Summer cover crops can increase stored soil water in long fallows and improve wheat yields—Bungunya

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Research Questions: *Can summer cover crops increase the net water accumulation (plant available water) in dryland systems with low ground cover (<30%) in the Northern Region?*

- *What is the net water cost to grow summer cover crops?*
- *What is the net water gain to subsequent grain crops (fallow and early growth periods)?*
- *What is the impact on the yield of the grain crops?*

Key findings

1. Summer cover crops can be very profitable; improving ground cover and increasing fallow water storage in long fallows to improve grain yields and boost returns in northern farming systems.
2. A later spray-out produced additional levels of a cover that is more resilient and stored more water in the longer fallow. Delaying spray-out too long reduced fallow water storage considerably.
3. Using a summer cover crop saved two fallow herbicide sprays and dramatically improved establishment of the subsequent wheat crop.
4. Yields and returns were increased by the cover crops, and yields were well in excess of those expected from the increased soil water storage alone.

Background

Cover crops can protect the soil from erosion in low stubble situations, return biomass that helps maintain soil organic matter and biological activity, and provide additional nitrogen (when legumes are used). However, cover crops may also offer opportunity to increase infiltration and fallow moisture storage for higher yields and more profitable grain and cotton crops.

Advances in agronomy and support from commercial agronomists have resulted in better use of available soil water to improve individual crop performance. However, effective capture and storage of rainfall across the whole farming system remains a major challenge for grain and cotton growers in the Northern Region, where dryland crops typically transpire only 20-40% of rainfall. Up to 60% of rainfall is lost to evaporation and a further 5-20% lost in runoff and deep drainage. Indeed, every 10 mm of extra stored soil water available to crops is worth up to 150 kg/ha extra yield for grain crops.

Farming systems projects funded by the Grains Research and Development Corporation (GRDC) are assessing ways to improve the use of our total rainfall, with the aim of achieving 80% of the water and nitrogen-limited yield potential in our cropping systems. Past research from GRDC's Eastern Farming Systems and Northern Growers Alliance projects suggests that cover crops and increased stubble loads can reduce evaporation and increase infiltration to provide net gains in plant available water over traditional fallow periods. Consequently, cover crops may be a key component of improved farming systems; providing increased productivity, enhanced profitability and better sustainability.

Scientific rationale

Stubble and evaporation

Retained crop stubble protects the soil from rainfall impacts and so improves infiltration to store more water in the soil. Past research also shows that increased stubble loads can slow down the initial rate of evaporation, but that these gains are short-lived and lost from accumulated evaporation after about three weeks. However, further rain within this three-week period provides opportunity to reduce total evaporation and so accumulate more plant available water (Photo 2).

Cover crops are used in Southern Queensland and Northern New South Wales to overcome a lack of stubble and protect the soil from rainfall impacts following low residue crops (e.g. chickpea, cotton), or following skip-row sorghum with uneven stubble and exposed soil in the 'skips'.

Growers typically plant White French millet and sorghum, and spray them out after 6–10 weeks to allow recharge in what are normally long fallows across the summer to the next winter crop. Allowing these 'cover crops' to grow through to maturity can lead to big losses of stored soil water and low yields in the subsequent winter crops. However, the Eastern Farming Systems project showed only small deficits (and even water gains) accrued to the subsequent crops when millets were sprayed out within six weeks, with average grain yield increases of 360 kg/ha. Furthermore, the Northern Growers Alliance suggested that the addition of 5-40 t/ha extra stubble (hay) after winter crop harvest reduced evaporation; initial studies showed 19-87 mm increases in plant available water that could increase yields by up to 1300 kg/ha. These gains will be valuable if validated in further research and captured in commercial practice.

Our current project is monitoring sites intensively to quantify the impact of different stubble loads on the accumulation of rainfall, the amount of water required to grow cover crops with sufficient stubble loads, the net water gains/losses for the following crops and the impacts on their growth and yield. This paper reports on the first 'grain' site in Southern Queensland, which will be used in simulation/modelling later in the project to assess the wider potential and economic impacts of cover crops in both grain and cotton production systems.

What was done

The Bungunya experiment was in a long-fallow paddock following skip-row sorghum. The sorghum was harvested in early February 2017, deep phosphorus was applied in August 2017, and the paddock was 'Kelly-chained' in September 2017 to level the surface. The paddock subsequently had little cover for the planned wheat crop.

Eight cover crop treatments were established on 11 October 2017 with ~120 mm of Plant Available Water in the soil (Table 1, Photo 1), while the rest of the paddock was sown to a White French millet cover crop by the host grower. Each treatment had five replicates to monitor for ground cover, dry matter (DM) production and fallow soil water until the subsequent wheat was planted on 1 May 2018.

Table 1. Cover treatments applied at the Bungunya site included millet, sorghum and lablab.

Cover crop treatment	Terminated	Biomass (kg/ha)
Control (bare fallow)		
Millet (White French)	Early	1533
Millet (White French)	Mid	2327
Millet (White French)	Late	4365
Millet (White French)	Late + Roll	4737
Sorghum	Mid	2481
Lablab	Mid	1238
Multi-species (millet, lablab, tillage radish)	Mid	1214

Three planned termination times matched key growth stages of the main cereal treatments:

- Early-termination at first node (Z31) when stem development began;
- Mid-termination at flag leaf emergence (Z41) when the reproductive phase began; and
- Late-termination at anthesis (Z65) for peak biomass production.

Photo 1. A range of summer cover crops were planted and sprayed out at different times at Bungunya to assess their impact on the soil water storage during a long-fallow period after skip-row sorghum, prior to planting wheat.

One millet plot was ‘missed’ when spraying the late-termination; its removal two weeks later provided additional unreplicated biomass data and water use figures for an ‘extra late’ termination.

Soil water was estimated using soil cores to measure gravimetric soil water at key times across the fallow and the subsequent wheat, along with regular neutron moisture meter (NMM) and EM38 readings in each plot. These NMM and EM38 readings and the percentage ground cover were recorded every 2–4 weeks while the cover crops were growing, and every four weeks in the fallow once all cover crops were terminated. These soil water measures continued every four weeks in the growing crop until canopy closure, with a final soil water measure at harvest. Wheat yields were estimated with hand-cuts on 12 October and mechanical harvesting on 26 October 2018.

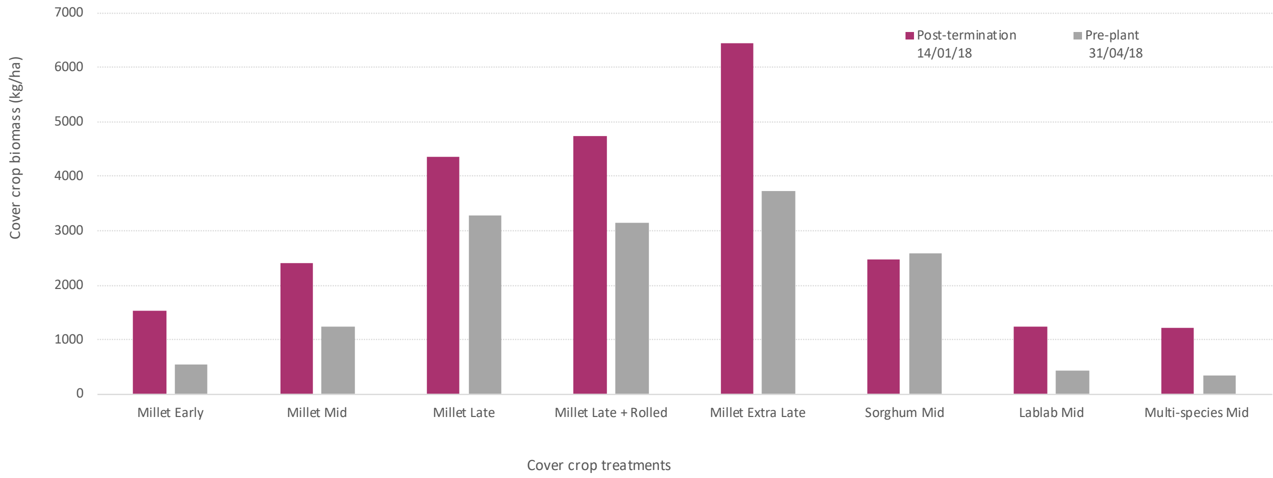

Figure 1. Above-ground biomass accumulation for the cover crop treatments at Bungunya show reduced biomass level by the end of the fallow.

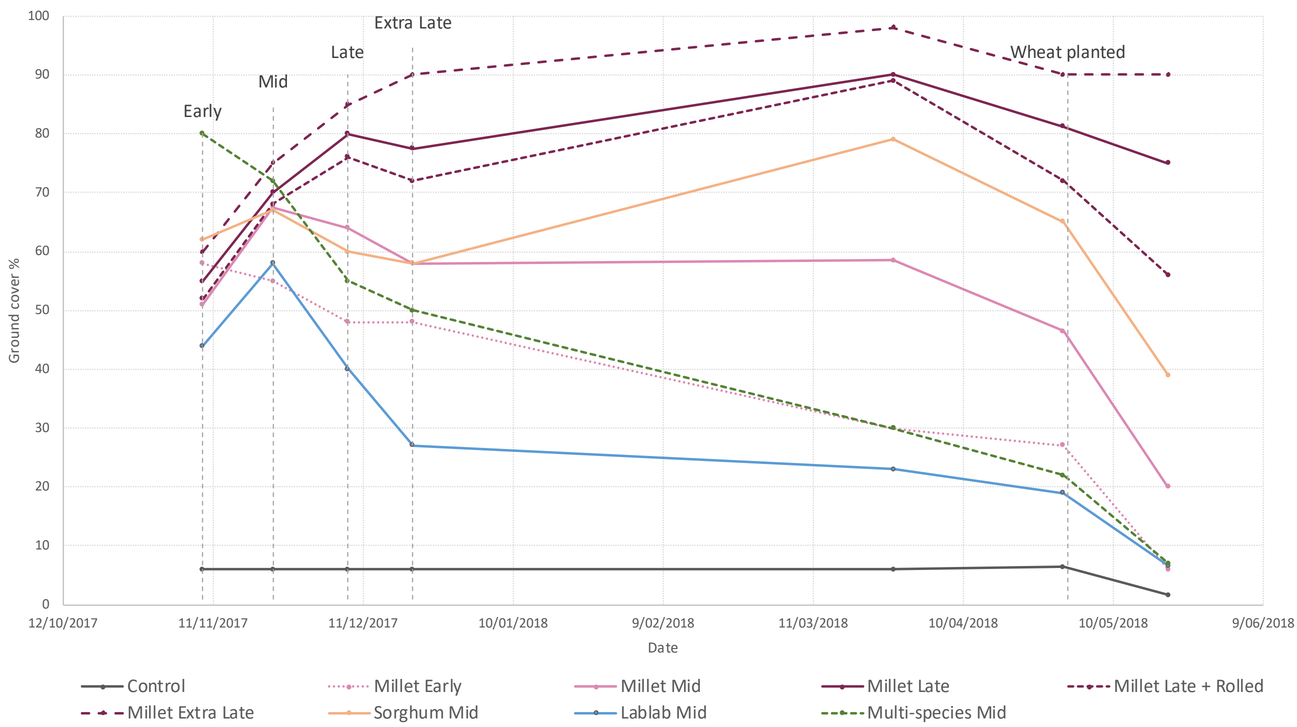

Figure 2. Visual assessments of ground cover over time at Bungunya also show reduced cover over the fallow, especially for lablab.

Results

Biomass and ground cover

Biomass of the millet cover treatments ranged from 1533 kg DM/ha for the early-termination, up to 4737 kg DM/ha for the late-termination. The lablab and multi-species treatments produced less dry matter than the cereals, and biomass fell below 1000 kg DM/ha prior to planting wheat in the early terminated millet, the lablab and the multi-species treatments (Figure 1). These three treatments also fell to only 20-30% ground cover by the end of the fallow (Figure 2).

Soil water

The water cost of growing the millet cover crops, relative to the Control treatment in the early stages of the fallow was ~50 mm for the early-termination, ~40 mm for the mid-termination and ~60 mm for the late-termination treatment (Figure 3). The lablab mid-termination treatment also cost ~60 mm to grow, relative to the Control treatment (Figure 4).

The unreplicated 'extra' late termination (two weeks later) used an additional 55 mm of water.

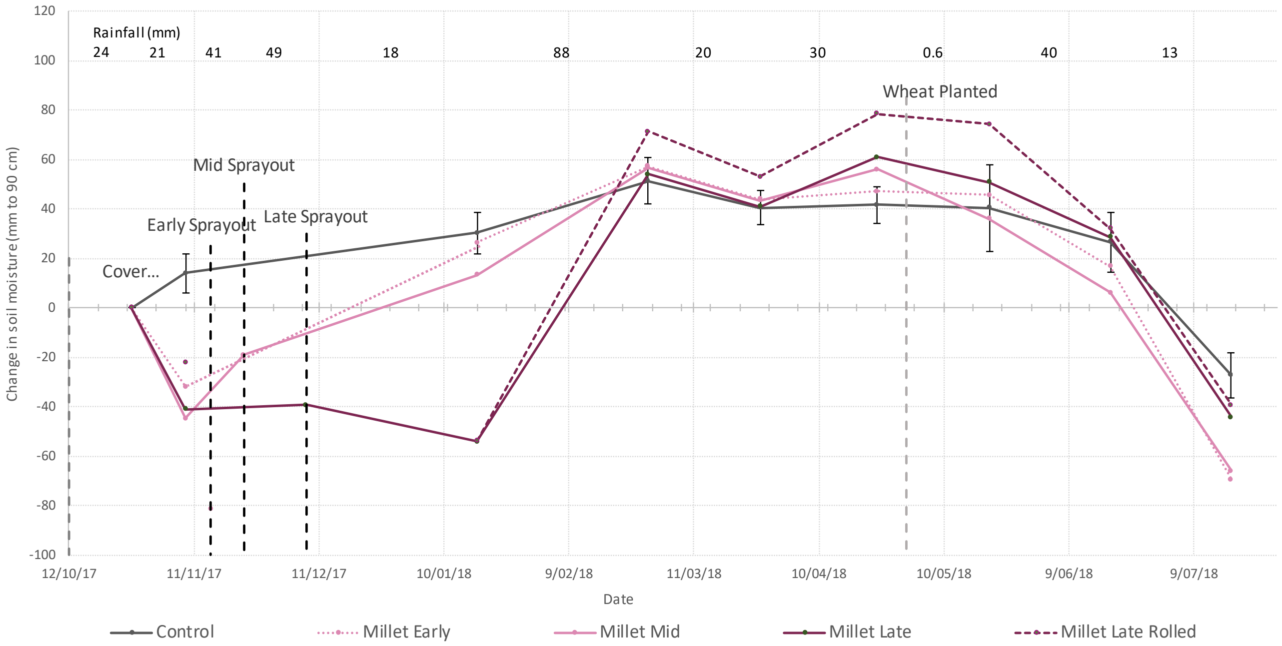

Figure 3. Changes in soil water (mm to 90 cm) from planting of millet cover crops to canopy closure of the subsequent wheat crop at Bungunya show that stored water can be increased over the fallow.

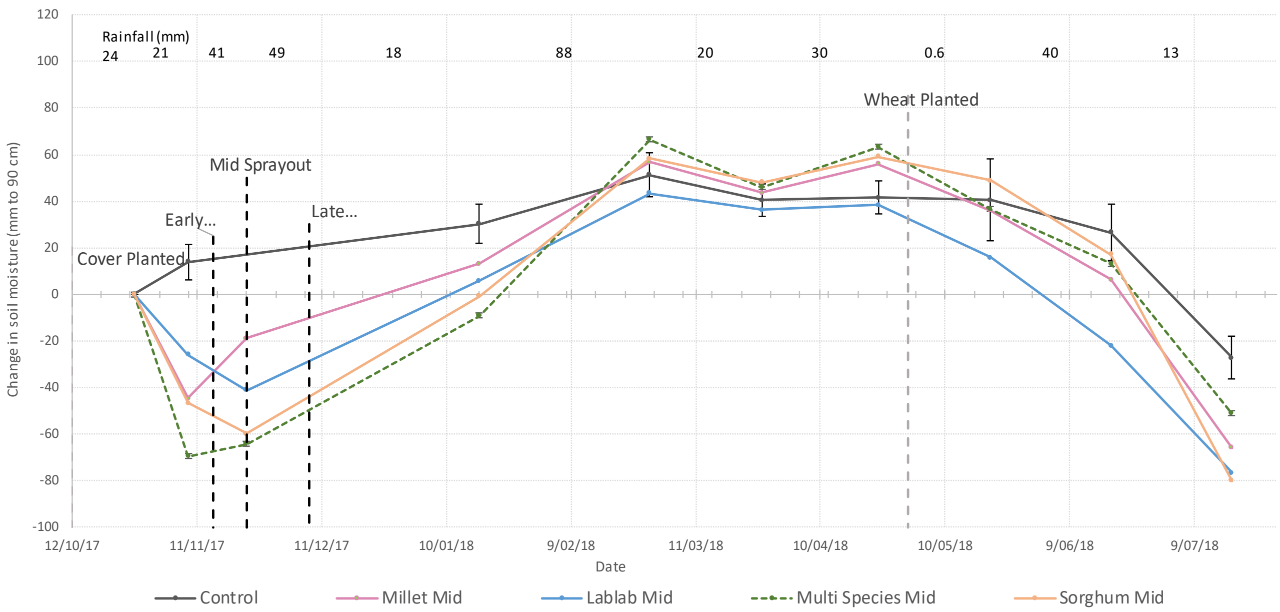

Figure 4. Changes in soil water (mm to 90 cm) after planting cover crops until canopy closure of the subsequent wheat crop at Bungunya show that soil stored less water under legume stubble than cereal stubble.

These results reflect additional rainfall and different rates of infiltration achieved in each treatment (some of which were still growing) between the soil water measurements:

- Plant of cover crops to Mid-termination, 86 mm in four events (11/10/17 to 22/11/17)
- Mid-termination to plant of wheat, 205 mm in 11 events (22/11/17 to 1/5/18)
- Plant to maturity 41 mm in 3 events (1/5/18 to 5/10/18)
- Maturity to post harvest soil sample 72 mm in 7 events (5/10/18 to 5/11/18).

Between mid-termination and early March 2018, 175mm of rainfall had fallen in 10 events, and the millet treatments had regained similar soil water levels to the Control, except the late terminated (rolled) treatment (Photo 2), which now had ~20 mm more stored water.

When the subsequent wheat crop was planted, the mid-terminated millet had ~14 mm more soil water than the Control treatment, the late terminated millet ~19 mm more, and the late terminated and rolled millet ~36mm more soil water (Table 2). Interestingly, water extraction by the wheat crop was greater from all of the millet cover crop plots than the Control, which had poorer establishment and lower yields, and probably reduced root development.

Crop performance

All cover crop treatments increased the yield of the final wheat crop (Table 2). They also required two less fallow weed sprays, a saving of ~$40/ha.

Photo 2. This photo shows the stubble effect three days after ~30 mm of rain at the site. A Late + Rolled treatment is in the foreground with a Control plot visible behind it. The theory is that stubble reduces evaporation and keeps the soil surface wetter for ~21 days, so if more rain falls in that time, more water will be stored.

However, the biggest yield increases were from the cereal cover crops, especially the late-terminated millet and the sorghum. The water differences at end of the fallow may explain some of the observed yield differences. However, the establishment of the wheat crop was also dramatically better after the cover crops, especially where cereals were used (Photo 3).

The expected yield increases from the higher fallow water storage alone would typically be ~200 kg grain in wheat (assuming 15 kg grain/mm water) for the mid-terminated millet (worth ~$50/ha), ~280 kg grain for the late millet (worth $75/ha) and ~540 kg grain for the late +rolled millet (worth $150/ha). These gains would represent net returns of $20/ha, $45/ha and $120/ha respectively. However,

Table 2. Net change in water storage over the life of the fallow (relative to the Control) and final wheat yield for each cover crop treatment at Bungunya shows cover crops can increase stored water.

Cover crop treatment	Terminated	Water gain (cf control)	Wheat yield (kg/ha)
Control (bare fallow) Starting water ~120 mm PAW		42 mm (fallow gain)	1436 f
Millet (White French)	Early	+5 mm	2223 cd
Millet (White French)	Mid	+14 mm	2386 bc
Millet (White French)	Late	+19 mm	2897 a
Millet (White French)	Late + Roll	+36 mm	2565 b
Sorghum	Mid	+17 mm	2634 ab
Lablab	Mid	-4 mm	1795 e
Multi-species (millet, lablab, tillage radish)	Mid	+21 mm	1954 de

the measured yield gains for these same three treatments were 950 kg/ha, 1461 kg/ha and 1129 kg/ha respectively, representing increased returns of between $250 and $380 /ha.

Implications for growers and agronomists

These results show that cover crops can indeed help increase net water storage across fallows with otherwise limited ground cover. How often these soil water results will occur across different seasons will be explored with further experiments and simulation modelling.

More dramatically, these 'initial' results and the impact on the subsequent wheat crop (and cotton at Yelarbon, page 69) are dramatic, and provide big dollar returns; far beyond what could be expected from the increases in net soil water storage across the fallows. Improved establishment of the following wheat crop is an obvious contributor in this experiment. However, there was also greater water extraction from some treatments (especially at depth) in the 'sister' cotton experiment at Yelarbon. How much of the responses can be attributed to these factors, how often such results might occur, and the contributions of different factors remains to be explored.

Acknowledgements

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Trial details

Location:	Bungunya
Crop:	Wheat long-fallowed from skip-row sorghum with White French millet and other cover crops
Soil type:	Brigalow, Brown Vertosol
Rainfall:	332 mm (291 mm Cover/Fallow and 41 mm in wheat)

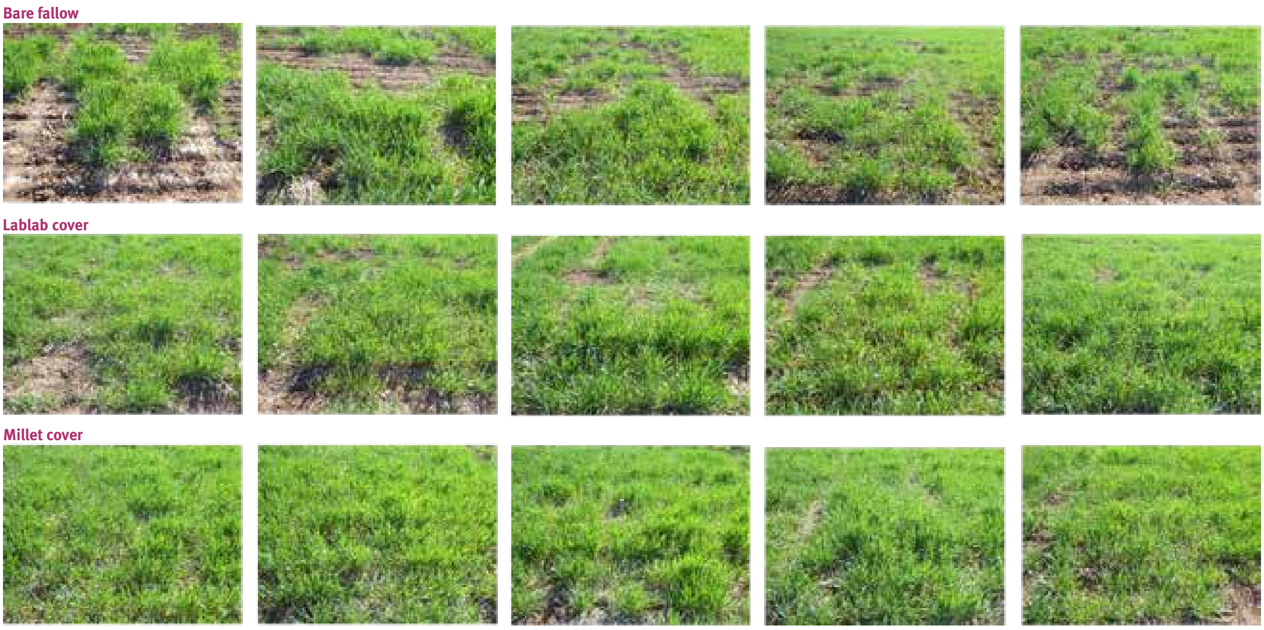

Photo 3. These photos show the poor establishment of the wheat crop following a normal low-cover fallow (Control) and a lablab cover crop, compared to a White French millet cover crop (five photos/reps of each).