

Using degradable polymer film (DPF) to mitigate the impacts of climate variability on agricultural production in low rainfall areas

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Abstract

Degradable polymer film (DPF) is a new technology that can potentially assist cropping farmers in the low rainfall cropping areas of Australia to manage and adapt to climate change and seasonal climate variability by concentrating limited rainfall, conserving evapo-transpiration and enhancing the water-use efficiency of crops. Modeling indicates that film-based wheat production can be an economic option for farmers (cf. current management) and that the optimum configuration varies with season.

Key words

Farm system modelling, polymer film, climate variability, wheat

Introduction

Degradable polymer film (DPF) is made from a thin layer of transparent, impervious and stretchable polyolefin that degrades within the life of the crop. There are three modes in which DPF can be configured:

1) *Crop overlay*. In this mode, strips of DPF are laid over the newly sown crop and the edges buried on either side with soil. The sowing of the crop and film laying operation are typically done in a single pass. The film acts like a glasshouse to capture and concentrate soil and plant CO₂ emissions, recycle evapo-transpiration (ET) losses back to the soil, attenuate radiation and trap heat leading to increases in above and below ground temperature. During the period of cover, incident rainfall is diverted away from the crop and concentrated in the uncovered space between film strips where a portion will enter the soil and become available to the crop. The magnitude of these effects will vary with location, time of year, soil type and DPF characteristics.

2) *Skip-row*. In this mode, strips of the film are laid prior to, or at sowing at intervals across the paddock. The crop is sown in the uncovered ground between the film strips and receives both direct rainfall plus runoff from the film alongside. By concentrating rainfall in this way, the film acts to increase water availability to the crop and potentially reduce water stress. This mode reduces the production area by 50% and hence is only likely to be attractive in low rainfall seasons or locations where reducing the crop area is a risk management strategy.

3) *Skip-row/overlay*. This mode combines the potential benefits of both the skip-row and overlay modes. The full cropping area is sown and then half of the crop is covered with film, with the remaining uncovered area receiving runoff from the film. Key advantages are that film costs are halved and the crop area is maximised.

The aforementioned effects of DPF on the growing environment will impact on key biological, chemical and physical processes within the cropping system. The nature and extent of these impacts will be further influenced by seasonal climate variability and farmer management practices. While overseas trials with plastic film have demonstrated production benefits for wheat and other crops (Li et al. 1999, Rosa-Ibarra et al. 2005), recent trials conducted at Birchip, Victoria have not shown significant and consistent

production benefit (Makin *et al* 2009). In this paper, farm system modelling is used to gain insights into the impact of film on dryland wheat production grown at Birchip and to assess the future viability of this technology.

Method

The farming system model APSIM (Keating *et al.* 2003) was used to configure and compare film-based scenarios with a baseline scenario representing current practice. Each scenario was run over a 50 year period from 1958 to 2008 with soil water, nitrogen and organic matter content reset on January 1 of each year in order to isolate seasonal climate variability effects. The baseline scenario was based on the cultivar Yitpi, sown with a basal fertiliser application rate of 40 kgN/ha (no topdressing). In each year, sowing was triggered when >20 mm of rainfall occurred over a five day period between April 20 and June 15. In the film overlay scenario, DPF was laid at sowing and assumed to be effective for a period of 60 days after sowing during which time daily maximum temperature was increased by 13 °C, minimum temperature by 2 °C, radiation was reduced by 20% and atmospheric CO₂ concentration ([CO₂]) was increased by 100% (Lisson and Howden 2008). Half of the rainfall falling on the film was assumed effective and all evapo-transpiration occurring under the film was returned to the soil. In the case of the skip-row scenario, film was laid 30 days prior to the commencement of the sowing window and was effective through until October 1, with daily rainfall adjusted to reflect the runoff received from adjacent film strips. In the combined skip-row/overlay scenario, two separate model runs were conducted, one for the covered portion of the crop and a second for the uncovered portion. The reduction in incident rainfall for the covered crop (due to film shedding) was allocated to the uncovered portion of crop (via an equivalent increase in rainfall). The film effects were configured in APSIM using the inbuilt climate change capability which enables daily adjustment of all climate variables including [CO₂]. The effect of increased [CO₂] on crop growth is captured in the model via an increase in transpiration efficiency (Wu *et al.* 2004). Costs associated with the use of film are based on a total film cost (including laydown) of \$200/ha. These costs are assumed to be halved under the skip-row configuration. Fertiliser cost was set at \$1.05/kgN and wheat price at \$200/tonne. All simulations were based on typical soil physical and chemical properties for the Birchip region.

Results and discussion

Growth and development response of wheat to the overlay film mode

Field trials conducted in recent years with DPF at Birchip have been based on the overlay mode, using crop management practices that are otherwise identical to current farming practice. Typically, film-covered plants have been observed to establish and grow more rapidly early on, but are eventually caught up by the uncovered control plants resulting in comparable and non-significantly different yields (Makin *et al* 2009). Modelling shows that covering the baseline wheat crop with film for a period of 60 days after sowing promoted emergence by an average of 5 days and flowering by 31 days in response to higher temperatures under the film (which will also increase the frost risk). This in turn abbreviated canopy growth and hence biomass production and yield potential. In a favourable season these impacts might be expected to lead to a yield penalty under film (cf. uncovered baseline scenario). In drier seasons however, the reduced demand for water associated with the abbreviated growing season and smaller crop, combined with enhanced water supply through ET recycling and increased water-use efficiency (WUE), may result in higher yields under film. This seasonality in film response is reflected in results from the 50 year simulation with 33/50 years showing a yield gain from the use of film (cf baseline) with the highest gains tending to occur in below-average (<284 mm March to November rainfall) seasons (Figure 1). Of these 33 years, 10 are economic with revenue from the extra yield in excess of film costs. For the remaining years (17/50), there was a yield penalty associated with the use of film ranging from 110 kg/ha up to 1546 t/ha.

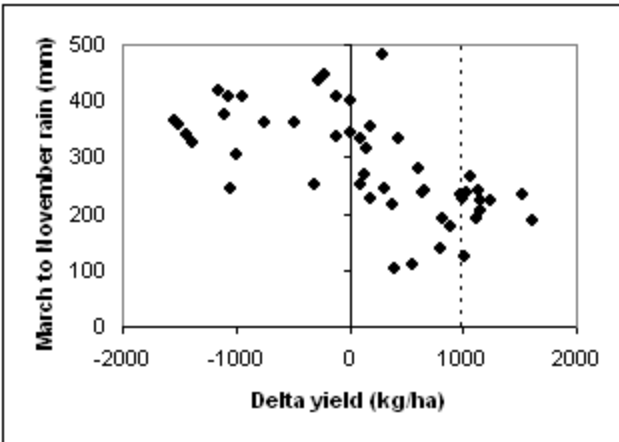


Figure 1. Seasonal rainfall (March to November) versus yield difference between the film overlay scenario and the baseline scenario for the period 1958 to 2008. The dotted line shows the breakeven yield difference.

Response from later flowering cultivars and higher N rates under film

The effects of film on promoting crop development, suggest the potential for later maturing cultivars that make better use of the growing season and the available resources under film. Replacing Yitpi in the model with a cultivar that matures (under film) at a comparable time to uncovered Yitpi, resulted in a small increase in the number of years with positive yield gains (35/50) and a modest increase in the long-term average yield from 1624 kg/ha to 1937 kg/ha. Not surprisingly, these gains in biomass resulted in increased levels of crop nitrogen stress (results not shown). This, coupled with the increased availability of water and higher WUE, justifies the use of higher rates of nitrogen fertiliser in film-based scenarios. The addition of an extra 25kgN/ha both at sowing and as a topdressing, increased the average yield to 2323kg/ha and the number of years showing a positive yield gain to 44/50 (Figure 2). Of these 44 years, 7 are economic. Interestingly, when the same amount of additional fertiliser is applied to the uncovered baseline treatment, average yield increases from 1624kg/ha to 2100kg/ha and is economic in 21/50 years. Profitability however is confined to above-average rainfall seasons which are otherwise constrained by nutrient availability. The current reluctance of farmers to increase fertiliser rates reflects the risk-averse approach adopted in this low rainfall environment.

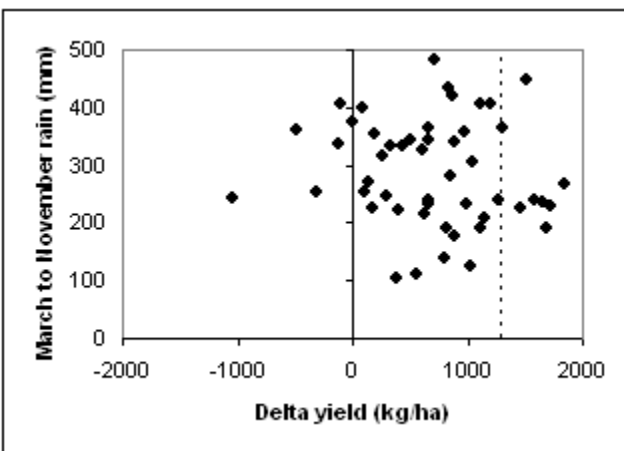


Figure 2. Seasonal rainfall (March to November) versus yield difference between the film overlay scenario based on a later maturing cultivar and an additional 50kgN/ha and the baseline scenario for the period 1958 to 2008. The dotted line shows the breakeven yield difference.

Response to the skip row film mode

An alternative scenario thought to be appropriate in dry years as a risk management strategy is to lay the film prior to sowing and retain it in place for much of the crop life in order to maximise the benefits of rainfall concentration. In the modelled scenario, the film was laid on March 15, one month prior to the commencement of the sowing window and retained through until October 1. Extra N was applied at sowing and as a topdressing (25kgN each) to harness the additional water running off from the film. In response to this 'extra' rainfall, the sowing break conditions were satisfied earlier in some years (up to 42 days). Average yield in this scenario increased to 2584kg/ha (cf. 1624 kg/ha for the baseline). It must be noted that these yields are achieved over only half the cropping area with the other half taken up by film. When compared against an uncovered skip-row crop layout, the film covered scenario produced yield gains in all years, but only 10 of these years were economic. Most of these economic years correspond to above average seasonal rainfall which reflects the water limited nature of the Birchip growing environment and the rainfall concentrating effect of the skip-row mode. In these above-average rainfall seasons, the baseline scenario with extra nitrogen is a more economic and less risky proposition.

Response to the combined skip row / overlay mode

In this scenario, the full cropping area was sown and half of the area then covered with film (at sowing and effective for a period of 60 days) with the remaining uncovered area receiving runoff from the film strips. Two cultivars were employed with the later flowering type used under the film. The average modelled yield for this scenario was 2499kg/ha. It generates higher yields than the baseline in 49/50 years and is economic in 21 of those years (Figure 3). These economic years cover below to above-average rainfall seasons.

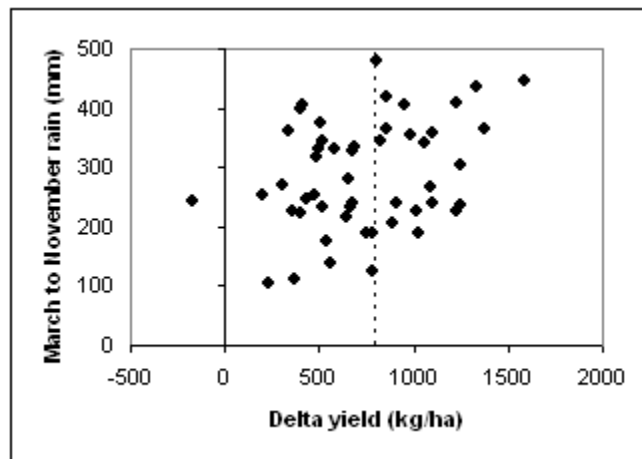


Figure 3. Seasonal rainfall (March to November) versus yield difference between the overlay/skip-row scenario and the baseline scenario for the period 1958 to 2008. The dotted line shows the breakeven yield difference.

Conclusions

- Modeling indicates that film-based wheat production can be an economic option for farmers (cf. current management) at Birchip and that the optimum configuration varies with season;

- When used in conjunction with current management practices as an overlay, film may lead to substantial yield and financial penalties in average to above-average rainfall seasons. Economic yield gains are more likely to occur in below-average seasons;
- Crop development rates are promoted under film. Hence, more consistent and higher average yield gains can be achieved through the use of later maturing cultivars, which make better use of the available growing season and the gains in water supply and use efficiency under film. These changes also justify a less risk-averse nitrogen fertiliser strategy in these low-rainfall environments;
- The skip-row mode of film use tends to be economic in average to above-average rainfall seasons. However, in these seasons, higher nitrogen rates applied to current management is likely to be a more economic, lower risk option;
- The combined skip-row/overlay film mode generates the highest number of economic crops.
- The profitability of polymer is sensitive to grain prices. With wheat prices forecast to increase by 15-40% over the next decade (<http://www.fao.org/news/story/en/item/43208/icode/>), it is likely that the profitability of using polymer films will be greater than indicated here.

Acknowledgements

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