Cover crops improved fallow efficiency in Queensland

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Abstract

Fallow periods with low ground cover tend to have low fallow efficiency and are more prone to erosion. Cover crops can be planted, then terminated prior to seed set and left on the surface to increase ground cover. Six experiments were established in Queensland to measure the cost to plant available water (PAW) for growing cover crops, and whether the improved fallow efficiency was sufficient to recover this water use relative to a bare fallow.

These experiments were conducted in very dry seasons (decile 3-1 rainfall). The best cover crop treatments had more PAW at the end of the fallow, than the bare fallow (Control) in five of the six sites. However, the worst treatments used too much water or stover decomposed too quickly and had 0 mm to 55 mm less PAW than the bare fallow. Cover crops also allowed more even crop establishment, which in-turn extracted more soil water, and captured more water from over-head irrigation, so crops yielded more after cover crops in two of the four sites planted to a subsequent cash crop.

These results confirm a well-managed cover crop can improve ground cover without a negative impact on PAW. The duration of cover crop growth will determine the PAW used and resilience of stubble produced, with the most appropriate duration dictated by the length of fallow to proceed.

Keywords

Cover crop, ground cover, plant available water.

Introduction

In a Queensland (Qld) farming system, plant available water (PAW) is ‘king’, but in dryland crops only 15-30% of fallow rainfall is captured for use by dryland crops, with up to 75% being lost to evaporation, and a further 5-20% lost in runoff and deep drainage (Freebairn et al. 2009). Recent farming systems research in Queensland and northern New South Wales has measured higher fallow efficiency (FE, the proportion of fallow rainfall captured in the soil) after crops that leave higher stubble loads (e.g. wheat) than those that have low stubble loads or break-down quickly (e.g. chickpea) (Erbacher et al 2019).

Cover crops offer an opportunity to increase ground cover which can protect the soil from erosion, suppress weeds, boost nitrogen levels when legume species are included, maintain soil organic matter and improve FE. However, growing crops that do not produce grain or fibre is typically considered ‘wasteful’ of both rainfall and irrigation. Previous on-farm research has supported grower experience that cover crops may provide their benefits with little or no loss of soil water (Whish et al. 2009). This research focused on using rigorous soil water measurements to assess the impact of cover crops in low-cover fallows and the subsequent yield of ‘cash’ crops.

Methods

A part of a project joint funded by Grains and Cotton Research and Development Corporations (GRDC and CRDC) and Queensland Department of Agriculture and Fisheries (DAF), six sites were established in Qld over three years from April 2017 and were supported by CSIRO with APSIM modelling. Sites were preceding overhead irrigated cotton near Yelarbon, Goondiwindi and Croppa Creek, in a long fallow after skip row sorghum near Bungunya and Yagaburne, and in a short fallow with low cover after chickpea near Billa Billa. This period was the driest three years on record, so only two of the paddocks were planted to the planned crop following cover crops; Yelarbon to irrigated cotton and Bungunya to wheat. Yagaburne and Billa Billa had wheat established with trickle irrigation, but yielded less than 0.6 t/ha.

Cover crops were sprayed out and soil water use and recharge was monitored regularly, using gravimetric and neutron moisture meter (NMM) measurements. The yield of the following ‘cash crop’ was measured as another estimate of the (water) benefit of the cover crops.

Cereals were selected as the primary cover crop species to improve FE and sprayed out at different timings to create a range of biomass volumes and resilience at each site. These were sprayed-out: ‘early’, at first node when the plants start producing stem; ‘mid’, at flag leaf emergence when reproduction begins; or ‘late’, at anthesis when peak biomass is produced. Cereals used were barley, wheat, millet or sorghum. A range of other cover crop species were also included at some sites and sprayed-out at the ‘mid’ timing. These included vetch, Lablab (legumes) and tillage radish either alone or in a mixture. When millet was the primary cereal sorghum was included as a comparison.

Results

Cover crop biomass and ground cover

All experiments successfully increased ground cover levels from ~10% in the control treatments, to over 50% in the 'droughted' sites trials, and between 60-95% in the other locations (**Error! Reference source not found.**).

The cereal cover crops were most effective in producing and maintaining ground cover. They produced more dry matter and ground cover than the brassica and legume treatments that were slower to accumulate biomass and provide cover and faster to breakdown. The cereals established between 2.5-4 t /ha of dry matter (DM) for the mid-termination treatments typically used in commercial plantings, the late terminations between 4-5 t DM /ha, and the 'very late' crops and those grown through to harvest produced up to 10t DM/ha. The exceptions were two severely 'droughted' plantings, such as the Yagaburne experiment that only grew between 0.1-0.5 t DM/ha for the winter cover crops and 0.5-2.5t DM/ha for the summer cover crops.

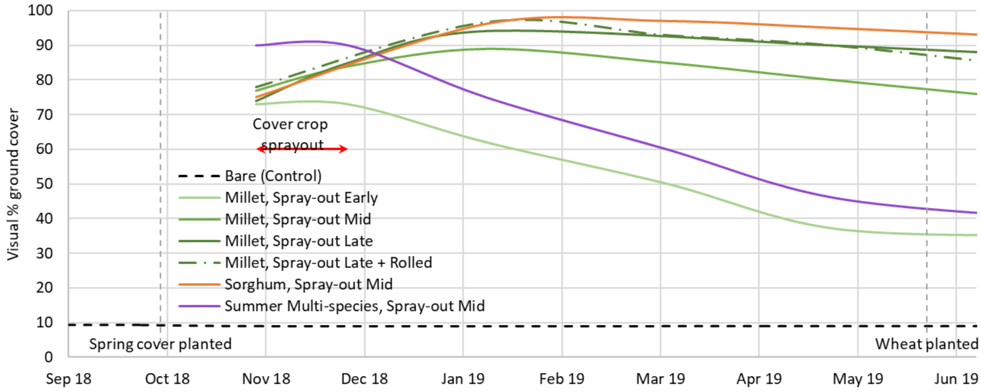

Figure 1: visual assessment of % ground cover of spring cover crops at the Yagaburne site.

Fallow water dynamics

The best cover crop treatments typically recouped their water deficits at termination to finish the fallows with similar or better soil water levels as the Control treatments (**Error! Reference source not found.**). However, extreme treatments that used more water or did not maintain cover (e.g. very late termination, harvested cereals, terminations without subsequent fallow rain, some tillage radish and/or legume treatments) finished the fallows with significantly less stored soil water ($P = 0.05$). The natural variation in soil water made it difficult to confidently measure differences; something often seen in soil water studies. Despite these limitations, the trends in the results were very consistent across sites and treatments. The results, best illustrated for summer cover crops at Bungunya (Figure 1Figure 2), matched simulation case studies. These net water trends for the focal (commercial) cover crop treatments across sites were: a net loss of stored soil water at one site (Billa Billa summer cover crops in a short fallow); recovery to similar net water storage at three sites (Yagaburne, Goondiwindi, Croppa Creek), and net water gains at two sites (Bungunya, Yelarbon). The water-deficit (cost) at termination of the cover crops varied with the growth stage, the species, their water use and the cover provided, and the season with differing amount and timing of rain while they grew (Figure 3). The typical net-water-deficit to grow the cover crops for early termination was ~20 mm (range 0-50 mm), mid-termination was ~30 mm (range 15-70 mm) and late termination was ~50 mm (range 0-90 mm). When cover crops were left grow beyond anthesis (after late termination) this deficit was 100-120 mm with no additional biomass, showing that timely removal is critical to avoid dramatic losses.

The recovery of soil water from these deficits after termination was equally dramatic and consistent across the project. The drier soil profiles and extra cover boosted infiltration and storage of water for the rest of the fallows in-line with theory. The millet cover crop at Bungunya (Figure 2), was planted on ~120 mm of PAW, used 50-60 mm more water than the bare fallow (control) through to late termination but, had an overall fallow efficiency of 17% for the whole fallow compared to 14% for the bare fallow. This was due to its very high fallow efficiency (>70%) in the shorter period once the cover crop was sprayed out.

Similar results across the other sites saw most treatments recover the deficits on their first major rain event after cover crop termination and then finish with similar levels of soil water by the end of the fallow. Cover crops with less water than the bare fallow were the late terminations that did not provide sufficient fallow time to recover their larger deficits, and some legume and brassica cover crops, in which their stover broke down too quickly to maintain cover for the whole fallow. At the Yelarbon site this 'high fallow efficiency' period continued after planting of the cotton crop, with higher ground cover increasing water capture from over-head irrigation in early crop growth (up to canopy closure).

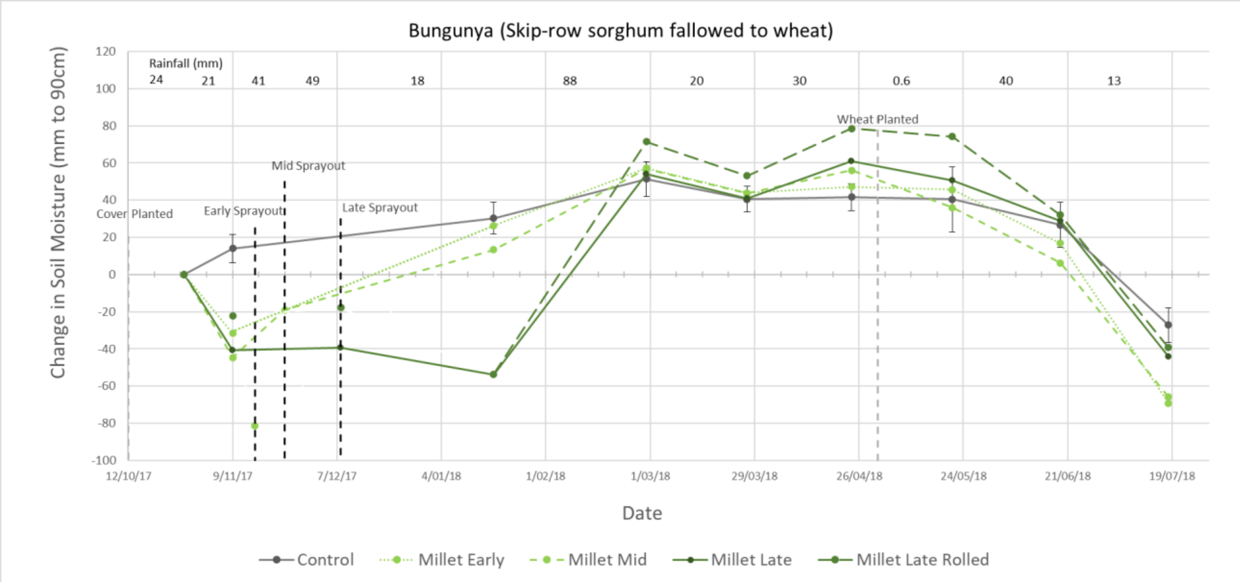

Figure 2: Soil water dynamics at the Bungunya site, showing soil water use by millet cover crops with different termination timings, and recharge over the following fallow.

Table 1 Summary of fallow water storage for 'Control' (~10% cover) and the cover crop treatments

Cover crop experimental sites	Fallow water storage by Control	Fallow water balance compared to the Control	
		Best	Worst
Yelarbon	56 mm	+38 mm	-4 mm
Buyngunya	42 mm	+31 mm	-5 mm
Goondiwindi	30 mm	+10 mm	-8 mm
Yagaburne	14 mm	+6 mm	-19 mm
Croppa Ck	11 mm	+20 mm	0 mm
Billa Billa	28 mm	-37 mm	-55 mm

Effect on subsequent 'cash' crops

Increasing ground cover has maintained surface moisture for longer, which had a marked effect on the capacity to plant the following cash crops. At two experiments the site was assessed for planting two weeks after rainfall. The cover crop treatments had varying amounts of cover, all greater than the bare control. At both sites, Theta (0-10 cm capacitance probe) readings were higher under higher ground cover. Bungunya was planted and established a patchy stand of wheat where cover was low. Whereas, less than half the treatments at Yagaburne had sufficient surface moisture, so the site was irrigated to establish an even population to assess any impact of water storage.

Yields of subsequent 'cash' grain and cotton crops reflected the general soil water trends across dryland and irrigated sites. More soil water at planting produced more yield at Billa Billa and Yagaburne which had an even plant stand established. At Yagaburne, PAW differences at planting were small so yielded similarly (0.6 t/ha), whereas at Billa Billa cover crops had less PAW and yielded less than the bare fallow (0.02-0.36 t/ha vs 0.7 t/ha). Bungunya had a patchy plant stand in the Control (bare fallow), so also left ~50 mm more PAW at harvest and yielded 1 t/ha less than the cereal cover crop treatments (1.3 t/ha vs 2.0-2.6 t/ha).

In overhead irrigated cotton at Yelarbon, the cover crop treatments captured more water in early irrigations. With 650 mm irrigation over the season, all cover crops had a similar yield benefit of 3-4 bales/ha over the bare fallow (Control, 9 bales/ha), irrespective of the soil water differences at planting.

Simulation

APSIM modelling from the Bungunya experiment, using a water deficit of 20 mm/t dry matter produced by the cover crops, showed PAW benefits from cover crops in 45% to 70% of years (Figure 3a). In dry years, net water losses were predicted for 10% of years for early terminations and up to 50% of years for late terminations with at least 3 t/ha of biomass. However, all systems were predicted to finish with similar moisture levels in the wettest 5% of years. This conservative analysis means cover crops can recoup or improve soil water storage in 70% of years (Rainfall percentiles 25-95%) for early terminated crops producing 1 t DM/ha and 45% of years (Rainfall percentiles 50-95%) for late terminations producing 3 t DM/ha. For the years with in-fallow rainfall of 200-500mm, net soil water accumulation was predicted to increase by 17 mm on average, which assuming 15 kg/mm aligns to the grower's experience over the last 10 years of 0.2-0.3 t/ha grain yield increase where cover crops have been grown.

The reduction in erosion risk (Freebairn model) during fallows by reducing runoff volumes and sediment concentration in runoff water (Figure 3b) is an added benefit of cover crops quantified in the simulations. Erosion was reduced in 99% of years with cover crops. Even small stubble levels (1 t DM/ha) are predicted to eliminate sediment losses in up to 50% of years. While cover crops may have little benefit for water storage in very wet years, higher levels of stubble are predicted to be effective in preserving soils during these years of high erosion risk. Cover crops that produced 1 t DM/ha were predicted to reduce long-term erosion by 82%, 2 t/ha by 96% and 3 t/ha by 99%. This reduction in erosion would deliver savings to growers in reduced earthworks (i.e. contour bank maintenance) and associated economic and environmental benefits from reduced sediment, nutrient and pesticide losses.

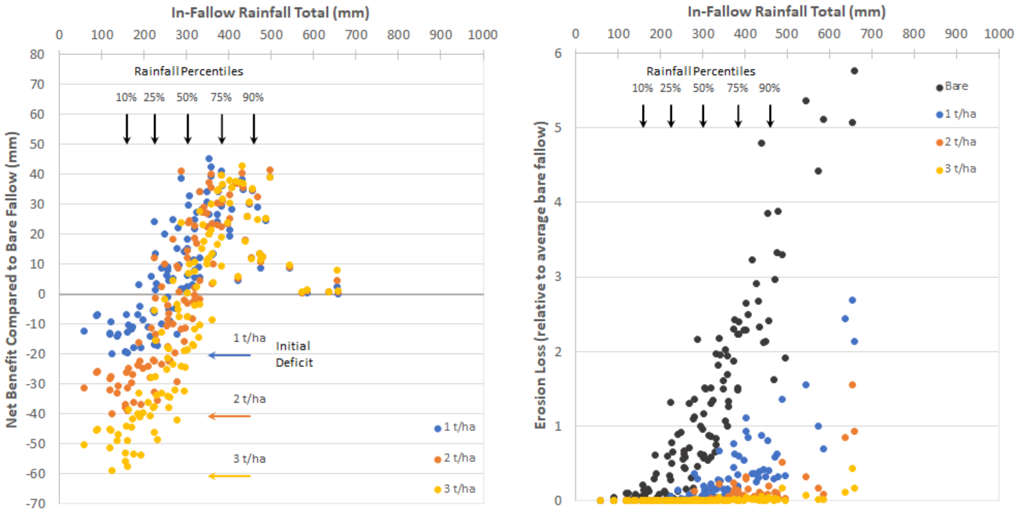

Figure 3a) Net benefit of Spring cover crops of varying stubble mass on stored soil moisture for the following winter compared to bare soil fallow with 60mm starting PAW, and b) Relative reduction in erosion losses due to cover crops during the fallow. Bare soil erosion rates are shown for comparison. Rainfall percentiles for the fallow period are shown. The initial soil water deficit for the fallow period due to cover crop water use is indicated for each scenario.

Conclusion

Growing cover crops is a useful strategy for increasing ground cover in low stubble fallows. The most appropriate cover crop treatments matched stubble resilience and PAW use with fallow length, that is early termination for short fallows and late termination for long fallows, and typically finished with more stored water than the traditional fallow.

Increasing cover produces a higher fallow efficiency, which provides more stored water at planting, improving the yield potential of the crop. Dry soils have a very high fallow efficiencies in the short-term (>70%); combined with the longer-term higher fallow efficiency from increased ground cover, the fallow after a carefully managed cover crop can recover the soil water used to grow the extra ground cover. Reducing evaporation provides an additional benefit by maintaining moisture near the surface for longer, extending the time moisture is available in the seedbed for planting. This can allow a wider window of opportunity to plant cash crops on the optimum date for maximum yield potential and/or planting larger areas of crop, without the need of time critical rainfall.

Soil loss in run-off was a major driver for the shift to zero or minimal till farming systems. Whilst not measured in our field trials, the simulation demonstrated the potential to reduce erosion with cover crops. Preventing erosion will deliver savings in earthworks (contour bank and drain maintenance) and will reduce losses of nutrients and pesticides attached to the sediment, which delivers both economic/agronomic and environmental benefits.

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