid adjacent to a white on black polyethylene mulch (23 micron manufactured by Polyam Advance) on 21 April 2010, on a red soil high in quartz, ironstone and young granite (Euchrozem). This soil is similar to that reported on for the 2009 season, where Mater-Bi® mulch had performed poorly in a crop of cucumber; see Page 30 for details. While there was some slippage of Mater-Bi® from under pressure wheels during the laying operations where soil was cloddy, very little damage was observed. The beds were planted with tomato two days after laying mulch, with slight plant wheel damage observed.

The tomato crop was harvested at 11 weeks after laying, onwards. A final assessment was made at 19 weeks after laying, when plants had been pulled from the trellis. Both 12 and 15 micron Mater-Bi® gave similar bed coverage to polyethylene. Some damage through tractor wheels, Figure 35, and other farm operations, were observed in both Mater-Bi® and polyethylene beds.

Mater-Bi® started to show some signs of brittleness by 7 weeks after laying. However, this did not cause significant loss of bed cover, with all 4 beds of Mater-Bi® retaining 95% bed cover at the last assessment, at 19 weeks after laying. There were no consistent differences in brittleness, relative integrity or bed cover between the 12 and 15 micron Mater-Bi® beds.

Buried edges of 12 micron Mater-Bi® were brittle by the third assessment at 7 weeks after laying, and the 15 micron Mater-Bi® was brittle by the following assessment at 9 weeks. Differences in biodegradation between the two thicknesses however were not consistent over time.

Farm 5 – Rockmelons and capsicum

Rockmelon

Two beds of 12 micron Mater-Bi® (NF803/P) were laid alongside polyethylene (pre-stretched 20 micron from Integrated Packaging) on 9 April 2010 on a light alluvial loam. Rockmelon, *Cucumis melo spp*, seedlings were transplanted a week later. Mater-Bi® was laid and planted without problems. A follow up trial of 12 and 15 micron Mater-Bi® (NF803/P) was laid in early July and planted with rockmelon a week later. As in previous trials with melons, Mater-Bi® provided excellent bed coverage throughout the life of the crop.

Mater-Bi® performed well, providing 99% bed coverage until harvest. There was no noticeable difference in plant growth or crop yield between Mater-Bi® and the polyethylene beds. The buried edges of Mater-Bi® became brittle quite early however, as noted for trials at Farm 2, the buried mulch retained some elasticity until trial end.

Capsicum

On the same farm, a short section of bed was laid with 15 micron Mater-Bi® (NF803/P) alongside beds of white on black polyethylene in early July and planted with capsicum seedlings several days later, Figure 36.

The ratings for mulch film were similar in capsicum to that reported in melon above.

Figure 36: A short section of 15 micron Mater-Bi® laid alongside beds of white on black polyethylene (S. Heisswolf).

Farm 7 – Tomato and capsicum

Tomato

Two beds each of 12 and 15 micron Mater-Bi® (NF803/P) were laid on 11 June 2010 on a medium alluvial clay. The mulch was over 6 months old and was not planted with tomato seedlings until 8 weeks after laying in early August. The mulch laid well and very little planting damage was observed, Figure 37. On this farm, seedlings are planted by hand without the aid of a transplanting machine.

Both thicknesses of Mater-Bi® performed well. First signs of brittleness occurred within a month of laying mulch however, there was little loss of relative mulch integrity until mulch had been in the field for over 16 weeks. At this time bed coverage was still rated at 99% for all four beds. Figure 39 shows 12 micron Mater-Bi® after 16 weeks in the field).

The buried edged of 12 micron Mater-Bi® were somewhat brittle by the third assessment at 8 weeks after laying. The 15 micron Mater-Bi® showed the first signs of brittleness by the fourth assessment after 12 weeks. While deteriorating, the buried mulch edges were still noticeably elastic by the final assessment at 16 weeks after laying, which was unexpected.

Capsicum

On the same farm, 12 and 15 micron Mater-Bi® (NF803/P) were laid in short sections of bed on 11 June 2010, in a soil similar to that of the tomato block. Capsicum seedlings were planted 10 weeks later. The time the mulch, which was already over 6 months old, was exposed to photo-degradation likely affected mulch performance.

The 12 micron Mater-Bi® showed significant loss of integrity by the third assessment 12 weeks after being laid, with bed coverage estimated at 80%, see Figure 40. At the final assessment after 16 weeks in the field, bed coverage had dropped to around 70%, while 15 micron Mater-Bi® retained 95% bed coverage. Weed incidence was also higher in the Mater-Bi® sections when compared to polyethylene. This is in part due to planting holes being larger at the outset, due to the mulch becoming somewhat brittle by time of planting. This brittleness causes plant holes to tear over time, as seen in Figure 38.

Figure 37, top left: Very little planting damage was caused to 12 and 15 micron Mater-Bi® during hand planting operations, Figure 38, top right: Brittleness causes plant holes to tear, Figure 39, bottom right: Excellent bed coverage of 12 micron Mater-bi® in tomato after 16 weeks in the field, and Figure 40, bottom left: Bed coverage at 80% for 12 micron Mater-Bi® in capsicum 12 weeks after being laid (S. Heisswolf).

Farm 8 – Eggplant (aubergine)

Two beds of 15 micron Mater-Bi® (NF803/P) were laid on 8 June 2010 alongside polyethylene (Aperio black) on a light alluvial soil and planted with eggplant 5 weeks later. After some fine tuning, Mater-Bi® laid and planted well, although planting holes were larger than in polyethylene. Mater-Bi® mulch tended to split across the beds by 5 weeks after laying. By the fourth assessment at 12 weeks after laying, Mater-Bi® became more brittle and the northern more sun exposed side of the beds started to lose bed cover, with splits observed intermittently along bed edges, see Figure 41. However, at this stage, bed coverage was still rated at 95%. Mater-Bi® continued to deteriorate, particularly along the northern side of the bed, to harvest in mid-September.

The crop was ratooned mechanically in early November and a final assessment was performed at 25 weeks after laying. This assessment showed that Mater-Bi® mulch was still remarkably intact on the southern side of the beds. Weed growth was higher when compared to the polyethylene beds. Overall bed coverage for Mater-Bi® was rated at about 40% with polyethylene still at 99%. Figure 42 shows that on the left side of the bed, Mater-Bi® mulch was still largely intact (the southern, left side of the bed) while on the right side of the bed (the northern more sun exposed side) it had lost most of its mulch cover. The mulch had been in the field for 25 weeks by this time and the grower seemed quite satisfied with its performance.

Buried edges of Mater-Bi® started to become brittle by the third assessment after 8 weeks. As noted on two other farms this season, the mulch did still display some signs of elasticity, despite its extensive time in the field.


Figure 41, left: Splitting observed in 15 micron Mater-Bi® mulch film planted with eggplants, 12 weeks after laying, and Figure 42, right: The left side of bed is still largely intact after 25 weeks, with the right or northern, sun exposed side has lost significant bed coverage (S. Heisswolf).

On-farm evaluations 2011

Farm 7 – Tomato

This grower almost exclusively uses 15 micron Mater-Bi® (CF04/P) biodegradable mulch film for tomato and capsicum production. Beds of 15 micron Mater-Bi® and black polyethylene were monitored for mulch film performance between August and October 2011. Mulch film was laid on the 20 August 2011 and tomato seedlings were transplanted by hand five days later. During hand planting, we noted contractors constantly walked on the biodegradable mulch films. This caused little damage, indicating biodegradable mulch films were flexible enough to resist some impacts, see Figure 43.

Both polyethylene and biodegradable mulch films retained bed cover of at least 95% for 10 weeks after laying. Bed cover after 10 weeks was maintained at 85%, right up until the final harvest days, when at 14 weeks, all mulch films were severely damaged by harvest machinery, see Figures 44 and 45. At 13 weeks after being laid, polyethylene bedcover dropped to 50% and 15 micron Mater-Bi® to 60%. Strength and elasticity started to decline after 10 weeks and biodegradability increased on the buried edges by harvest.

Weeds were initially controlled by inter-row spraying and intermittent hand weeding. Weed incidence in both polyethylene and biodegradable mulch film beds remained low throughout the life of the crop.

Figure 43: Very little damage was caused to 15 micron biodegradable mulch film during hand-transplanting despite transplanters walking on the films (S. Limpus).

Figures 44 and 45: Damage to biodegradable mulch films caused by machinery. Similar damage was also caused to the polyethylene beds and this will requite extra costs to remove adequately from the field (S. Limpus).

Farm – Capsicum and Sweet corn

Capsicum

Mater-Bi® biodegradable mulch film (CF04/P) in 12 and 15 micron were laid with polyethylene on the 15 June 2011. Capsicum seedlings were transplanted 6 weeks later in double rows.

Mulch cover in the capsicum plots was retained at 95% for 9 weeks after laying, with a gradual decline in 12 micron mulch film to 80% ,after 14 weeks. At 19 weeks, 15 micron mulch film cover had declined to 80%, with 12 micron declining to 70%, see Figure 46. At harvest, mulch film cover in 15 and 12 micron was recorded at 80% and 65% respectively.

Sweet corn

Mater-Bi® biodegradable mulch film (CF04/P) in 12 and 15 micron were laid with polyethylene on the 15 June 2011. Six weeks after laying, a 15 m section of the three beds were sown with sweet corn, *Zea mays spp*, seeds 15 cm apart in double rows. Sweet corn seedlings were fully emerged six days later.

Strength and flexibility declined after 14 weeks and mulch films were torn when tapped firmly at harvest. Significant biodegradation of both buried mulch film edges and on the surface of the bed began 14 weeks after laying; ,see Figures 47 and 48. These plots also had significant weed pressure increases after 15 weeks. This was partially due to biodegradation on the surface of the bed, where small clumps of soil and decaying leaves were resting on the mulch films. By this stage, both sweet corn and capsicum canopies were fully developed and likely did not cause any yield losses.

Mulch cover in the 12 micron biodegradable film sweet corn plots declined to 50%, 15 weeks after laying. Bed cover continued to decline and was recorded at 35% at harvest. The 15 micron biodegradable film plots retained 85% bed cover over this same period, decreasing to 80% at harvest at 16 weeks; see

Figures 49, 50 and 51. The significant difference between the bed cover of the capsicum compared to the sweet corn plots is likely a result of the delay in canopy development in sweet corn. Here, above ground mulch films were exposed for a longer period of time to sunlight, accelerating biodegradation of exposed surfaces.

Figure 46: Tractor damage sustained to 12 micron Mater-Bi® in capsicums contributed to the decline in bed cover 19 weeks after laying (S. Limpus).

Figure 47, left: Biodegradation of above ground surfaces of 15 micron Mater-Bi® where soil and leaves were resting on the surface, promoting microbial activity, and Figure 48, right: Below ground degradation of 15 micron Mater-Bi® showing evidence of microbial activity, 14 weeks after laying (S. Limpus).

Figure 49, top: Polyethylene film bed in sweet corn retaining 99% bed cover at harvest some 16 weeks after initial laying, Figure 50, middle: 12 micron Mater-Bi® bed coverage declined to 80% at harvest, and Figure 51, bottom: 12 micron Mater-Bi® bed coverage declined to 35% by harvest (S. Limpus).

Conclusions

Over the years, growers have noticed an improvement in mulch characteristics, indicating the technology is advancing and manufacturers are aware of grower requirements. In most cases, biodegradable mulch films of NF803/P (no longer manufactured in Australia) Mater-Bi® and its next generation CF04/P developed by Novamont performed well, with results comparable to polyethylene mulch films. When using biodegradable mulch films, there are some points to consider which can prevent films performing as per these results. These are:

- Rough and stony soils can damage films and thicker gauges, such as 15 to 20 micron, may be required.
- When machine transplanting, beds should be irrigated prior to planting operations, to prevent wheel damage to films.
- Extended exposure to sunlight considerably weakens the films. This can cause enlarged holes during transplanting and advanced biodegradation of upper surfaces before harvest.

Some growers encountered problems during fruit development, where the ripening fruit would split the mulch film. Here, the fruit could contact wet soil and rot, or films could adhere to the base of the fruit. Both could cause quality concerns, however most growers noted that this did not lead to increased rejection of fruit or washing. Based on these results, biodegradable mulch films did not interfere with yields and adequately proved bed coverage and weed suppression for the life of most crops and is a suitable replacement product for polyethylene mulch films.

Chapter 3: Technology Transfer and Extension

Media

The technology transfer and extension of this project was a considerable and important component. It was designed to engage as many interested parties as possible, such as researchers, manufacturers and the community, with the focus on growers.

Advertisements and media releases regarding field days, project updates and outcomes helped public awareness of local issues. These outlets allowed community members to witness growers proactively seeking solutions to waste reduction and responsible waste management.

The project created interest amongst developers of biodegradable plastic technology. In response to media releases, project updates, newsletters and field days, we were and continue to be contacted by numerous manufacturers of these products, service providers who wish to be able to stock the products and researchers from other Queensland vegetable production regions and states asking for information. This helped to increase the visibility of these products as a potential solution to a major problem not just in the Bowen Region, but also most other vegetable production regions in Australia. The published results increased the awareness of manufacturers of the existence of potential markets for biodegradable film technology, production environments and previous problems with products, to improve and develop new technology. This will hopefully lead to the development of a better, more efficient and cost effective product for Queensland vegetable growers.

Extension events and materials

A field day was held at a local grower's property in 2009. Here, growers were able to experience the mulch film and growing conditions physically on a commercial farm. It provided an opportunity for growers to interact with each other, discuss their requirements and concerns regarding biodegradable mulch films. The field day provided technical information about the potential of the products, their benefits and assimilation in a commercial production system. Numerous times during the course of the project, growers and manufacturers asked to view the products in the field individually. These occasions were welcomed and visitors were able to learn about the results, gain technical advice on laying and handling biodegradable mulch films, experience the physical qualities of the products and crop performance.

Regular newsletters were distributed to local growers, manufacturers, researchers and grower organisations to disseminate information gathered during the project. These newsletters summarised results form trial work and provided technical advice on laying and handling. A leaflet was produced in 2012 detailing the benefits of biodegradable mulch films, choosing products based on soil, crop type and situation, handling and laying, as well as techniques to maximise the products longevity in the field. This leaflet was disseminated at the 2012 forum and crop health seminars, as well as via email to growers, manufacturers and researchers.

On a number of occasions, students interested in the agricultural industry were given a tour of the Bowen Research Facility. Part of this included a presentation on the use of biodegradable films in vegetable production. As a result, students at the Bowen State High School were given rolls of biodegradable mulch film to use in their vegetable crops on school grounds.

Biodegradable mulch film forum

A biodegradable mulch film forum was held at the Bowen Research Facility on the 28 February 2012 to inform growers about these products. Growers, agronomists and agricultural consultants and suppliers gathered with DAFF officers, Whitsunday Regional Council representatives and biodegradable plastic manufacturers, to discuss the benefits and share knowledge on using biodegradable mulch film products in irrigated vegetable production. The afternoon was punctuated with in-depth discussions about the impediments to adoption and the benefits, techniques and considerations growers need to be aware of when using biodegradable mulch films. For more information on the forum, see Chapter 4.

The cost of adoption

Cost of biodegradable mulch products when compared to polyethylene is by far the most critical barrier to adoption. In 2007, Mater-Bi® was first manufactured in Australia from imported resin to help reduce price. Despite this, in 2010, black 15 micron Mater-Bi® CF04/P distributed by Australian Bio-plastics was twice the cost of black polyethylene, even when savings in retrieval and disposal costs were factored into the equation. This will vary with the value of the Australian dollar and changes in the oil price, but also individual farming operations and disposal options available in different districts. Scaling up of production runs would help to reduce costs somewhat, however the high cost of the resin itself, even if it were manufactured in Australia under license, will continue to impact on competitiveness with polyethylene in the near future.

The inclusion of biodegradable mulch in the Reef Rescue incentives program has helped to offset the price of biodegradable mulch products to participating growers and encouraged environmentally sustainable thinking among local growers. The recent implementation of a waste management strategy, by the Queensland Government in December 2011, has also encouraged growers to seek out alternatives to polyethylene mulch film. This strategy attempts to encourage better waste management of commercial businesses by making waste disposal more expensive. A forum held as part of this project in February 2012 at the Bowen Research Facility also highlighted the rising costs of traditional farming practices, see Chapter 4. A representative from the local Whitsunday Regional Council updated growers on the capacity of the current disposal site and the financial implications of polyethylene mulch disposal at council landfill. Also presented at this forum was a cost-benefit analysis tool growers can use to estimate the cost of adopting biodegradable mulch, which includes the current and potential costs of disposal at Queensland landfill sites, see Appendix I.

Note: Contact the Bowen Research Facility for a copy of this tool on 07 4761 4000.

Technology, transfer and extension outputs

Newsletters, information and tools

Sue Heisswolf, 2009, "Biodegradable mulch trials: On-farm trials 2009", Industry Newsletter, Bowen Research Facility, Queensland Department of Agriculture, Fisheries and Forestry

Sue Heisswolf, 2010, "Biodegradable mulch film trials: Project update May 2010", Industry Newsletter, Bowen Research Facility, Queensland Department of Agriculture, Fisheries and Forestry

Sue Heisswolf, 2010, "Biodegradable mulch film trials: Project update December 2010", Industry Newsletter, Bowen Research Facility, Queensland Department of Agriculture, Fisheries and Forestry

Sarah Limpus, 2011, "Biodegradable mulch film trials: Project update December 2011", Industry Newsletter, Bowen Research Facility, Queensland Department of Agriculture, Fisheries and Forestry

Sarah Limpus, 2012, "Biodegradable mulch film trials in irrigated vegetable production: Tips for choosing and using", Industry Newsletter, Bowen Research Facility, Queensland Department of Agriculture, Fisheries and Forestry

Tom Mullins, 2012, "Biodegradable Vs. polyethylene mulch film cost analysis tool", Excel spreadsheet presented at the Biodegradable mulch film forum, Bowen Research Facility, 28 February, 2012, Bowen, Queensland

Karl Murdoch, 2012, "Whitsunday Regional Council waste reduction and mitigation strategies", presentation Biodegradable mulch film forum, Bowen Research Facility, 28 February, 2012, Bowen, Queensland

Warwick Hall, 2012, "Developments in biodegradable mulch film technology: Novamont", presentation Biodegradable mulch film forum, Bowen Research Facility, 28 February, 2012, Bowen, Queensland

Extension events

Sue Heisswolf, 2009, "Biodegradable mulch trials: Farm walk", 13 October, 2009, Mr Dale Williams' property "Euri-Gold Farms"

Sue Heisswolf, 2009, “Biodegradable mulch film trials”, November 2009, Bowen Research Facility, Queensland Department of Agriculture, Fisheries and Forestry

Sarah Limpus, 2012, “Biodegradable mulch forum”, 28 February, 2012, Bowen Research Facility, Queensland Department of Agriculture, Fisheries and Forestry (see Appendix … for forum report)

Sarah Limpus, 2012, “Soil and crop health seminar”, 17 April, 2012, Ayr Research Facility, Queensland Department of Agriculture

Industry events

Sara Guerrini for Sue Heisswolf, 2010, Chair “Workshop 19: Biodegradable plastics in horticulture”, 28th International Horticultural Congress, 22-27 August, 2010, Lisbon Congress Centre, Lisbon

Sara Guerrini for Sue Heisswolf, 2010, “Biodegradable mulch film use in drip irrigated field vegetable production in Queensland Australia”, 28th International Horticultural Congress, 22-27 August, 2010, Lisbon Congress Centre, Lisbon

Sarah Limpus, 2011, “Biodegradable mulch film in drip-irrigated vegetable cropping systems in Bowen, Queensland, Poster presentation at the 2011 AUSVEG National Convention, Trade Show and National Awards for Excellence, 14-16 April, 2011, Sebel-Citigate Hotel, Brisbane, Queensland

Sarah Limpus, 2011, “Working with horticultural producers to promote sustainable vegetable production and environmental health in Bowen, Queensland”, Poster presentation at the 2011 Australasia-Pacific Extension Network National Forum, “Hitting a Moving Target; Sustaining Landscapes, Livelihoods and Lifestyles in a Changing World”, 28-30 November, 2011, University of New England, Armidale, New South Wales

Media

Queensland Department of Agriculture, Fisheries and Forestry, “Farm walk allows inspection of biodegradable mulch trials”, Media Release 8 October 2010, http://www.dpi.qld.gov.au

Queensland Department of Agriculture, Fisheries and Forestry, “Biodegradable mulch film solves headache for vegetable growers”, Media Release May 2010, http://www.dpi.qld.gov.au

Queensland Department of Agriculture, Fisheries and Forestry, “DPI&F seminars for pest and disease management” (includes a biodegradable mulch project update)”, Media Release 23 March, 2009, http://www.dpi.qld.gov.au

Bowen-Gumlu Growers Association, 2011, “Update on DAFF projects”, June-July Edition, Bowen, Queensland

Australian Melon Association Inc., 2012, “Biodegradable mulch trial a success”, Melon News, Summer: Volume 39, Brisbane, Queensland

Queensland Department of Agriculture, Fisheries and Forestry, 2012, “Grower forum on biodegradable mulch films to be held in Bowen”, Media Release 17 February, 2012, http://www.dpi.qld.gov.au

Bowen Independent, 2012, “Seeking solutions from the waste up”, 22 February, 2012, Page 4, Townsville, Queensland

Queensland Department of Agriculture, Fisheries and Forestry, 2012, “Soil health seminars for vege growers in Bowen and Ayr”, Media Release 4 April, 2012, http://www.dpi.qld.gov.au

Ayr Advocate, 2012, “Soil health seminars for vege growers”, 4 April, 2012, Page 5, Townsville, Queensland

Queensland Department of Agriculture, Fisheries and Forestry, 2012, “Plastic not so fantastic when it comes to mulch”, Media Release 8 May, 2012, Brisbane, Queensland

Bowen Independent, 2012, “Plastic not so fantastic when it comes to mulch”, 30 May 2012, Page 3, Townsville, Queensland

Approved project reports

Sue Heisswolf, 2009, Project Milestone Report 101 – “Agreement signed, voluntary contributions received and IP arrangements in place”, 24 August, 2009, Bowen Research Facility, Queensland Department of Agriculture, Fisheries and Forestry

Sue Heisswolf, 2009, Project Milestone Report 102 – “First year of trial work underway, farm walk held”, 31 December, 2009, Bowen Research Facility, Queensland Department of Agriculture, Fisheries and Forestry

Sue Heisswolf, 2010, Project Milestone Report 103 – “First year’s trail work completed successfully, progress report written and summary of results disseminated to industry”, 31 May, 2010, Bowen Research Facility, Queensland Department of Agriculture, Fisheries and Forestry

Sue Heisswolf, 2010, Project Milestone Report 104 – “Product screening and on-farm evaluations completed for 2010 season, summary of results disseminated to industry”, 31 December, 2010, Bowen Research Facility, Queensland Department of Agriculture, Fisheries and Forestry

Sarah Limpus, 2011, Project Milestone Report 105 – “Third year of trial work underway, progress report written”, 31 May, 2011, Bowen Research Facility, Queensland Department of Agriculture, Fisheries and Forestry

Sarah Limpus, 2011, Project Milestone Report 106 – “Third year’s trial work completed successfully, reports written, summary of results and ‘how to use’ leaflet disseminated to industry”, 31 December, 2011, Bowen Research Facility, Queensland Department of Agriculture, Fisheries and Forestry

Chapter 4: Biodegradable Mulch Film Forum

Summary

The biodegradable mulch film forum was held at the Bowen Research Facility on the 28 February 2012, to inform growers about these products. Thirteen growers, agronomists and agricultural consultants and suppliers gathered with DAFF officers, Whitsunday Regional Council representatives and biodegradable plastic manufacturers, to discuss the benefits and share knowledge on using biodegradable mulch film products in irrigated vegetable production, see Figure 52.

Figure 52: Attendees of the biodegradable mulch film form held on 28 February 2012, listen to growers Dale Williams and Jamie Jurgens discuss their experience working with the products.

Forum Agenda

Polyethylene disposal and costs

Disposal site update

Karl Murdoch, Whitsunday Shire Council Waste Management Officer, discussed current and future disposal considerations, costs and funding to implement waste reduction measures. The current mulch film disposal site is located at the shooting range and is expected to reach capacity within the next three years. This means that an alternative landfill site will need to be indentified and developed once the current site is exhausted. Disposal of agricultural plastic at landfill will incur charges for vegetable growers.

Note: The arrangement for plastic disposal at the shooting range is between Sporting Shooters Association of Australia Bowen Branch, the growers and the plastic transport company, see contact details.

Waste reduction levy

The previous Bligh Government implemented new legislation, starting December 2011, governing waste reforms to promote waste reduction and recycling of commercial, industrial, construction and demolition waste. This includes a levy of $35 per tonne charged to landfill operators. This charge is passed onto businesses for disposal. The levy collected will boost funding for developing recyclable products, recycling infrastructure and other waste reduction measures that may include biodegradable mulch films.

Note: The 2012 Queensland Government may repeal the Waste Reduction Levy.

Cost analysis tool

Tom Mullins, DAFF Farm Financial Councillor, performed a demonstration of a cost-benefit analysis for vegetable growers comparing polyethylene mulch films to biodegradable products on farm. The cost-benefit analysis costs included such as purchasing the different products, labour to roll and clean up plastic and levy charges. The tool would then calculate all the costs associated with using each product. The example used during the demonstration, with grower input, estimated that using biodegradable mulch films would be just $160 more expensive than using polyethylene mulch film. This will vary from farm to farm based on grower practices. Please contact Sarah Limpus for an electronic copy (Microsoft Excel file) of the cost analysis.

Project update

Sarah Limpus, DAFF Development Horticulturist, reported on the outcomes of the project “Comparison of biodegradables mulch products to polyethylene in irrigated vegetable, tomato and melon crops” funded by HAL through voluntary contributions by the Bowen Gumlu Growers Association, Novamont, Queensland Government and the Australian Government. The project concludes in May 2012 and aimed to identify replacements for traditional polyethylene mulch films and accelerate grower uptake of practical solutions to reduce the volume of agricultural waste.

The results of work on the research facility and on-farm indicate the biodegradable product, Mater-Bi® developed by Novamont and Marketed by Australia Bio-Plastics, provided adequate bed coverage and weed suppression while maintaining yield when compared to polyethylene films. Biodegradable mulch films are fragile compared to polyethylene films; they must be handled with care. Thin films may not be suitable for use in stony or rough soils.

Mater-Bi®, made from 50% plant starch and polyesters, has biodegradable and compostable certification under Australian Standard 4736. Mater-Bi® complies with biodegradability and compostable tests and toxicity tests to soil fauna and plants.

New technology

Warwick Hall, Novamont, discussed the Mater-Bi® technology and their commitment to product improvement based on trial, growers and researcher's experience and comments. New Mater-Bi® products will be available for testing in 2012 and they are continually developing the Mater-Bi® product to include more renewable starch content to a point where it can be almost 100% starch based polymer in future. Mater-Bi® is certified biodegradable and compostable under Australian Standard 4736, as well as European, Japanese and American Society of Testing Materials standards.

Reef Rescue funding

Denise Kreymborg, Bowen Gumlu Growers Association Industry Development Officer, informed growers they can apply for grants to purchase biodegradable mulch films as part of the Reef Rescue Initiative. Contact Denise on bdgainc@bigpond.com or 07 4785 2860 for more information.

Grower's comments

Several vegetable grower's have had experience using biodegradable mulch films and shared their knowledge with other growers, DAFF staff and manufacturers at the forum. From this discussion, it was clear that biodegradable mulch has been a benefit to growers. It eliminates the need for extra labour in cases where mulch films become significantly damaged by harvesting machinery and weeds. No significant changes to laying and operations and implements have been made to accommodate the films and yields have not been negatively affected. Growers expressed that they rely on the health of their soil and environment to grow food for Australia, the world and so must utilise products, and practices they are sure will maintain and/or benefit their farming systems.

Grower comments on benefits

- There is no difference between nutgrass populations in biodegradable compared to polyethylene mulch films. However, high nutgrass populations in polyethylene prevent efficient lifting and rolling, and emu parades are required to collect all plastic pieces.

- Adequately controls early crop weeds. When films begin to biodegrade, weed interference does not affect yield after 5 to 6 weeks (after transplanting tomato) and after 8 weeks, harvesting operations commence.

- Biodegradable mulch films tended not to flap in windy conditions like polyethylene, causing the seedling to become damaged by the film or the heat on the film resting near or on the seedling.

- Biodegradable mulch films may have a slight cooling effect on fruit sitting on the film and the film absorbs water and dew preventing diseases.

- During harvesting operations, machinery will damage mulch films, which causes problems when using polyethylene. The plastic is pressed into the moist soil and can be very difficult to lift and roll it later. A tomato grower mentioned a 170 horsepower tractor was needed to do this and because of this issue, using biodegradable products is the cheaper option.

Grower comments on laying and handling

- Suggested machinery-laying speeds are 5 km/hour for 12 micron and 10-12 km/hour for 15 micron.

- Implement rollers need to be clean and smooth to prevent damage during laying. The roller need light sanding with a fine sand paper to remove soil and rust.

- Transplanting into biodegradable mulch films occurs within four weeks of laying. In cases where planting has been delayed, films still provide adequate cover before biodegradation accelerates at 10 to 12 weeks after laying.

- The biodegradable mulch film degradation is complete by the beginning of the next season and to prevent it from breaking apart and flying away growers use implements such as offset disc ploughs to cover the film. This increases the contact soil and soil organisms, that consume biodegradable films, have with the film.

Further work

Since the first field trials of Mater-Bi® at Bowen 15 years ago, Novamont have continued to develop and improve their products. Work is underway to reduce costs while retaining biodegradable film performance. New products are available for screening in 2012. Novamont wish to maintain the relationship developed through the current project with growers and DAFF for continual improvement of the product. Novamont are interested in exploring other benefits of biodegradable mulch films in vegetables which may include: yield and quality improvements, environmental and farm sustainability and inclusion in organic vegetable production.

Novamont expressed their willingness to enter into a new agreement with Bowen Gumlu Growers Association and DAFF to screen and assess the performance, cost effectiveness and environmental and agronomic performance of the new Mater-Bi® products.

Acknowledgements

Sarah Limpus would like to thank Jamie Jurgens, Dale Williams, Laurie Land, Karl Murdoch, Tom Mullins, Denise Kreymborg, Warwick Hall and Steve Matheson for their contribution to the forum. Thank you also to the forum participants for their interest and comments and the Bowen and Gumlu growers for their involvement in the project.

Contacts

Denise Kreymborg

(07) 4785 2860 or bdgainc@bigpond.com

Sarah Limpus

(07) 4761 4000 or sarah.limpus@daff.qld.gov.au

Department of Environment and Resource Management

13 74 68 or info@derm.qld.gov.au

Whitsunday Regional Council

(07) 4761 3600 or info@whitsundayrc.qld.gov.au

Sporting Shooters Association of Australia Bowen Branch

0408 850 220 or publicofficer@ssaabowen.org.au

Chapter 5: Conclusions and Recommendations

Assessment of mulch properties

While mulch assessments remain somewhat subjective and are based on estimates rather than objective measurements, they appear to be robust enough to pick up gross differences and trends between mulch treatments. Quantifying initial mulch degradation (i.e. changes from 100 to 90% cover) can be difficult. Assessments became easier as changes in mulch properties accelerate. The following notes summarise overall trends observed at the research facility and on farms, as well as some points to consider for improving assessment techniques.

Bed cover and mulch film integrity

Mater-Bi® maintained excellent bed coverage throughout the cropping cycle. Early losses in bed coverage (as a direct result of laying or planting operation or animals) can dramatically accelerate bed cover losses later in the season. Using biodegradable mulch that is more than six months old, or is exposed to extended periods of photo-degradation before planting the crop, will also accelerate biodegradation and lead to bed cover losses and increased weed density.

Uncropped plots at the Research Facility provided good bed cover for up to three months, which is consistent with on farm results. On a number of occasions during on-farm trials, mulch was laid for up to eight weeks prior to planting. This weakened the integrity of the films, resulting in significant damage during planting and crop maintenance operations. The cropped plots at the research facility were planted with capsicum six weeks after mulch was laid and provided good cover for 18 weeks. If planted within a reasonable time of laying mulch and providing mulch integrity is not overly compromised by laying or planting equipment, animals or workers' activities, then Mater-Bi® is likely to provide at least four months acceptable bed cover.

The loss of bed cover tended to lead to more weeds in the Mater-Bi® treatments than the polyethylene, especially where mulch had been damaged early on (through difficult soil, or the laying and planting operations). These differences in weed population were not substantial and seemed to reduce as the crop matured.

On two farms in 2010, age of mulch and extended sun exposure led to larger plant holes and early loss of integrity. This resulted in higher weed populations towards the end of the cropping cycle when compared to polyethylene. A substantial loss of integrity and bed cover relatively early in the trial potentially results in increased evaporation losses. Permeability to soil moisture movement (at the microscopic level) of Mater-Bi® probably also increases as the mulch deteriorates. While permeability was not measured directly, the brittleness and tear strength rating provides some indication of mulch deterioration and weakening, despite the inherent variability and subjectiveness of this assessment technique.

Biodegradability

Integrity of the buried edge of the mulch indicates biodegradation of the mulch. However, since edge integrity may also be lost through mechanical means, especially during laying, the assessment was qualified with a note on the brittleness of buried mulch edges. This combines a rating of gradual change in mulch integrity with an absent/present rating of whether or not the mulch shatters and disintegrates when touched.

The first signs of brittleness can be as early as three to four weeks after laying Mater-Bi®, with most observations showing mulch edges deteriorating from eight weeks onwards. After four to five months in the field there is usually substantial biodegradation of buried mulch edge.

Irrigation regime, possibly also soil type and degree of crop shading, tended to impact on biodegradability, with mulch edges in well-irrigated melons and cucumbers grown on a light alluvial soil showing the highest rate of biodegradation. Biodegradation was delayed where the soil in contact with mulch was dry, as would be expected.

Technical considerations and handling

Biodegradable mulch films should be stored in a dark, dry place and used as quickly as possible to prevent accelerated photodegradation after exposure to sunlight. For best performance, biodegradable mulches should be used within six months on manufacture. It is preferable to lay films no more than four weeks prior to transplanting. Results on-farm and on the research facility indicate up to eight weeks can pass between laying and transplanting, however delays of more than four weeks greatly increase the risk of losing bed cover. This time allows weed seeds to germinate and die below the film. Early development of the crop canopy reduces the films exposure to sunlight and therefore decelerates degradation. Thicker gauges, such as 15 to 25 micron, of biodegradable mulch film will be better suited to soils that are cloddy or have sharp gravel or stones.

Mater-Bi® biodegradable mulch films are capable of being laid using commercial equipment, with no or little adjustment to equipment or speed during laying. In some cases, it was reported that films needed to be laid with slightly less tension than would be used to lay polyethylene, but in most cases this was not required. Equipment that use rollers to press the mulch into the soil surface may need light buffing to remove soil and rust, which can create small holes in biodegradable mulch. These small points of damage could become enlarged as the season progresses. During laying and planting operations, it is important to remain vigilant, as biodegradable mulch film are more fragile and prone to tearing than polyethylene. We recommend irrigating beds prior to transplanting. This prevents the wheels pressing sharp clods of soil or stones into the mulch, damaging it.

Cost-benefit considerations

During the writing of this report, biodegradable mulch film costs were $160 more expensive per roll than the cost of using and disposing of polyethylene. However, prices are likely to fluctuating with the exchange rate, while the resin continues to be imported from Italy. The cost of polyethylene removal and disposal can vary widely depending on labour costs associated with lifting and removing mulch from the field, cost of transport to and fees charged by the disposal site. A general estimate is to add at least 50% to the polyethylene purchase price for mulch disposal. An added benefit is the ease with which Mater-Bi® is dealt with at the end of a long and perhaps stressful growing season compared to polyethylene, especially in weedy and nutgrass infested paddocks.

As a business decision, most growers cannot justify the up front cost of Mater-Bi® when compared to polyethylene, especially during difficult seasons with low market returns for produce. Until the environment around use of polyethylene changes, most vegetable growers are likely to continue to use polyethylene despite the obvious advantages of biodegradable plastic mulch films.

An increase in the biodegradable mulch film adoption rate will be influenced by the following:

- The price of polyethylene increases substantially,
- The absence of responsible disposal options and increased disposal costs,
- A reduction in the price of biodegradable mulch, either through advancement of technology and/or competition in the market,
- The continuation of financial subsidies for using sustainable products such as biodegradable mulch film.
- The development of a white biodegradable mulch film with the same qualities as the black product evaluated in this project.

A small and slowly increasing proportion of growers have decided the up front cost of biodegradable mulch film is offset by the benefits of using a product with no end of crop disposal issues and lower end of crop costs. Nutgrass infestations play a role in this business decision for some, as growers do not have to hire contactors to collect small shattered pieces of plastic from the soil. Business' approach to sustainability issues, and how well the product fits into the vegetable production systems of more innovative growers that are seeking to improve their environmental credentials, also play a role in increasing adoption.

Further work

Growers have noticed a definite improvement in biodegradable mulch technology over the years of this project and those previous. The quality and desirable traits of biodegradable mulch will continue to be enhanced as this technology and techniques of manufacture are perfected. Over time, other companies will recognise and potentially enter this market, adding to the expertise and increasing competition. During this project, we have focused on the Mater-Bi® product manufactured by Novamont, because it appears to the most advanced. Novamont have worked closely with us to constantly enhance the desirable qualities and understand the needs of growers.

A confusing factor is the emergence of products marketed variously as biodegradable, oxodegradable or degradable, becoming available as replacements for conventional polyethylene mulch films. A critical review by Kyrikou and Briassoulis (2007) tackles this issue at some depth, explaining the differences associated with polymers that are biodegradable, bioerodable, hyrobiodegradable, photodegradable, controlled degradable or only partially biodegradable, in relationship to polyethylene products.

The Plastics and Chemicals Industry Association has also acknowledged this problem by initiating a product stewardship process to demonstrate self regulation and address the problem of false and misleading information creating consumer confusion (PACIA 2007). Until such time as these products can be certified as biodegradable similar to *European Standard EN13432 "compostable and biodegradable"* and *Australian Standard AS 4736-2006 "Biodegradable plastics suitable for composting and other microbial treatment"*, growers are reluctant to use them. So far, we have not been given conclusive evidence that these products are 100% biodegradable.

References

Dodd, I., He, J., Turnbull, C. G., Lee, S. and Critchley, C., 2000, "The influence of supra-optimal root zone temperatures on growth and stomatal conductance in *Capsicum annuum* L.", *Journal of Experimental Botany*, 51, 343, pp 239-249

Kyrikou, I. and Briassoulis, D., 2007, Biodegradation of Agricultural Plastic films: A Critical Review, Journal of Polymers and the Environment 15, pp 125-150

Meurant, N,. Wright, R., Olsen, J, and Fullelove, G., 1999*, Capsicum and Chilli Information Kit*, Queensland Horticulture Institute Department of Primary Industries (now DAFF), Brisbane, Queensland

Olsen, J. K., 2001, *Horticulture Australia Limited Project VG97021: Investigation of plastic mulch alternative for intensive vegetable production*, Queensland Department of Agriculture, Forestry and Fisheries (formerly Queensland Department of Primary Industries), Brisbane, Queensland, www.horticulture.com.au

Olsen, J.K. and. Gounder, R.K., 2001, Alternatives to polyethylene mulch film – a field assessment of transported materials in Capsicum. *Australian Journal of Experimental Agriculture,* 41, pp 93-103

Product and Chemical Industries Association, 2007, *Using degradable plastics in Australia: A product stewardship guide and commitment*, , Australian Government Department of the Environment and Water Resources, Canberra, Australian Capital Territory, http://www.pacia.org.au

Rogers, G., Little, S. and Giggins, B., 2006, *Horticulture Australia Limited Project VX01033:– Establishment of no-till, permanent bed, vegetable production systems in major vegetable production systems in the major vegetable growing regions in Australia*, Applied Horticultural Research, Bundeena, New South Wales, http://www.ahr.com.au

Rutgers, R., 2003, *Horticulture Australia Limited Project VG95031: – Development and assessment of low cost biodegradable mulch films*, University of Queensland, Queensland Department of Agriculture, Forestry and Fisheries (formerly Queensland Department of Primary Industries) and CRC for Food and Packaging, Brisbane, Queensland, www.horticulture.com.au

Acknowledgements

Jamie and Melita Jurgens	Vee Jay's Tomatoes
Dale and Lionel Williams	Euri-Gold Farms
Rodney Emerick	Mulgowie Farming Company
Andrew Sipple	Black Earth Cotton Co.
Carl and Trudy Walker	Phantom Produce
Laurie Land	
Campbell Turner	
Russel and Simon Chapman	
Raymond Totorica	
Trevor Gerhardt	
Ross Wright	
Otto Cath	
Tom McConchie and Joe Gagliardi	Australian Bio-Plastics
Chris Minogue	Weed Gunnel
Peter Halley	University of Queensland
Joanne Grey and Sian Fullerton	QDAFF
Siva Subramaniam	QDAFF
Craig Henderson	QDAFF
Anna Geddes	Growcom
Karl Murdoch	Whitsunday Regional Council

Appendix I

Cost Analysis of Biodegradable vs. Polyethylene Mulch Films

Developed as part of MT09068 – Comparison of biodegradable mulch products to polyethylene in irrigated vegetable, tomato and melon crops

BOWEN GUMLU GROWERS ASSOCIATION INC. *Collectively we grow*

HAL Horticulture Australia

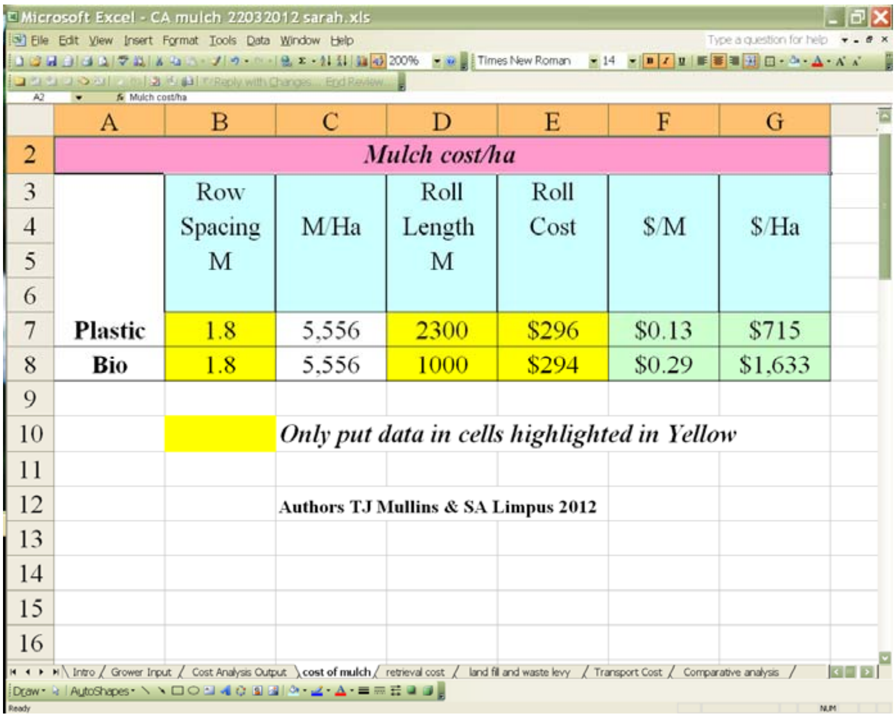
Novamont

Queensland Government

Created March 2012 by T.J. Mullins and S.A. Limpus

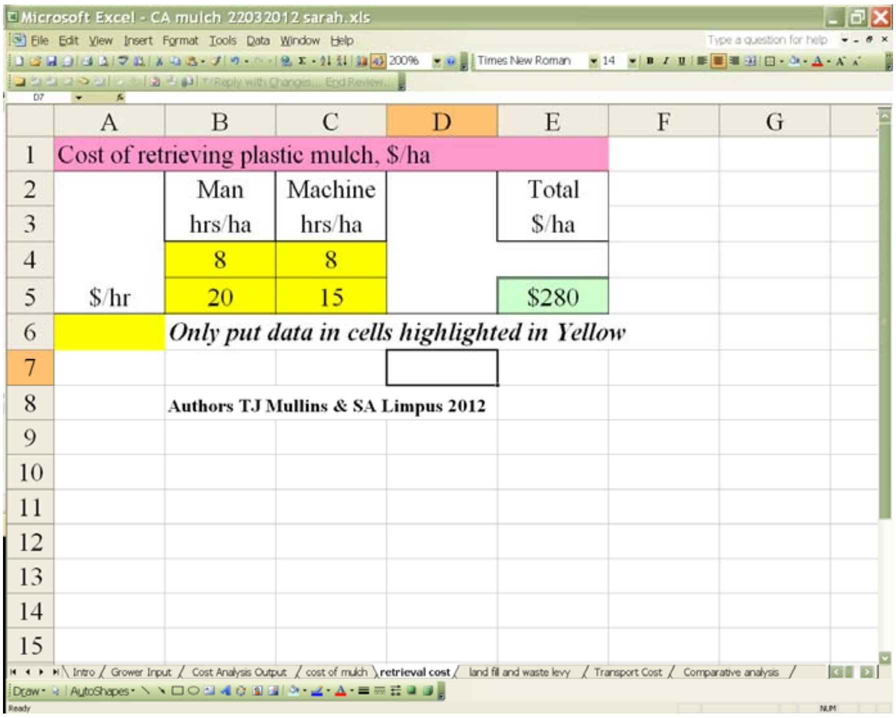
Contact the Bowen Research Facility on 07 4761 4000 for more information

Introductory page of cost analysis tool for comparing the use of polyethylene and biodegradable mulch films to help assist growers in decision making.



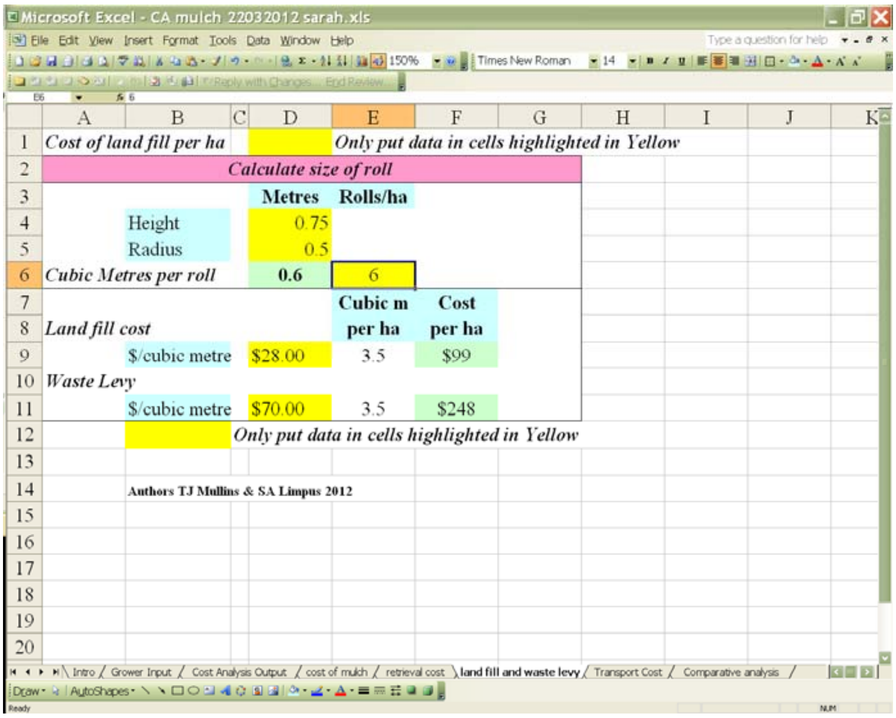
	A	B	C	D	E	F	G
2	*Mulch cost/ha*						
3–6		Row Spacing M	M/Ha	Roll Length M	Roll Cost	$/M	$/Ha
7	**Plastic**	1.8	5,556	2300	$296	$0.13	$715
8	**Bio**	1.8	5,556	1000	$294	$0.29	$1,633
10			*Only put data in cells highlighted in Yellow*				
12			**Authors TJ Mullins & SA Limpus 2012**				

Step 1: Insert cropping and mulch costs into yellow cells only to calculate $/meter and $/hectare for both polyethylene and biodegradable mulch films.



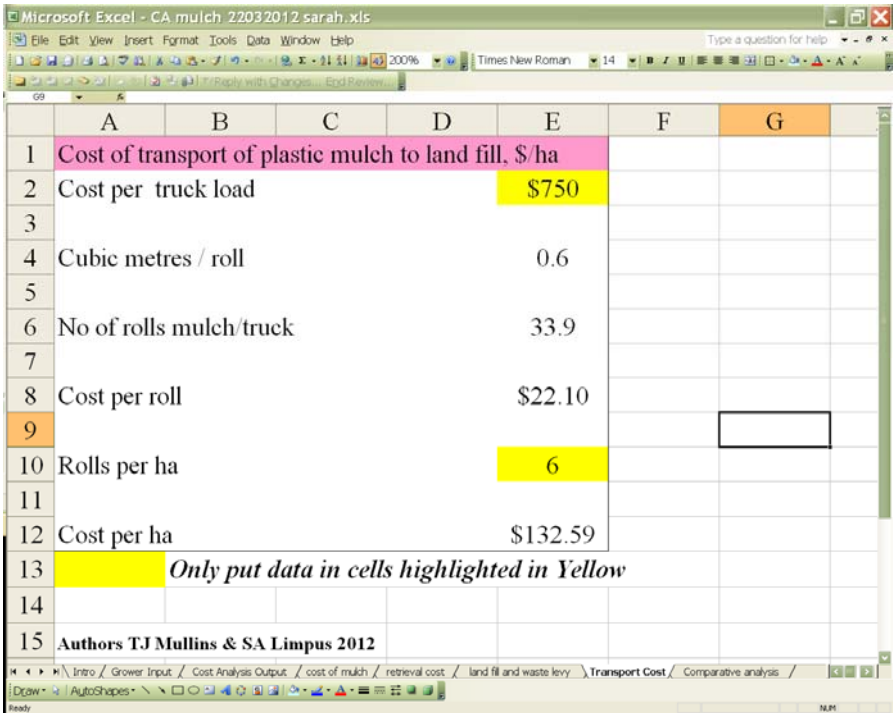
	A	B	C	D	E
1	Cost of retrieving plastic mulch, $/ha				
2–3		Man hrs/ha	Machine hrs/ha		Total $/ha
4		8	8		
5	$/hr	20	15		$280
6		*Only put data in cells highlighted in Yellow*			
8		**Authors TJ Mullins & SA Limpus 2012**			

Step 2: Insert the costs of retrieving polyethylene mulch films after cropping in the yellow boxes to calculate cost/hectare.



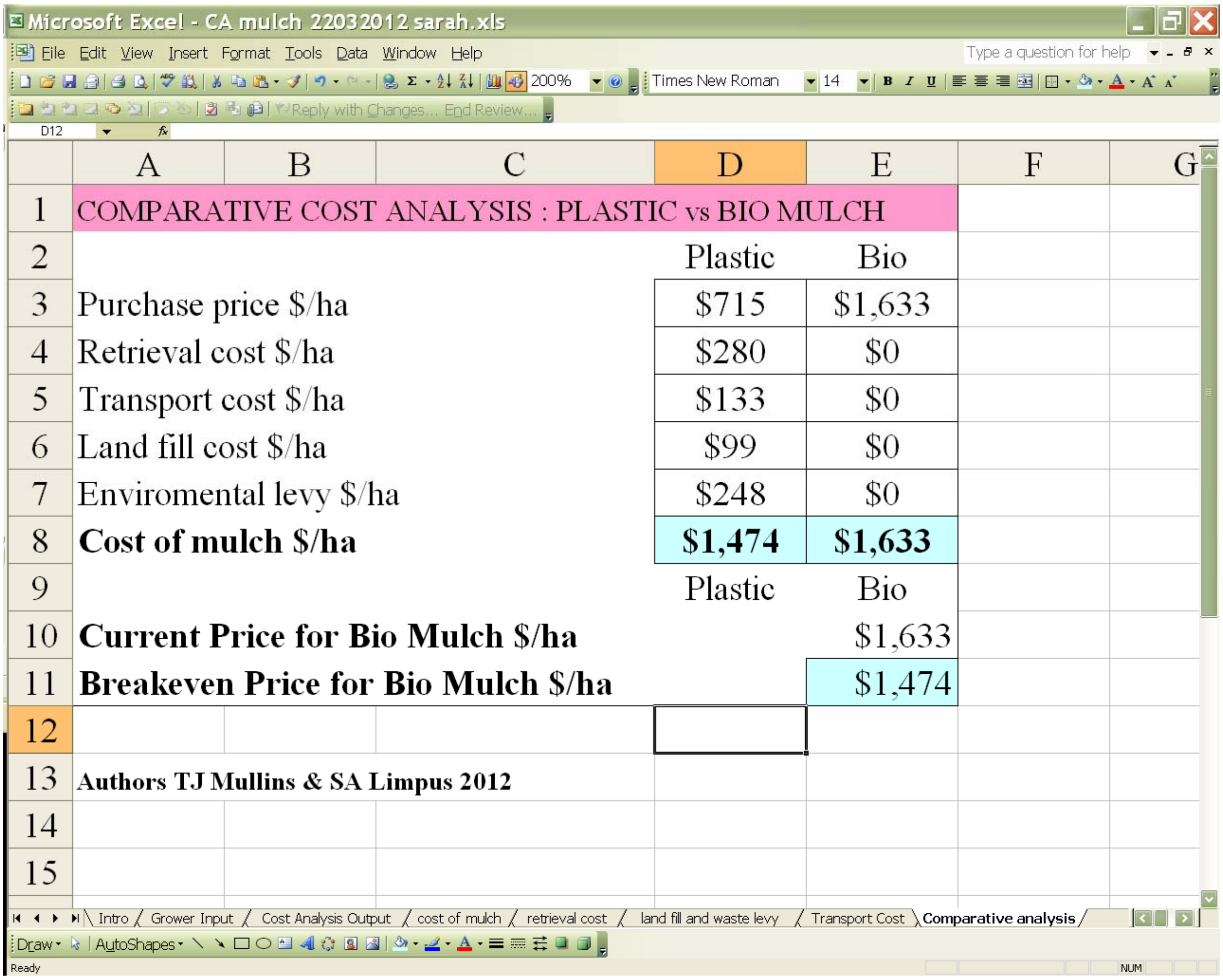
1	*Cost of land fill per ha*			*Only put data in cells highlighted in Yellow*		
2		*Calculate size of roll*				
3			**Metres**	**Rolls/ha**		
4		Height	0.75			
5		Radius	0.5			
6	*Cubic Metres per roll*		**0.6**	6		
7				**Cubic m**	**Cost**	
8	*Land fill cost*			**per ha**	**per ha**	
9		$/cubic metre	$28.00	3.5	$99	
10	*Waste Levy*					
11		$/cubic metre	$70.00	3.5	$248	
12			*Only put data in cells highlighted in Yellow*			
14		**Authors TJ Mullins & SA Limpus 2012**				

Step 3: To calculate the cost of transport and disposing at land fill, insert details on the size of the mulch rolls and the costs of transportation/cubic meter.



1	Cost of transport of plastic mulch to land fill, $/ha	
2	Cost per truck load	$750
4	Cubic metres / roll	0.6
6	No of rolls mulch/truck	33.9
8	Cost per roll	$22.10
10	Rolls per ha	6
12	Cost per ha	$132.59
13	*Only put data in cells highlighted in Yellow*	
15	**Authors TJ Mullins & SA Limpus 2012**	

Step 4: Insert the cost of transportation/truck load into the yellow box and the number.


Microsoft Excel - CA mulch 22032012 sarah.xls

COMPARATIVE COST ANALYSIS : PLASTIC vs BIO MULCH		
	Plastic	Bio
Purchase price $/ha	$715	$1,633
Retrieval cost $/ha	$280	$0
Transport cost $/ha	$133	$0
Land fill cost $/ha	$99	$0
Enviromental levy $/ha	$248	$0
Cost of mulch $/ha	**$1,474**	**$1,633**
	Plastic	Bio
Current Price for Bio Mulch $/ha		$1,633
Breakeven Price for Bio Mulch $/ha		$1,474
Authors TJ Mullins & SA Limpus 2012		

Intro / Grower Input / Cost Analysis Output / cost of mulch / retrieval cost / land fill and waste levy / Transport Cost / Comparative analysis

Calculated cost analysis: The spreadsheet calculates all the entered data into this sheet to give a cost analysis of using and disposing of polyethylene compared to biodegradable mulch films.