Field Crops Research 184 (2015) 91–103

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Soil temperature and soil water potential under thin oxodegradable plastic film impact on cotton crop establishment and yield

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ARTICLE INFO

Article history:
Received 10 June 2015
Received in revised form 7 September 2015
Accepted 7 September 2015
Available online 26 September 2015

Keywords:
Plastic mulch
Emergence
Lint yield
Fibre quality
Modelling
Cold days
Frost

ABSTRACT

Field experiments were undertaken to determine the effect of oxodegradable thin film on cotton establishment and lint yield. It was hypothesised that the use of thin oxodegradable plastic film would increase soil temperature and conserve seedbed water possibly reducing the risk in early planting, while not reducing lint yield or fibre quality of cotton. Experiments were conducted near Narrabri, NSW Australia during the 2010, 2012–2014 and the 2012 and 2013 seasons near Griffith, a cooler region in southern NSW with three or four thin oxodegradable plastic films with different formulations and break down rates being compared with a bare soil treatment. Planting depth soil temperature and soil water potential was monitored at three hourly intervals. Soil temperatures were elevated by 2–4 °C under the film compared with the bare soil that resulted in earlier (2–4 days) emergence of cotton under the film compared with bare soil. Soil also remained wetter beneath the film. Two films began to degrade at the time when cotton seedlings emerged (10–20 days), resulting in greater seedling survival (2–7 vs 12 plants/m). Seedlings were unable to penetrate four films on emergence and did not survive. When these films were slit to allow seedling growth, survival depended on subsequent environmental conditions; whether overcast/sunny or cool/warm conditions occurred. Using film that had been slotted prior to being laid in the field also increased soil temperature and conserved seedbed water. This enhanced (50–80%) emergence and survival of emerged seedlings, and overcame the need to slit film in the field.

A climate analysis and simulation study was also conducted to determine the benefit or otherwise of thin film and early planting over a longer-term than is possible from field studies. Results for both sites indicated that the earlier the planting date (August/September), compared to a “normal” planting date (October) there was a greater the chance of cold (6.5 vs 2.5 days) and frost (2.5 vs 0 days) being experienced, which resulted in lower or no lint yield. Lint yield tended to be greater (3200 vs 2800 kg lint/ha), although not significantly so, with thin film compared with bare soil. Fibre quality parameters were not affected by the use of thin film. All surface film had degraded by the end of the season posing no risk of contamination of the lint. Film below ground did remained intact, but this does not pose a contamination risk for the cotton lint at harvest. No plastic film was detected in ginned cotton after being machine harvested at both sites.

There was no significant benefit in lint yield due to thin film, while all fibre quality parameters made base grade. Long-term simulation of early planting, with and without thin film, indicated that lint yield was variable with no consistent benefit due to the presence of thin film for the locations simulated. There is still a risk of cold weather or frost occurring when planting early with thin film that growers need to consider. In practical terms it is anticipated that growers would potentially only plant 5% of their area early depending on the seasonal forecast.

1. Introduction

The use of mulches in agriculture is not a new concept as straw, leaves, gravel and composts have been used for centuries (Lightfoot, 1996). The recent development of new products such as plastic films offers new opportunities in the use of mulches. A major issue

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http://dx.doi.org/10.1016/j.fcr.2015.09.009
0378-4290/

with using plastic film as a mulch has been the problem of disposal as it did not degrade (Shogren, 2000), however, new formulations which degrade to water and carbon dioxide overcome this limitation. Also, there is potential environmental pollution from plastic mulches, which may have long-term consequences for soil conditions and human health (Chen et al., 2013). The degradation and potential pollution from plastic mulch depends on the type of film and the conditions under which it is deployed (Kyrikou and Briassoulis, 2007). The newer oxodegradable film reduces the amount of plastic mulch currently being disposed in land-fill (Dai and Dong, 2014).

Thin plastic film has been used to increase soil temperature, conserve soil water and to improve crop establishment for crops such as maize (Zhou et al., 2009; Zhang et al., 2011; Liu et al., 2009, 2013), vegetables (Cavero et al., 1996; Waterer, 2010; Yaghi et al., 2013; Qin et al., 2014) and cotton (Stathakos et al., 2006; Dai and Dong, 2014).

Plastic mulch has previously been studied locally in Fusarium and black root rot control (Anderson et al., 2006; Nehl et al., 2004). During this time period oxodegradable plastic was not available and the plastic was considered to be a contamination risk to cotton fibre which results in significant penalties to the grower and the industry's reputation. However, film can now be manufactured to degrade at a known rate so that emerging plants are not impeded (Kasirajan and Ngouajio, 2012), which presents an opportunity to examine new oxodegradable polymer films in cotton systems. It is postulated that using oxodegradable polymer films may allow earlier planting, improve crop establishment, improve early season growth, enhance water and nutrient use efficiency and reduce weed competition during crop establishment; the end result being increased lint yields. Benefits may be greater in cooler regions through elevation of soil temperatures and conservation of seedbed water enabling manipulation of season length, planting date or timing of harvest.

Thin films can induce diurnal effects on air and soil temperature (levels higher during the day and lower during the night) and carbon dioxide levels beneath the film when compared to a bare soil. These effects can be altered by the various additives that affect the film's reflectivity, absorption and water passage through the film (Tarara, 2000). If the film is impermeable to water, evaporation from soil is reduced altering evapotranspiration (ET). There can be an advantage in rainfed situations by conserving available water and improved crop water use efficiency (WUE, kg lint/ha/mm). This can assist with reducing seasonal variability associated with rainfall (Bu et al., 2013; Wang et al., 2009; Zhou et al., 2012). Under irrigation there is potential to reduce water use (ET) and increase WUE (Yaghi et al., 2013; Zhang et al., 2013), which will be attractive as the price of water increases or security of access to and supply of water decreases. Also, it may be possible to harvest rain water from the film covered areas (Li et al., 2008; Ruidisch et al., 2013). However, consideration would need to be given to field layout for runoff and erosion potential due to slope. Recently a biodegradable spray on mulch was developed as an alternative for thin plastic film for potential use in horticulture (Immirzi et al., 2009). This would allow the use of the product under stubble retained situations, when planting into wheat stubble for example.

This research was undertaken to examine the hypothesis that the use of thin oxodegradable films would improve cotton establishment in cooler cotton regions of Australia, conserve seedbed water and not decrease lint yield or fibre quality of cotton. The effect of early planting in conjunction with the use of thin film in two cotton regions of Australia was also examined using a cotton simulation model. The objective of this part of the study was to determine if thin film would reduce the risk of early planting over a longer time frame than is possible from field experiments and whether a crop would grow to maturity if it experienced periods of cold (air $T_{min} < 11\,^{\circ}C$) or frost (air $T_{min} < 2\,^{\circ}C$) at some time after emergence.

2. Materials and methods

Details of field experiments for each season at each site are summarised in Table 1. The film thickness was nine microns for film A–C and G and ten microns for film D, E, F1 and F2. Normal

Table 1
Site and experimental details for thin film experiments 2009–2014. All experiments were on 1 m row spacing.

Site	Season	Treatments	Planted	Film slit	Irrigation	Plots	Cultivar
ACRI Expt 1	2009/2010	Control film: A–D (4 Reps)	5/11/2009	10/11/2009	1/10/2009 21/10/2009 4/12/2009 22/12/2009 20/1/2010 29/1/2010 5/3/2010	5 rows by 10 m	Sicot 71 BRF
ACRI Expt 2	2010/2011	Controlfilm: E, F1, G (3 Reps)	21/10/2010		2/11/2010	5 rows by 5 m	Sicot 71 BRF
ACRI Expt 3	2012/2013	Control film: F1, F2 (3 Reps)	24/9/2012 2/10/2012 18/10/2012	3/10/2012 14/10/2012 1/11/2012	5/10/2012 2/11/2012 13/12/2012 21/12/2012 7/1/2013 17/1/2013 21/2/2013 20/3/2013	3 rows by 5 m	Sicot 71 BRF
ACRI Expt 4	2013/2014	Control film: F2 Spray-on (20% Na alginate soln.) (4 Reps)	12/9/2013 25/9/2013 3/10/2013	8/10/2013 18/10/2013 18/10/2013	13/9/2013 13/9/2013 4/10/2013 6/1/2014	4 rows by 7 m	Sicot 71 BRF
Expt G1	2012/2013	Control film: F1, F2 (4 Reps)	3/10/2012	17/10/2012 23/10/2012	7/10/2012 12/10/2012	3 rows by 5 m	Sicot 71 BRF
Expt G2	2013/2014	Control film: F2 Spray-on (40% Na Alginate soln.) (3 Reps)	17/9/2013 30/9/2013 8/10/2013	Used slotted film	22/9/2013 3/10/2013 9/10/2013	3 × 200 cm beds by 10 m Beds	Sicot 74 BRF