The potential for thin biodegradable film in the Australian cotton industry

Michael Braunack and Jo Price

CSIRO, Plant Industry, Cotton Community Catchments CRC, Locked Bag 59, Narrabri, NSW 2390. michael.braunack@csiro.au and jo.price@csiro.au

Abstract
The use of thin plastic film potentially offers the opportunity to plant cotton earlier, due to increased soil moisture and soil temperature. This may assist regions to obtain successful plant stands earlier where cool conditions reduce germination and emergence; such as southern NSW. Season length may also be increased due to the ability to plant earlier, which may increase yield potential. This paper presents a preliminary study on the effect of thin biodegradable plastic films on soil water and temperature on cotton emergence, whether cotton would penetrate the film and the breakdown of the film over time. Field experiments were conducted at the Australian Cotton Research Institute (ACRI). The thin film elevated soil temperature and conserved water from planting to emergence. Plant emergence was earlier and more uniform under the film compared with the bare soil control. However cotton plants were not able to penetrate the film and died, so yield could not be assessed. No film remained on the soil surface at harvest, so not presenting a contamination problem.

Key Words
Soil temperature, soil moisture, emergence

Introduction
The use of mulches in agriculture is not a new concept as straw, leaves and composts have been used for centuries. The recent development of new products such as plastic films offers new opportunities in the use of mulches that are currently used in Spain and China. A major issue with using plastic film has been the problem of disposal as it did not degrade. New formulations are now available which are biodegradable and overcome this limitation. The biodegradable film breaks down into carbon dioxide and water and obviates the need to retrieve and dispose of plastic as in the more traditional plastic mulch systems. Contamination of cotton fibre, especially from plastic, results in significant penalties to the grower and the industry's reputation as a whole, so the biodegradable film potentially resolves the problem. Film can be manufactured to degrade at a known rate so that emerging plants are not impeded. The use of thin plastic film offers the opportunity to plant earlier, due to increased soil moisture and soil temperature, which may assist the industry in cooler areas. Season length may also be increased due to the ability to plant earlier, which may increase yield potential or allow for crop compensation as a result of insect or disease pressure. Studies in California determined that soil temperature was elevated and soil moisture was conserved under applied plastic mulch resulting in earlier emergence compared with non-mulched plots (Fereres and Goldhamer 1991). This resulted in a longer season and greater final yields from the mulched plots compared with the non-mulched. Using transplanted cotton plants Dong et al (2007) found that plastic mulch enhanced plant growth, which translated into higher yield, compared with non-mulched plots. Soil temperature was greater in the mulched plots which promoted early growth compared with the non-mulched plots.

This paper presents a preliminary study of planting date on the effect of thin biodegradable plastic films on soil water and temperature on cotton emergence, whether cotton would penetrate the film and the breakdown of the film over time.

Methods
A field experiment was established at ACRI, Narrabri ($149^0 40'$ E, 30^0 10' S) NSW, Australia on a grey self mulching vertosol (Isbell, 1996). Nitrogen fertiliser was applied as anhydrous ammonia pre-planting at the rate of 180 kg N/ha. Weeds and insects were managed as per Bollgard® II Roundup Ready Flex protocol and plots irrigated as required. Cotton was planted on 15 September, 28 September and 20 October 2011 to provide a range of soil water and soil temperatures for cotton germination and emergence. Three films (542, 544, and 557, Integrated Packaging) of different formulation and rate of breakdown were placed over three rows by 5 m.

The maximum and minimum soil temperature at the planting depth (5 cm), on the soil surface and in the head space under the film was monitored with J-type thermocouples and logged 3 hourly with a Datataker DT 50 logger. Soil water was measured daily at 09:00 using GBLite gypsum blocks. Plots were monitored daily to determine emergence and final establishment and whether cotton seedlings had penetrated the film, and for changes in the film, such as colour and appearance of lateral tears. It was not possible to undertake replicated measures of temperature or moisture due to equipment limitations.

Results

Soil surface and head space minimum and maximum temperatures for the first planting were between 20-25 and 25-30 °C during the emergence phase respectively (Fig 1a), with the minimum and maximum soil temperature at the planting depth was around 16-20 and 20-25 °C for the bare and film covered treatments (Fig 1b). The film covered plots were warmer than the bare soil at the planting depth. Logger failure restricted soil water measurement to the film plots only and indicated that sufficient water was available for emergence (Fig 1c).

For the second planting soil surface temperatures were lower than the head space temperatures as was bare soil temperature compared with the film covered plots and both increased with time (Fig 2 a, b). Soil under the film was wetter than that on the bare plots and did not dry to the same extent as the bare plots (Fig 2c). Soil surface temperatures were lower compared with the head space temperature under the third planting (Fig 3a). Soil temperatures were higher under the film plots compared with the bare plots and lower than surface or head space temperatures (Fig 3b). Soil moisture dried more on the bare plots compared with the film covered plots, until rainfall on day 7 when soil moisture became similar under both treatments (Fig 3c). Soil moisture under the bare and thin film treatments always remained in the readily available range.
Plant establishment was affected by the combination of temperature under the film and soil moisture, which resulted in desiccation and death of plants with the last two planting dates (Fig 4).

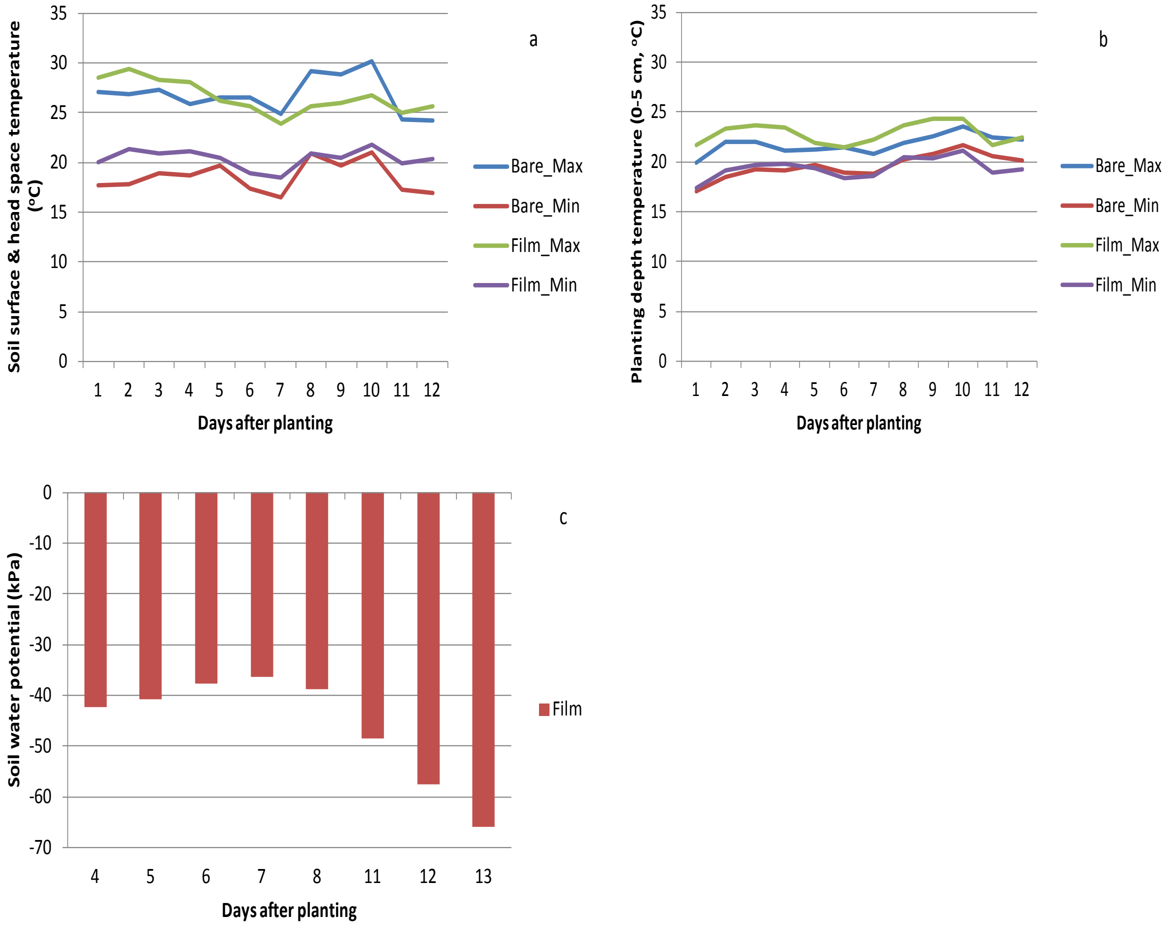

Figure 1, Planting 1, 15 Sep 2011 (a) Max & min soil surface and head space temperature (°C), (b) Max & min soil temperature (5 cm) at planting depth and (c) Soil water potential (0-5cm) at planting depth on bare and film covered plots (bars are standard error of the mean).

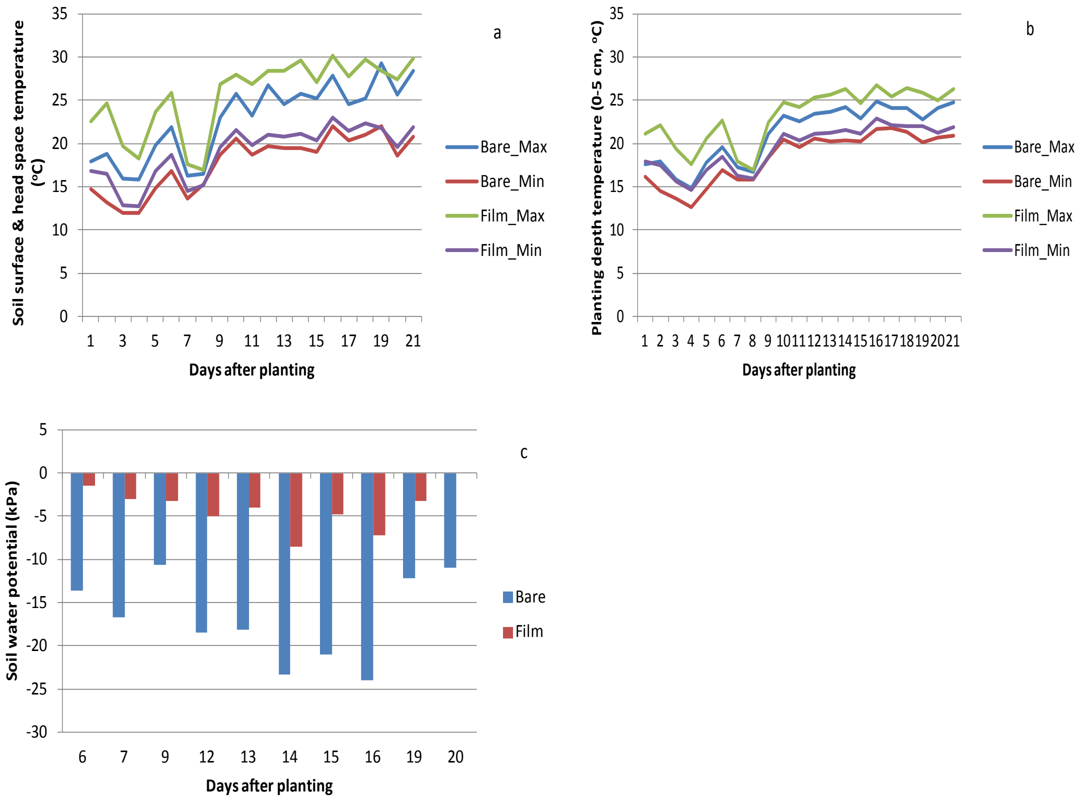

Figure 2, Planting 2, 28 Sep 2011 (a) Max & min soil surface and head space temperature (^{o}C), (b) Max & min soil temperature (5 cm) at planting depth and (c) Soil water potential (0-5cm) at planting depth on bare and film covered plots (bars are standard error of the mean).

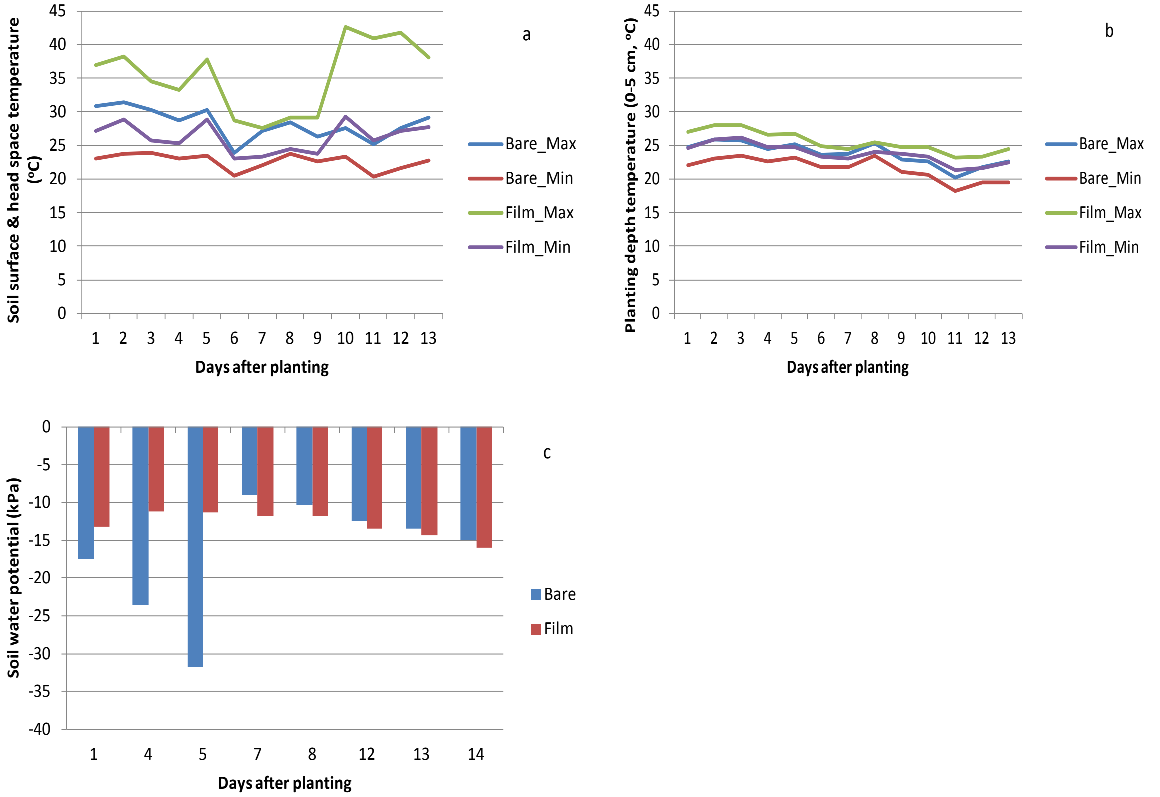

Figure 3, Planting 3, 20 Oct 2011 (a) Max & min soil surface and head space temperature (^{o}C), (b) Max & min soil temperature (5 cm) at planting depth and (c) Soil water potential (0-5cm) at planting depth on bare and film covered plots (bars are standard error of the mean).

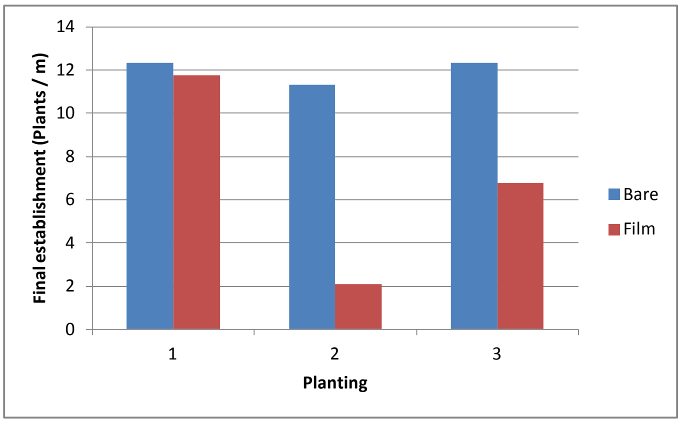

Fig 4 Final establishment for each planting date (1= 15 Sep 2011, 2= 28 Sep 2011 and 3= 20 Oct 2011)

Discussion

The main issue from prior experiments is the fact that cotton seedlings did not penetrate any of the thin films and as a result the crop did not survive. It has only been in this experiment with a new film formulation, which began to break down (approximately 20 days) as the cotton was emerging, that plants have survived. The critical soil temperature (minimum) for establishment of cotton is around 15^{o}C (OGTR 2008). The average soil temperatures were similar or higher than this, which promoted rapid germination and emergence. The head space temperatures were also high and this contributed to cotton seedling mortality especially for the last planting, even after slitting the film above the seedlings. Humidity under the film was high as condensation was observed under the film and the combination of high temperature and humidity is the equivalent of ‘cooking’ the seedling. Similar observations have been made by Anderson et al (2006) and Nehl et al (2004) when investigating the use of plastic mulch to solarise the soil for Fusarium and Black Root Rot control. Soil temperature at the depth of planting remained higher under the thin film compared with the bare control for the period of monitoring. A similar result was obtained by Nehl et al (2004) on the same soil type during their solarisation studies. An interesting observation from this experiment was that after the film was slit, the emerged plants appeared healthy; a period of cool overcast conditions resulted in many plants not surviving due to chilling injury.

Conclusions

Thin polymer film promoted earlier and uniform emergence of cotton seedlings, however, the later plantings compromised seedling survival due to excessive heat build-up in the headspace prior to slitting the film. The exposed film degraded completely prior to harvest, which suggests that contamination of the harvested lint may not be an issue. More research is required to determine nitrogen and water management options under thin film and the interaction with pests and disease incidence.

References

Anderson CMT, Nehl DB, Allen SJ (2006) Severity factors in Fusarium wilt of cotton. Final Report CRDC Project DAN176C.

Fereres E, Goldhamer DA (1991) Plastic mulch increases cotton yield, reduces need for preseason irrigation. California Agriculture 45, 25-28.

Dong HZ, Li WJ, Tang W, Li ZH and Zhang DM (2007) Enhanced plant growth, development and fibre yield of Bt transgenic cotton by an integration of plastic mulching and seedling transplanting. Industrial Crops and products 26, 298-306.

Isbell RF (1996) The Australian soil classification. CSIRO, Collingwood, Australia 143p.

Nehl DB, Jhorar OP and Mondal AH (2004) Managing black root rot of cotton. Final report CRDC Project DAN153C.

OGTR (2008) The biology of *Gossypium hirsutum* L. and *Gossypium barbadense* L. (cotton), Australian Govt., Office of the Gene Technology Regulator, 87p.