The potential for biodegradable film to improve cotton establishment and conserve water in cool regions

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Executive Summary

Planting date experiments were conducted at the Australian Cotton Research Institute and on a cooperators property near Coleambally, NSW. Soil temperature and soil water potential were monitored in the seedbed; with soil temperature being elevated by 1-2 °C and the seedbed remaining moister for longer under the film compared to the bare soil. This resulted in earlier emergence under the film compared with the bare soil. Plant development was similar at the early planting under both treatments; however plant development was more rapid under the film with the later planting presumably due to growth occurring when air temperature was increasing. Lint yield was similar from the early plant between treatments and was significantly greater under the film at the later planting. Fibre quality was not affected by either treatment with all fibre meeting base grade at all planting dates.

A simulation study was undertaken to assess the risk of early planting at both ACRI and Griffith; this indicated that there is inherent risk in planting too early. This is due to the crop being exposed to cold and/or frost conditions, after early emergence, killing the plants. This would necessitate in deciding whether to replant. The simulation suggests that targeting the third week in September for planting is less risky than planting earlier. This will depend on the reason for considering an early plant in the first instance; be it to change a harvest time or to modify season length. At both sites a greater number of early crops failed under the film and there was little improvement in lint yield when the simulation included frost as a component. However, when frost is not considered in the simulation there was no significant response in lint yield although all crops continued to produce a harvestable yield and there was a small yield improvement at Griffith.

Soil temperature at planting depth was elevated and seedbed moisture was greater under the thin film and this promoted earlier and uniform emergence of cotton seedlings compared with the bare control. Slotted thin film allows seedlings to emerge, however the film should be applied at planting to ensure alignment of slots with the plant line.

There is still an inherent risk involved in early planting in cooler cotton regions; the simulation study indicated that although the crop emerged earlier under thin film, compared with bare soil, the seedlings when exposed to cold or frost do not survive to produce a harvestable yield. The issue is defining an early planting date that allows the emerged crop to consistently survive to maturity.

From a practical perspective applying film on hills would be simpler than applying on beds. The exposed film degraded completely, which minimises the potential for plastic contamination of lint at harvest.

Although there was variability in profile soil water during the periods of measurement the thin film maintained profile soil water at a higher level between irrigations and rainfall events for both irrigated and dryland cotton systems. Both the film and bare control were re-wet to a similar level by irrigation indicating the buried film did not impede irrigation from subbing across into the hills.

Materials and Methods

A field experiment with a wider spread of earlier planting dates compared with previous experiments was established at ACRI. The cotton cultivar Sicot 71BRF was planted on 12 September, 25 September, 3 October 2013 to provide a range of environmental conditions for cotton germination and emergence. Plots were three rows with four replicates of each treatment; control, F2 and a spray on mulch (sodium alginate 20 % solution in water). Crop management and measurements were the same as in previous experiments. The film was slit on 8 October and 18 October 2013 for planting 1 and planting 2 and 3, respectively.

Soil temperature and water potential was measured with MPS-2 water potential and temperature sensors (ceramic disc/thermistor). Plots were monitored daily to determine emergence, whether seedlings had penetrated the film, final establishment, and for changes in the film, such as colour and appearance of lateral tears and to decide when to slit the film if necessary.

A field experiment was established on a Red Sodosol (Isbell, 1996) near Coleambally (34°, 1' 52" S, 145°, 46' 31" E), southern NSW.

This field experiment was conducted on a growers' property near Coleambally, southern NSW to examine the effect of planting date on cotton emergence under thin film compared with a normal planting during the 2013/2014 season. A logger and sensors (same as for experiments at ACRI) were installed for each plant date at 0.1 m to monitor soil water potential and temperature to compare the effect of the film with normal planting on germination and emergence.

Fields were planted on 17 Sept., 30 Sept and 7 Oct 2013 with the cotton cultivar Sicot 74BRF with thin film F2 manually slotted prior to being mechanically laid on three beds the same day after planting. Three adjacent uncovered beds were used as controls. The film in this experiment was slotted along either side to facilitate emerging cotton to grow, if a seedling emerged under a slit it continued to grow, however if emergence occurred beneath a strip of film it did not develop further. A small strip (4 m) of the plant line of one control was also sprayed with the sodium alginate (40 % solution) for comparison with the film. The concentration was increased to increase the viscosity of the solution giving an increased wetting of the soil surface. Previous studies at Narrabri indicated that the 20 % solution did not appear to wet the soil.

Lint yield was determined from handpicking a 1 m length from four adjacent rows on two beds of each treatment on 30 April 2014.

Field experiments were conducted at Narrabri and Carrathool under irrigation and at Willow Tree under dryland conditions to examine soil profile water conservation under thin film. All experiments compared slotted thin film covered areas with uncovered areas as the control. Two films were used at Narrabri (F1 & F2), one at Carrathool (F1) laid in 6 alternate rows and across 24 rows at Narrabri and Carrathool, respectively while the experiment at Willow Tree was a demonstration site with no replication. Fields were planted on 29 September 2014, 22 September 2014, and 4 October 2014 at Narrabri, Carrathool and Willow Tree, respectively with the thin film being placed mechanically on the same day at Narrabri and Carrathool and five days after planting by hand at Willow Tree. Plots were the three rows (1m spacing) by 180 m and 500 m at Narrabri and Carrathool, respectively, while only two rows by 10 m at Willow Tree. Cultivar Sicot 74 BRF was planted on ridges at Narrabri and Carrathool with Sicot 71 BRF being planted on flat ground at Willow Tree.

treatment tended to coincide, while the temperature under the film was consistently greater for all planting dates until the film was slit when all treatments coincided (Fig 1). The minimum soil temperatures were elevated more under the film compared with the control or spray-on.

Soil water potentials were similar under all treatments up to the time that the film was slit (Fig 2). After the film was slit the soil under the film was drier than the other treatments between irrigations under planting 2 (Fig 2b) and for the third planting the control was drier (Fig 2c). Over the period of measurement the soil was drier under the film and spray-on for the first and under the film for the second planting date.

A greater number of plants emerged under the film for the first and second planting with more emerging from the spray-on for the third planting (Table 1) compared with the other treatments. The final number of emerged plants was greater for the second and third planting with fewer establishing at the first planting (Table 1). Plant height and node number were only assessed at 41 DAP where a significant difference was observed in plant height between planting dates and treatment and no significant difference in node number at that point in time (Table 1).

Table 1 Plant establishment, height and node number for each planting date for the ACRI experiment

Site	Plant Date	Treatment	Plants/m	Height (cm)[1]	Nodes[1]
ACRI Expt 4	12/9/2013	Control	5.8	3.9	4.8
		F 2	6.3	5.9	9.7
		Spray-on	6.6	3.4	5.2
	25/9/2013	Control	11.3	5.8	8.8
		F 2	13.6	8.5	10.8
		Spray-on	10.6	5.8	8.4
	3/10/2013	Control	10.6	7.4	9.0
		F 2	9.6	10.3	8.9
		Spray-on	11.1	7.0	9.2
		LSD (P<0.05)	2.2 (plant date)	0.7 (plant date & trt)	ns

[1] At 41 DAP

There was no significant difference between treatments at each planting date in lint yield at ACRI (Fig 5). Also, there was no significant difference in fibre quality between treatments for each planting date in fibre quality (Table 2) with all parameters meeting base grade.

Southern NSW

This experiment was conducted under commercial conditions on a grower's property to examine the effect of planting date on emergence and subsequent growth of cotton. The third planting was abandoned a week after planting due to excessive weed growth. Soil temperatures were greater under the film with little difference between the control and spray-on for all planting dates (Fig 3). The difference between the film and the other treatments was less at the third plant date (Fig 3c). The minimum soil temperature was greater under the film and slightly warmer under the spray-on compared with the control for all plant dates, with the exception of spray-on for the last plant date.

Soil water potential was similar under all treatments over the period from planting to emergence at all planting dates (Fig 4). As the crop developed (planting 3) there was a greater decrease in soil water under the control and spray-on compared with the film (Fig 4c); this site was abandoned due to heavy weed infestation under the film. Planting two was a dry plant and the seedbed wet up after the applied irrigation (Fig 4b), while the seedbed for target plant date (Table 3). Also, as the plant date is delayed lint yield decreases and crop failure is less likely (Table 3). At both sites a greater number of early crops failed under the film and there was little improvement in lint yield when the simulation included frost as a component. However, when frost is not considered in the simulation there was no significant response in lint yield although all crops continued to produce a harvestable yield and there was a small yield improvement at Griffith.

Profile moisture

The larger the amount of water (mm) in the profile the wetter that treatment is relative to the others. For the Narrabri site the bare treatment started wetter and continued to be so throughout the season compared to the film treatments (Fig. 8), which contrasts the observations from previous studies (Li et al. 2014, Qin et al. 2014, Dai and Dong, 2014). This was unexpected and most likely due to starting profile water varying across the experimental site. To determine whether the film at this site was effective in conserving profile water the data were made relative to the starting profile water under each treatment; this ensured that all treatments were at the same start value. Although there was variation in profile water during the season the soil profile tended to be wetter from 42-65 DAP under the films (Fig. 8) with treatments being similar until 93 DAP when film 1 began to breakdown and the profile started to dry down. After 109 DAP the soil profile under film 2 was wetter until monitoring ceased, while both film 2 and the bare treatment dried to similar points between irrigations (Fig. 8). Film 2 did not degrade as rapidly as film 1. Irrigations of the experiment occurred on 1, 24, 66, 83, 106, 116, 128 and 138 days after sowing (DAS).

Similarly for the Carrathool site, the thin film maintained the soil profile slightly wetter though the season compared to the bare treatment (Fig. 9). The bare treatment was wetter after the first irrigation as it took longer for irrigation water to move from the furrows to the plant line under the film. Both treatments came together after subsequent irrigations with the film maintaining a wetter soil profile between irrigations (Fig. 9).

For the dryland site at Willow Tree, the thin film maintained higher soil profile water compared to the bare treatment over the period of monitoring (Fig. 10). The peaks in soil moisture coincide with rainfall events during the season (data not shown) and suggest that the rainfall was effective in replenishing profile water under the film and the bare treatment with the film protecting profile water.

Seedbed surveys

The proportion of 4 mm aggregates (> 50 %) increased from site 3 to the ex-rice site at Kera (Fig 11). The level of smaller aggregates (< 20 %) decreased across all sites (Fig 11). From a wider survey of seedbeds across the region it was found that seedbeds contained a majority of aggregates of 4 mm (40 to 65 %) of followed by < 1 mm (14 to 30 %) (Fig 12). The proportion of aggregates between 1 to 2 mm varied with site (Fig 12). Generally all seedbeds contained a greater proportion of > 4 mm and < 1 mm aggregates compared with sizes between. When sampling seedbeds across an individual field (Daisy Lodge) variation is observed (Fig 13), which reflects differences in moisture conditions at planting and the previous history of the field; such as whether an old traffic furrow was encountered corresponding to the new planting hill. Where a large proportion of aggregates > 4mm occur there tends to be a corresponding decrease in smaller aggregates (Fig 13, sites 1-3 vs. sites 4-6).

shock or frost which may slow growth or at worst kill the seedlings requiring the crop to be re-planted. Another outcome is the seedlings may survive and continue to slowly develop compromising final yield. These situations have not been considered by previous studies as only one planting time has been considered. Soil temperature was elevated between 0.2 and 6.6 °C and at times was cooler by 4 °C (depending on seasonal conditions) and seedbed soil water was conserved under the thin film which resulted in better crop establishment and is consistent with other studies.

The climate analysis was an attempt to identify planting windows that would minimise the risk of cold or frost on emerging cotton thereby providing confidence in the technology. Reasons for altering the "normal" target planting window vary from altering a harvest date to avoid wet conditions, to extend season length in cooler areas to providing time to plant an increased area within a planting window. The climate analysis indicated that there is potentially a greater risk from encountering a period of cold or frost with an early plant in the areas analysed, which is confirmed by the number of failed crops. What is unknown, however, if a crop has emerged and is at a certain stage of development and exposed to cold or frost, will growth be slowed, will the crop continue to develop with no yield loss or will the crop be killed? A further simulation including the effect of frost indicates that if the crop is planted early and emerges early and is exposed to frost the crop will not survive to produce a harvestable yield. The long-term simulation was undertaken to determine the benefit or otherwise of using oxo-degradable thin film in the longer-term compared to the relatively short-term of field experiments Results indicated a highly variable response in lint yield due to whether the emerging seedlings were exposed to cold or frost conditions. It is speculated that the slight lint yield advantage of the thin film would be insufficient to warrant the cost of purchasing and applying the film. For example if the film cost a grower about A$300/ha a yield advantage of 180 kg/ha of lint would be required on current cotton price (2014). The simulation results indicated potential yield advantages less than this. The risk of crop failure was greatest with early planting and this should to be considered when making a decision to plant early. From a practical view a grower would not plant the whole farm using thin film, realistically it may be feasible to plant 5 % of the area early as a strategy to manage/manipulate picking time or circumvent the effect of cool soil temperatures. The simulation does not account for many practices which could minimise crop failure.

There was little difference in lint yield between the film and bare soil with early planting, which is mainly due to seedling exposure to cool/cloudy days after emergence checking growth. With a later planting the film resulted in s significantly greater yield compared with bare soil. It is speculated that this was due to the fact that the seedlings emerged earlier from the film and this growth advantage was maintained as temperatures were increasing and the crop was not exposed to cold days or frost, which is consistent with the simulation results. This is also borne out through node development; the fact that at the later planting the crop emerged earlier under film and maintained, on average a 2 node advantage, over the bare planted cotton. This effectively translates into about an extra one to two weeks of growth and hence greater lint yield. Fibre quality was not affected by the treatments, it is not expected that the presence of a thin film to influence quality as the crop is exposed to the elements after emergence through the film as in a normal bare plant situation.

The results indicate that the profile was wetter under the film at the point when monitoring ceased at Carrathool and Willow Tree, while the profile was wetter under film 2 and drier under film 1 at Narrabri due to film 1 breaking down earlier than film 2. In the dryland system the profile dried down to a greater extent under the bare treatment compared to the film which suggests that water extraction patterns may be different under the two treatments.

Seedbeds only act or perform as such for a period of between 7 to 14 days, which is a critical period in crop establishment and potential yield. Seedbed conditions varied across both experimental sites and a small number of sites examined across the region, due to

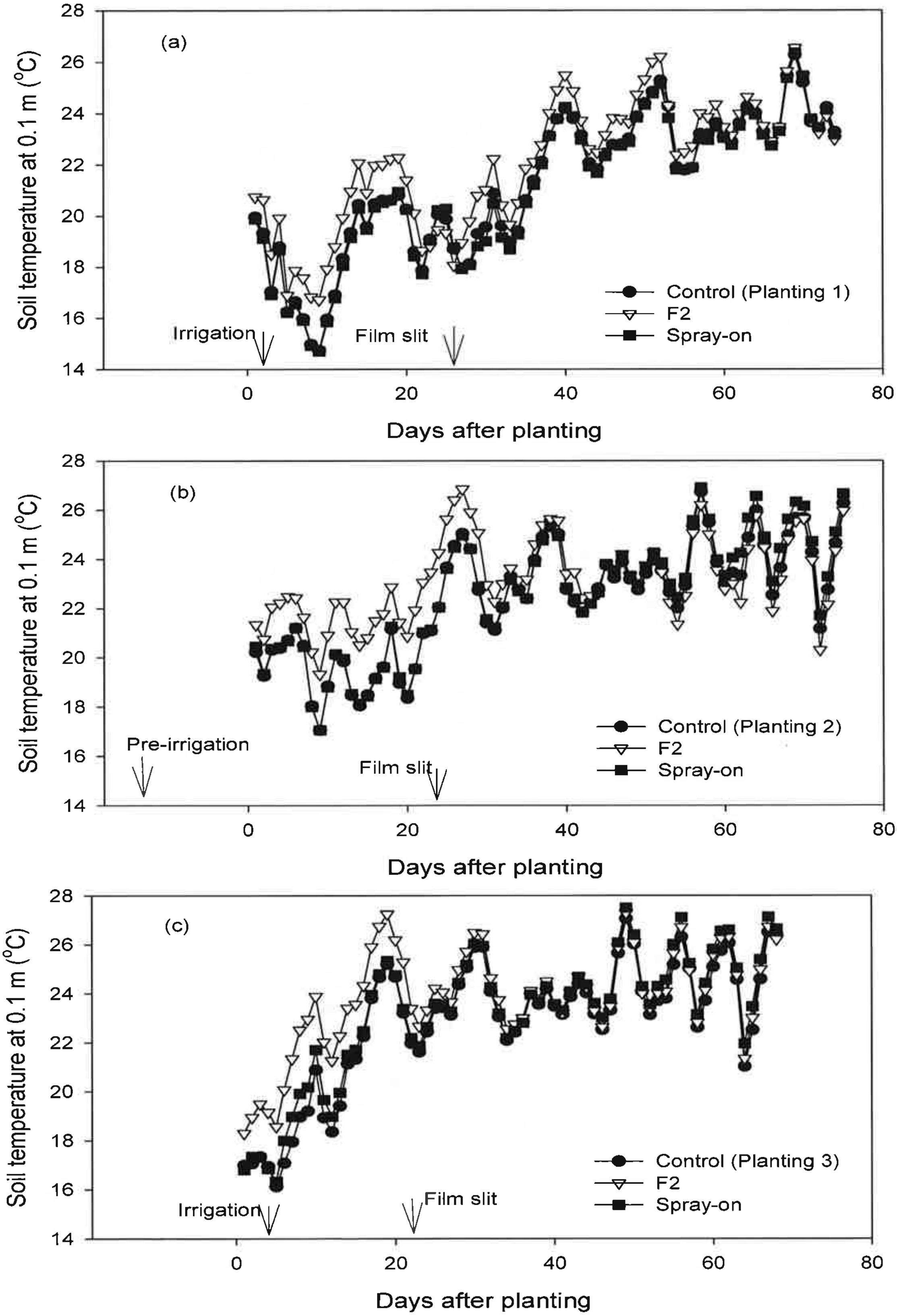


Figure 1. Soil temperature at planting depth (0.1 m) for (a) planting 1 (12 Sep 2013), (b) planting 2 (25 Sep 2013) and (c) planting 3 (3 Oct 2013) at the ACRI site.

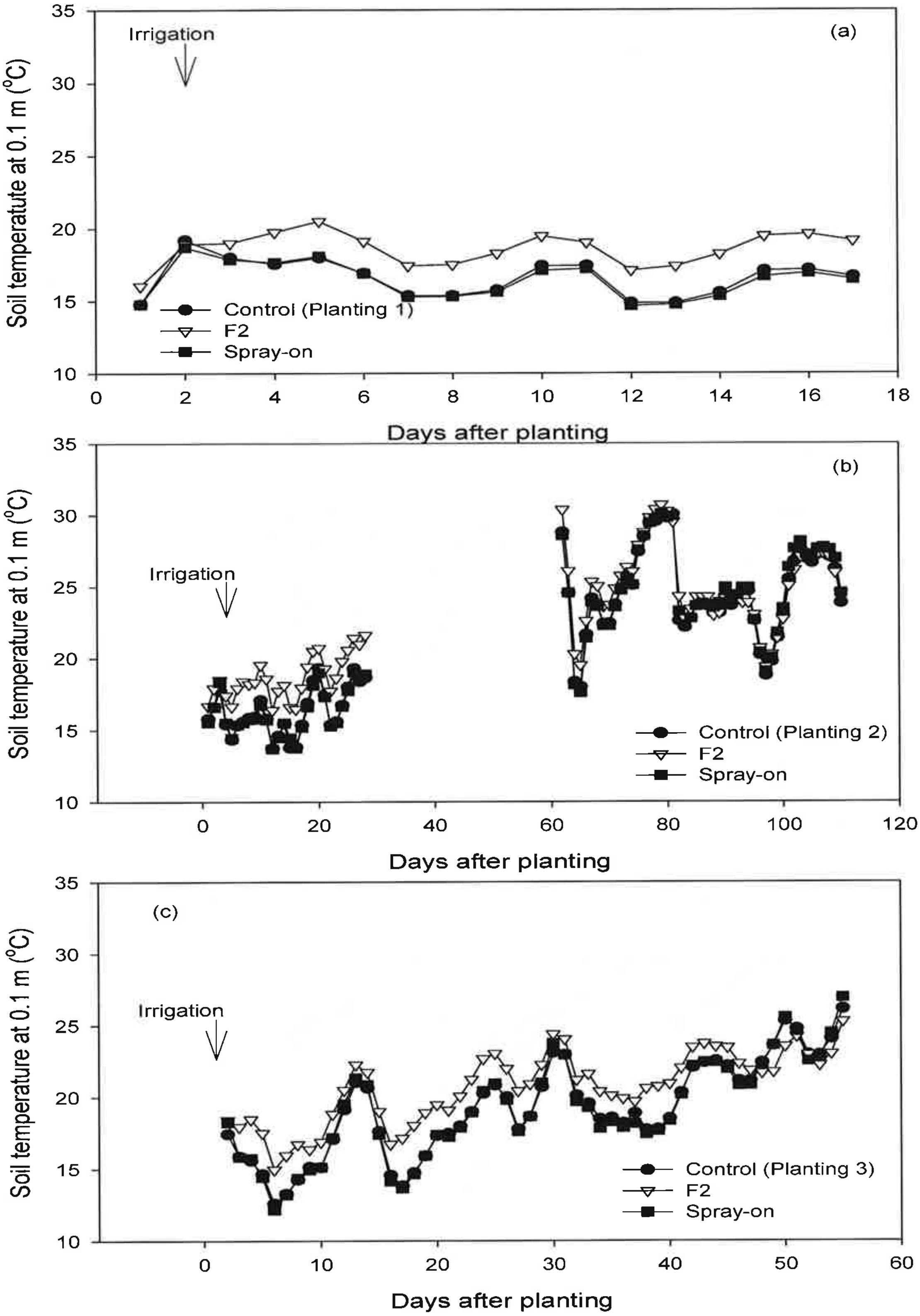


Figure 3. Soil temperature at planting depth for (a) planting 1 (17 Sep 2013), (b) planting 2 (30 Sep 2013 and (c) planting 3 (8 Oct 2013) at the Coleambally site.

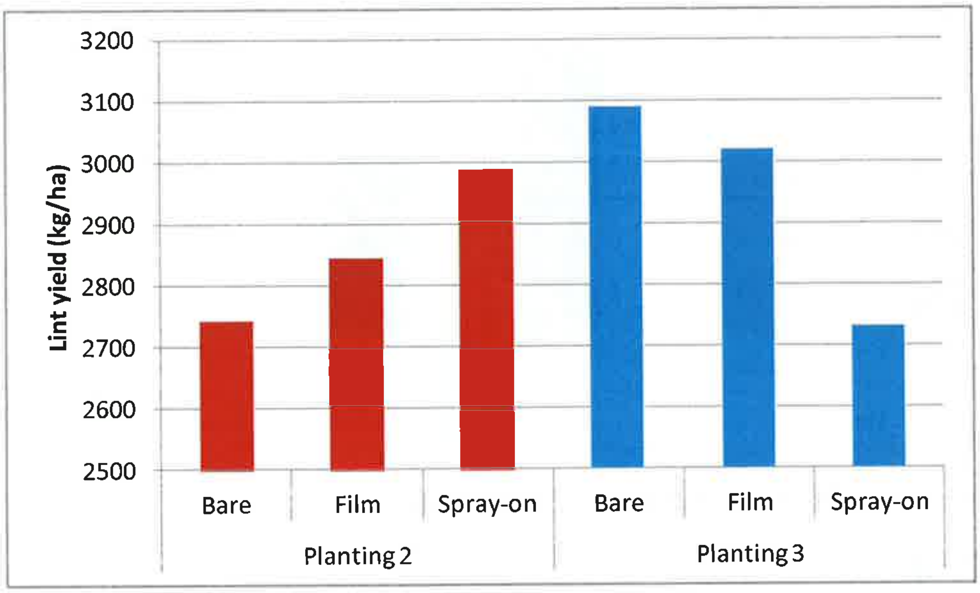
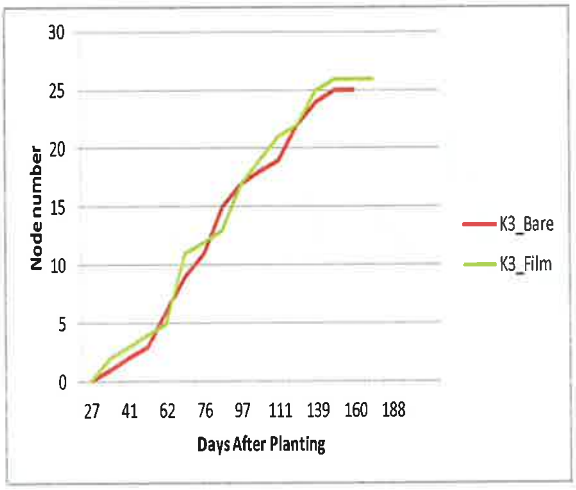


Figure 5 Handpicked lint yield (kg/ha) from planting 2 & 3 at the ACRI site.



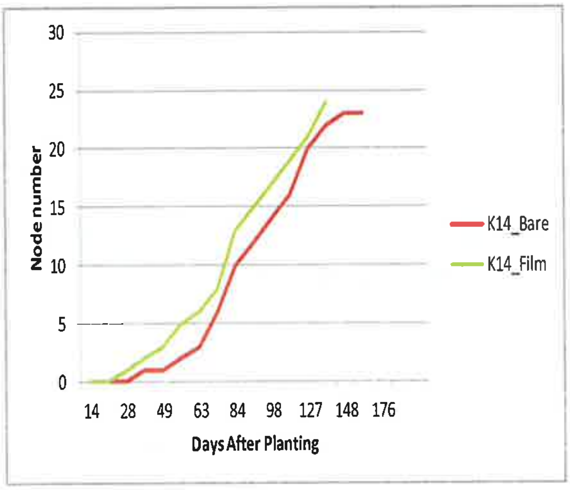


Figure 6. Node numbers at Kera 3 and 14 sites (K3, K14) under the bare and film treatments.

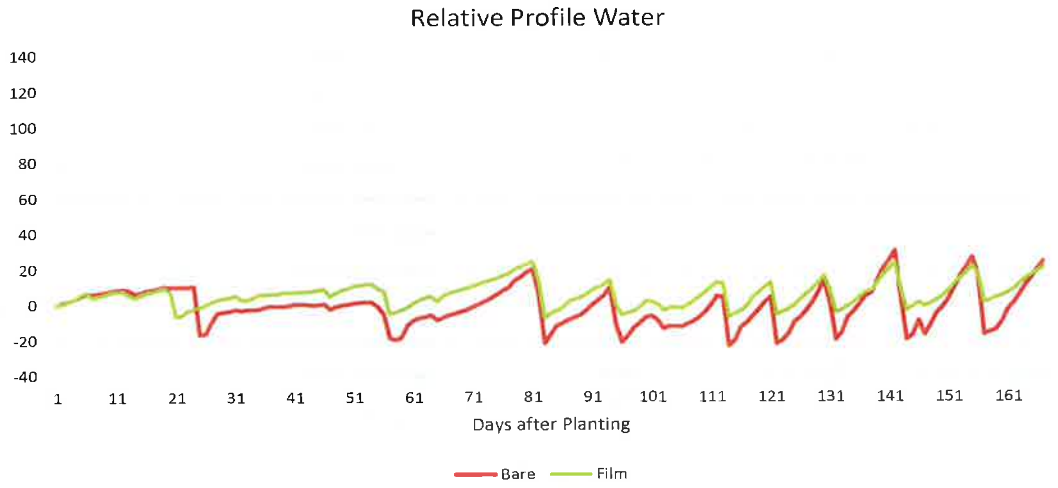


Figure 9. Relative change in profile water under film and bare treatments at the Carrathool irrigated site 2014-2015.

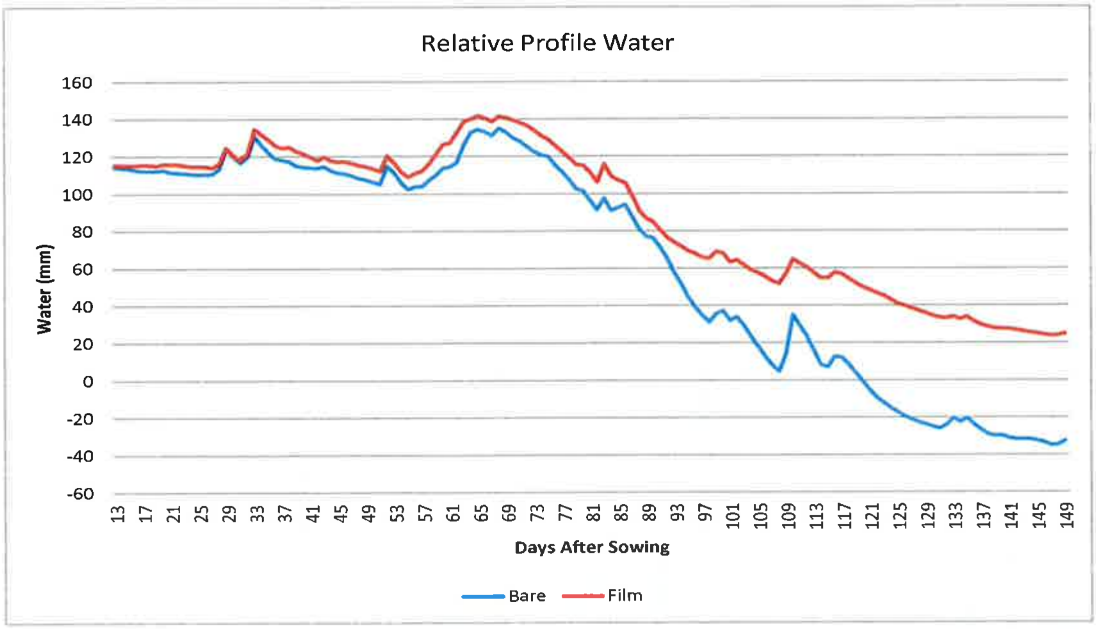


Figure 10. Relative change in profile water under film and bare treatments at the Willow Tree dryland site 2014-2015.

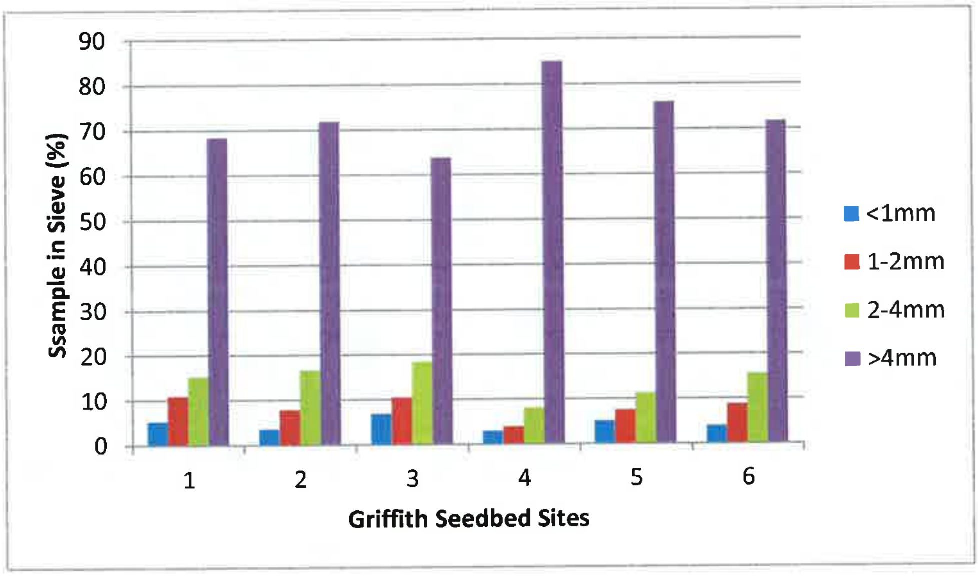


Figure 13. Aggregate size distribution in seedbeds after planting at Daisy Lodge 2014, sites 1-3 under thin film, sites 4-6 under control.

Photos: ACRI site 2014/2015

Laying film after planting (29/9/2014)



Film 1 Film 2 Bare

81 DAP (19/12/2014)



Film 1 Film 2 Bare

123 DAP (30/1/2015)