# Cover crops improve ground cover in a very dry season

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**Key words**

Cover crops, millet, ground cover, soil water storage, fallow management, stubble, evaporation, infiltration, plant available water

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**Take home messages**

- Previous trials have shown cover crops can increase stored fallow water and improve crop performance and returns in northern farming systems
- A cover crop in a long fallow (14 months) in a dry season allowed improved ground cover with no net deficit in soil water. The extra ground cover improved the opportunity to deep plant wheat.
- A cover crop in a short fallow had a water cost that translated to a yield penalty.
- When the sorghum stopped growing in dry conditions it continued to use water, for no biomass (or cover) increase when it wasn't sprayed out.

## Cover crops in the northern region

After missed or failed crops over recent seasons, ground cover is becoming increasingly important for maintaining fallow efficiency and importantly, for protection from wind and water erosion. Cover crops, sprayed out and left for ground cover, have been used to protect the soil from erosion in low stubble situations, with added benefits of returning biomass that helps maintain soil organic matter and biological activity and provide additional nitrogen when legumes are used. Cover crops also offer an opportunity to increase infiltration and fallow moisture storage for more profitable grain and cotton crops across the northern region of New South Wales (NSW) and Queensland.

## Scientific rationale

### *Stubble and evaporation*

Retained stubble provides ground cover, protects the soil from rainfall impacts and so improves infiltration to store more water in the soil. Conventional wisdom is that increased stubble loads can slow down the initial rate of evaporation, but that these gains are short-lived and often lost due to evaporation, unless follow-up rainfall occurs within several weeks. However, further rain within this period and the manipulation of stubble to concentrate stubble loads provides an opportunity to reduce total evaporation and to accumulate more plant available water.

Advances in agronomy and commercial agronomist support have seen growers better use their available soil water and improve individual crop performance. However, more effective capture and storage of rainfall across the whole farming system remain as major challenges for northern grain and cotton growers where only 20-40% of rainfall is typically transpired by dryland crops, up to 60%

of rainfall is lost to evaporation, and a further 5-20% lost in runoff and deep drainage. Every 10 mm of extra stored soil water available to crops could increase dryland grain yields for growers by up to 150 kg/ha, with corresponding benefits to dryland cotton growers as well.

The GRDC funded Farming systems projects (DAQ00192/CSA00050) are assessing ways to improve this system water use, and to achieve 80% of the water and nitrogen limited yield potential in our cropping systems. Previous GRDC Eastern Farming Systems and Northern Growers Alliance trials both suggest that cover crops and increased stubble loads can reduce evaporation, increase infiltration and provide net gains in plant available water over traditional fallow periods. Consequently, cover crops have potential to be part of improved farming systems; providing increased profitability and better soil protection.

***Dryland grain systems***

Cover crops are used in southern Queensland and northern NSW to overcome a lack of stubble and protect the soil following low residue crops (e.g. chickpea, cotton) or following skip-row sorghum with uneven stubble and exposed soil in the 'skips'.

In long fallows leading to a winter crop, growers typically plant white French millet or sorghum, and spray them out within ~60 days, to allow recharge of the soil water extracted by the cover crop. Allowing these 'cover crops' to grow through to maturity led to significant soil water deficits and yield losses in the subsequent winter crops. However, the Eastern Farming Systems projects showed only small deficits (and even water gains) accrued to the subsequent crops when millets were sprayed out after 6 weeks, with average grain yield increases of 0.36 t/ha in subsequent crops. Furthermore, the Northern Growers Alliance showed that the addition of extra stubble (from 5-40 t/ha) after winter crop harvest appeared to further reduce evaporation, with initial studies showing between 19 mm and 87 mm increases in plant available water. These gains will be valuable if validated in further research and are able to be 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.

**Summary of previous results**

Experiment 1 was a winter cover crop followed by overhead irrigated cotton near Yelarbon. Barley cover crops grew 1.2 t/ha biomass for early spray out and up to 5 t/ha for the late sprayed out barley. The early terminated barley had the most plant available water (PAW) when the cotton was planted, however, the extra resilience of the mid and late terminated barley captured more of the applied water in the soil, once irrigation of the young cotton crop commenced. Cotton yield showed a large benefit in all of the cover crop treatments over the bare fallow (control).

Experiment 2 was a spring cover crop followed by dryland wheat near Bungunya. The millet cover crops at this site produced 1.5 t/ha biomass (early terminated), and up to 4.5 t/ha for the late sprayed crop. The treatments with the most cover (and biomass) had the most stored water at the end of April. With the longer fallow after the cover crop, the early terminated cover crop broke-down before the wheat was planted. In deep planted wheat the treatments with higher ground cover established even wheat stands, while the bare fallow (control) and some treatments with fragile cover had an uneven / gappy wheat establishment. The wheat crop in the bare control yielded 1.4 t/ha, while the wheat following late terminated millet had 20 mm more PAW at planting and a more even wheat stand which enabled it to extract more of the stored water, so had an improved yield of 2.8 t/ha (net economic benefit of $280/ha).

A detailed summary of these trials can be found in Queensland grains research 2018-19: https://www.publications.qld.gov.au/dataset/queensland-grains-research/resource/3865017c-7ebf-40bc-89c9-640829b313c7

Or in a 2019 GRDC Update paper at:

https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2019/03/cover-crops-can-boost-soil-water-storage-and-crop-yields

**Learnings from a dry season**

This paper reports on two dryland sites in southern Queensland in the record breaking 2018/19 drought years.

The first experiment (Yagaburne) was in a long fallow from sorghum to wheat, so the cover crop was planted earlier in the season allowing earlier spray out and a longer fallow period to recharge the soil water used. This experiment had improved planting opportunities with higher ground cover, but no PAW difference at planting, so the evenly established wheat yielded the same in all treatments.

The second experiment (Billa Billa) was in a short fallow from chickpea to wheat. This cover crop was planted later in spring and had a shorter fallow period after spray out to recharge the PAW used by the cover crop. There was a PAW penalty for growing the cover crop in this season, which translated to reduced grain yield.

***Experiment 3 – Yagaburne (Skip-row sorghum, long- fallowed to dryland wheat)***

The Yagaburne experiment was in a long-fallow paddock following skip-row sorghum that was harvested in February 2018. This paddock was a zero till fallow, with standing sorghum and wheat stubble present. There were two times of planting for cover crops, with winter cover crops planted in July 2018 with 65 mm of PAW, and spring cover crops planted in October 2018 with 90 mm PAW. The subsequent wheat crop was planted on 30 May 2019, harvest in October 2019. Soil water was measured at key times with gravimetric soil coring, then more regularly with a neutron moisture meter and EM38. Cover crop biomass, and ground cover was measured at termination of the cover crop and periodically through the fallow. Grain yield of the wheat crop following the cover crop was measured to quantify the value of plant available water (PAW) differences between cover crop treatments.

The winter cover crop was wheat at 100 plants/$m^2$ and winter multispecies cover crop was half recommended rates of wheat, vetch and tillage radish (50, 30 & 20 plants/$m^2$). The summer cover crop was white French millet at 100 plants/$m^2$, sorghum cover crop was a sudan x sudan hybrid at 65 plants/$m^2$, and multispecies was with white French millet, lab lab and tillage radish at half recommended rates (50, 30 & 20 plants/$m^2$) (Table 1).

Three planned termination times matched key growth stages of the main cereal treatments: Early-termination at first node (Z31) when the crop begins stem development; Mid-termination at flag leaf emergence (Z41) when the reproductive phase begins; and Late-termination at anthesis (Z65) for peak biomass production. The site was planned to be planted to wheat in May 2019, but with no planting opportunity and no rain forecast, it was dry planted on 27 May 2019 using the growers single disc planter (33⅓ cm row spacing), with trickle irrigation applied for crop establishment.

**Table 1.** Cover treatments applied at the Yagaburne site prior to planting wheat, biomass at termination of each cover crop (does not include the 1700 kg/ha of residual stubble, centred mostly on the sorghum row, in all treatments including the 'bare control') and percentage ground cover at the last termination date and at the end of the fallow period.

| # | Cover crop | Termination time | Biomass grown (kg/ha) | Ground cover % 5/12/2019 | Ground cover % 2/05/2019 |
|---|---|---|---|---|---|
| **1.** | Bare (control) | | 0 | 8 | 8 |
| **2.** | Wheat | Early-sprayout | 86 | 12 | 11 |
| **3.** | Wheat | Mid-sprayout | 410 | 26 | 24 |
| **4.** | Wheat | Late-sprayout | 697 | 45 | 42 |
| **5.** | Wheat | Late-sprayout + roll | 718 | 50 | 45 |
| **6.** | Winter multi-species (wheat, vetch, radish) | Mid-sprayout | 538 | 38 | 31 |
| **7.** | Millet | Early-sprayout | 527 | 62 | 37 |
| **8.** | Millet | Mid-sprayout | 1412 | 89 | 80 |
| **9.** | Millet | Late-sprayout | 2043 | 94 | 87 |
| **10.** | Millet | Late-sprayout + roll | 1945 | 97 | 84 |
| **11.** | Sorghum | Mid-sprayout | 2551 | 96 | 93 |
| **12.** | Summer multi-species (millet, lab lab, radish) | Mid-sprayout | 1117 | 65 | 46 |

With the late planting date of the winter cover crop the early sprayed wheat grew 86 kg/ha of biomass, which did not provide useful levels of cover (Table 1).

The mid terminated winter cover crop had 36 mm less PAW at termination than planting (Figure 2) for 400 kg/ha biomass. With 50 mm rainfall in October the late terminated wheat was 5 mm drier than at planting with 700 kg/ha of resilient straw. All winter cover crops had recovered to similar PAW as the control when the summer cover crops were planted.

With an extra 90 days and 75 mm rain in fallow, the summer cover crop had 26 mm more PAW than when the winter cover crop was planted. The early, mid and late terminated millet cover crops were 25 mm, 46 mm and 80 mm drier at termination than when they were planted (Figure 2). Biomass produced by the millet was ~ 500, 1400 and 2000 kg/ha for early, mid and late termination respectively (Table 1).

The sorghum cover crop sprayed-out at its mid termination growth stage was sprayed out on the same day as the late terminated millet and used the same volume of water and grew similar biomass as the late terminated millet.

With the dry autumn of 2019, the paddock was assessed on 14 May for the potential to plant wheat across the trial. At ten days after 8 mm rain and 45 days since the last significant rainfall, the conclusion was that only the plots with the highest levels of cover (i.e. greater than 40% cover, but more was better, Table 1), had enough surface moisture to allow an even establishment of wheat. The four treatments with the best cover (mid, late and late + rolled millet and sorghum cover crops), had good moisture for planting; three treatments were too dry (bare control, early and mid wheat cover crops) and the other five treatments would have been a marginal planting opportunity. With no rain received by the end of May and no forecast rain, it was decided to dry plant and apply trickle irrigation to the seed row for crop establishment.

When the wheat 'cash crop' was planted, the bare control had similar PAW as when the trial commenced 11 months earlier after 240 mm rain (580 mm average annual rainfall). Previous trials have shown variability in sampling of +/- 10 mm, so there was no real difference in PAW at this time with the best cover crop treatments having 10 mm more PAW than the control and the worst had 10 mm less than the control. Volumetric soil water post-harvest had a similar spread with the wheat extracting on average 61 mm of PAW from the profile. With only 17 mm of in crop rain the wheat yielded 570 kg/ha.

Two plot header runs were taken for each plot at this site: one over the previous sorghum rows and the other over the skip (Figure 1). There was a consistent yield increase for yield in header runs taken over the old sorghum rows when compared to runs taken over 'the skip row', with an extra 126 kg/ha yield measured on the old sorghum rows versus the skip (632 kg/ha vs 506 kg/ha).

**Figure 1.** Residual stubble at the Yagaburne site at emergence of the winter cover crop and undisturbed on the right.

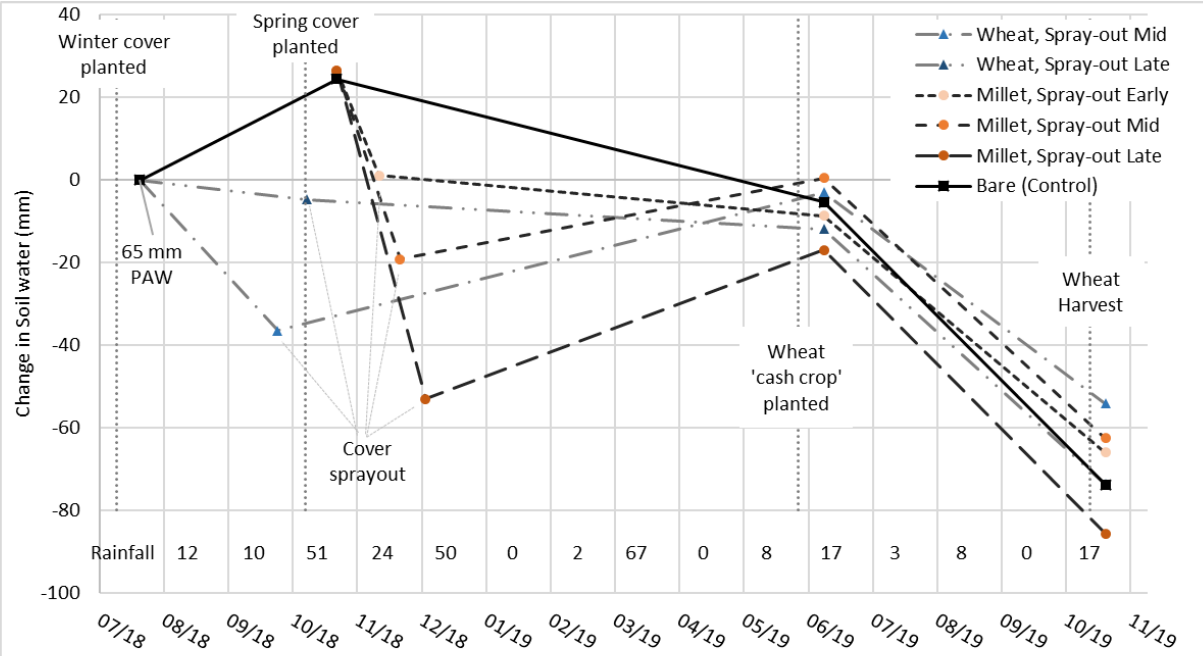


**Figure 2.** Change in plant available water for a range of cover crops at the Yagaburne site, measured with soil cores to 150 cm depth. Grids represent each month and numbers in the bottom row are mm rainfall for that month.

### Experiment 4 – Billa Billa (Chickpea or wheat fallowed to dryland wheat)

The Billa Billa experiment had plots pre-planted to wheat or chickpeas to create areas of high and low stubble cover, with the view to grow cover crops in the low cover plots left by the chickpea crops. The wheat plots were also harvested tall (50 cm) and left standing or rolled or harvested short (25 cm) with tops removed or left as mulch (Table 2).

Wheat and chickpea were harvested on 26 October 2018 and a sudan X sudan hybrid sorghum cover crop was planted a month later with 90 mm PAW. The sorghum established over 100 plants/m$^2$.

Three planned termination times matched to key growth stages were planned similar to previous experiments: early, mid and late. Early termination was sprayed five weeks after planting. With no in crop rainfall and high plant populations, the crop stopped development at second node, so mid termination was sprayed three weeks after the early spray, and late termination was held off until after rain fell, being sprayed 25 March 2019 (four months after planting).

**Table 2.** Crops planted at the Billa Billa trial to generate different cover levels and stubble or cover crop managements imposed in the fallow period.

| Preceding crop | Treatment |
|---|---|
| **Wheat** | Harvest high (50 cm) |
| **Wheat** | Harvest high and rolled |
| **Wheat** | Harvest low (25cm), tops spread |
| **Wheat** | Harvest low, tops removed |
| **Chickpea** | Bare (control) |
| **Chickpea** | Sorghum spray-out early |
| **Chickpea** | Sorghum spray-out mid |
| **Chickpea** | Sorghum spray-out mid + rolled |
| **Chickpea** | Sorghum spray-out late |
| **Chickpea** | Sorghum spray-out late + rolled |

At planting of the cover crop, the wheat stubble plots had 34 mm more PAW than the chickpea stubble plots. From the time of cover crop planting, PAW had decreased by 59 mm to early termination; by 81 mm to mid termination and by 60 mm to late termination (Figure 3). This shows that the sorghum continued to use water after it stopped developing, with minimal increase in biomass (Table 3). Biomass produced by the cover crops averaged 1.3 t/ha for the three termination timings. Whilst this offered a significant improvement in ground cover over the bare control, the cover crops had ~1 t/ha less biomass and ~15% less ground cover than the wheat stubble plots.

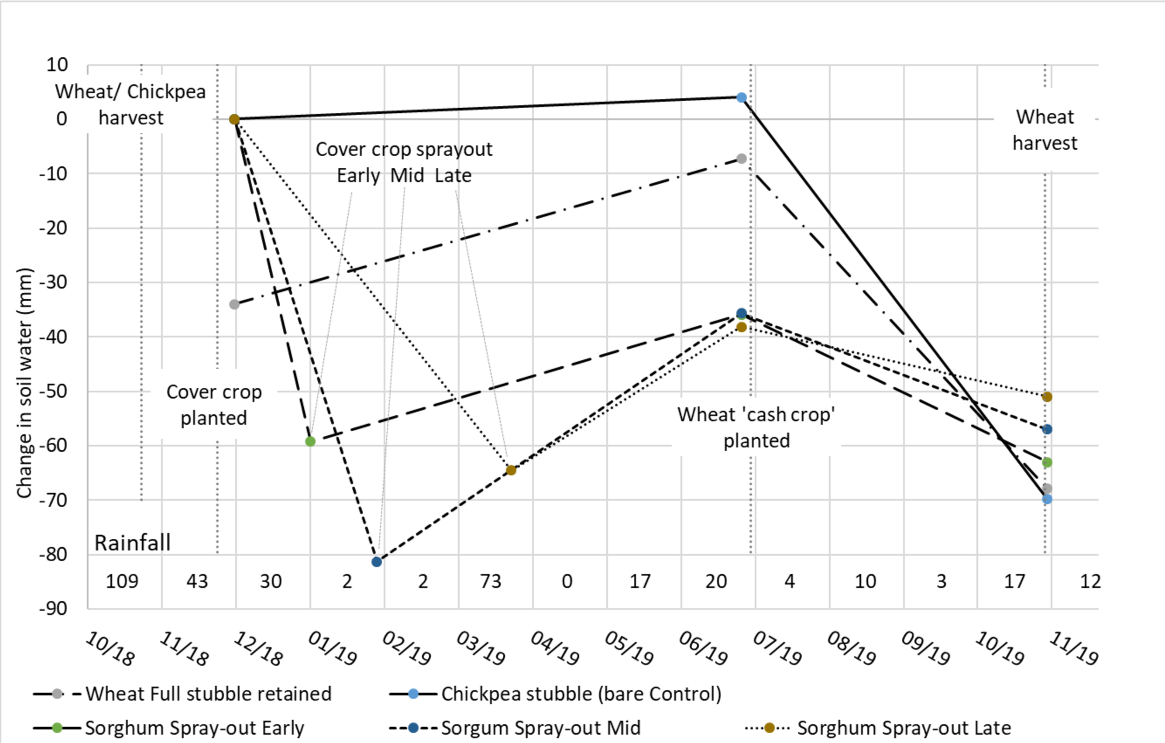


**Figure 3.** Change in plant available water for a range of cover crops measured with soil cores to a depth of 150 cm, at the Billa Billa site. Grids represent 30 days from the first of each month, and numbers in bottom row are mm rainfall for that month. Nb. Wheat stubble plots were 34 mm drier than ex-chickpea plots when cover crops were planted.

**Table 3.** Starting crop and stubble or cover crop treatment, stubble and cover crop biomass and percent ground cover at the end of the fallow period, and grain yield of the following wheat 'cash crop' at the Billa Billa site.

| Preceding crop | Treatment | Biomass (kg/ha) | Cover % 2 May 2019 | Wheat grain yield (kg/ha) |
|---|---|---|---|---|
| Wheat | Harvest high (50 cm) | 2662 | 77 | 526 |
| Wheat | Harvest high and rolled | 2357 | 78 | 566 |
| Wheat | Harvest low (25cm), tops spread | 1800 | 82 | 529 |
| Wheat | Harvest low, tops removed | 1755 | 73 | 551 |
| Chickpea | Bare (control) | 267 | 10 | 727 |
| Chickpea | Sorghum spray-out early | 1270 | 50 | 364 |
| Chickpea | Sorghum spray-out mid | 1419 | 67 | 74 |
| Chickpea | Sorghum spray-out mid + rolled | 1245 | 57 | 61 |
| Chickpea | Sorghum spray-out late | 1732 | 66 | 34 |
| Chickpea | Sorghum spray-out late + rolled | 1106 | 66 | 23 |

With insufficient rain received in May or June and no forecast rain, it was decided to dry plant and apply trickle irrigation to the seed row for crop establishment in the last week of June.

The fallow efficiency of the wheat stubble was higher than that of the chickpea stubble (control) as wheat stubble plots accumulated 23 mm more PAW over the fallow than the control with chickpea stubble. However, with 34 mm more PAW present after chickpea harvest compared to the wheat plots, the wheat stubble still had 11 mm less PAW, when the wheat was planted in June. This trend has also been measured in the farming systems trials, where pulses leave more water at harvest than cereals, but cereals have higher fallow efficiency, and thus reduce the gap by planting of the next crop (or eliminate the gap in non-sodic soils and be ahead after long fallows).

The cover crops recovered some of the water they used with 73 mm of rain in March, but with little rain after this event, the early, mid and late sprayed sorghum cover crops were 25 mm, 44 mm and 48 mm drier than the control when the wheat crop was planted (Figure 3).

The highest wheat yield was achieved by the fallowed chickpea stubble (bare control; 727 kg/ha), followed by the wheat stubble (average 543 kg/ha) and early sprayed cover crop (364 kg/ha). The mid and late sprayed sorghum cover crops had patches of wheat die during the season for final yields of 68 kg/ha and 29 kg/ha (Table 3). Trickle tape irrigation providing even establishment across all plots and with very low rainfall in crop (34 mm) the yield outcomes were directly related to starting PAW. These yields represent an average yield reduction of 11.6 kg/ha for every mm less water the wheat crop used (i.e. planting PAW – harvest PAW + in crop rain) compared to the bare control.

### Conclusions

The project has previously shown that cover crops can indeed help increase net water storage across the fallow and early crop growth in situations that have limited ground cover. We have also seen dramatic yield results for the subsequent cotton and wheat crops, which we attributed in part to more even populations established and greater water extraction.

In this dry season, improving ground cover allowed the opportunity to plant a crop, when the bare plots were too dry. At this longer fallow site (albeit dry) the cover crops recovered most of the water used, so planting with irrigation provided an even establishment and no difference in grain yield was observed.

The short fallow site had a PAW penalty for growing the cover crop and with no extra biomass growth in the later terminations, there was no advantages in persisting with the cover crop once it had stopped development. After an even establishment assisted by irrigation, the grain yield penalty to the wheat 'cash crop' was highly correlated to starting PAW.

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