Department of Primary Industries

Cover cropping in the cotton system to improve infiltration and water holding capacity in red–brown earth soils – Yanco 2019–20

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Key findings

- Cover cropping did not improve cotton yields in this experiment.
- High stubble loads from spraying out the cover crop after the cereals reached growth stage Z39 negatively affected established cotton plant numbers and consequently lint yield.
- Cover crops terminated at growth stage Z39 had no yield penalty, but stored more soil water than the fallow treatment.

Introduction

The aim of growing a cover crop during the winter fallow between summer crops is ultimately to improve soil structure. Cover crops can increase organic matter in the soil, providing increased aeration, aggregate stability, soil water holding capacity, nutrient cycling and erosion control.

This experiment aimed to improve the infiltration and water holding capacity of red–brown earth irrigated by furrow. Previous experiments on this soil type showed the type of cover crop grown has minimal influence on crop yields, however, the amount of biomass produced has an effect.

Establishing a desirable plant stand of cotton hinges on soil temperature, moisture and physical parameters. To ensure a field is suitable to plant cotton, there is great emphasis placed on having a uniform seed bed with the capacity to hold water once irrigated. If cover cropping is to have a place in the cotton system, the land must be prepared before the cover crop is planted. It is essential the field undergoes a no-till system to retain the cover crop and influence the subsequent cotton crop. The cover crop should then be terminated with enough time to establish cotton. The research question now posed is how much biomass needs to be produced to have a positive influence on the above soil parameters that can contribute to an increase in lint yield. In other words, when can a grower terminate the cover crop?

Site details

Location	Yanco Agricultural Institute
Soil type	Red–brown earth
Previous crop	Cotton
Sowing configuration	6 ft beds with John Deere Max Emerge 2 seeder
Mineral nitrogen (N)	114 kg N/ha (0–90 cm) at sowing
Fertiliser applied	• **Cover crop**: 100 kg/ha mono-ammonium phosphate (MAP) at sowing • **Cotton**: 260 kg N/ha as N26 water run in crop and 100 kg N/ha as urea broadcast

This research paper is an extract from the publication *Southern NSW Research Results 2021*, available at https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/southern-nsw-research-results

Australian Government
Cotton Research and Development Corporation

Variety	• **Cover crop**: Eurabbie oats (28%), Compass(ϕ) barley (47%), Morava(ϕ) vetch (19%) and Buster tillage radish (6%). • **Cotton**: Sicot 746B3F

Treatments

All plots (excluding the controls) were sown with the cover crop mixture in June 2019. The cover crops were terminated (sprayed out) as described in Table 1 and cotton was sown over the whole field on 9 October 2019.

Table 1 Spray out treatments and dates of termination.

Treatment	Description	Termination date
Control	Winter fallow	N/A
Early spray out	Cover crop terminated at cereal growth stage Z30 (pseudostem erect)	7 August 2019
Mid spray out	Cover crop terminated at cereal growth stage Z39 (flag leaf ligule visible)	3 September 2019
Late spray out	Cover crop terminated at cereal growth stage Z55 (ear half emerged)	30 September 2019

Results

Cover crop establishment

The cover crop mixture was sown at 80 kg/ha and achieved 200 plants/m^2. Plant proportion favoured cereals (barley and oats) up to 70% while the vetch averaged 14% of the mix and radish 11%. The crop was established on rainfall and was not irrigated through the season.

Cover crop biomass

The early spray out treatment returned 1.53 t/ha of dry matter (DM) consisting of green leafy material at almost complete ground cover and a normalised difference vegetation index (NDVI) reading of 0.8. There was 3.57 t/ha of dry matter produced from the mid spray out treatment, which returned an NDVI reading of 0.72 due to the large proportion of cereals undergoing stem elongation exposing the soil. The last spray out treatment returned an NDVI reading of 0.51 as the crop was drought stressed and undergoing premature senescence. It produced 5.46 t/ha of dry matter and was significantly lignified when terminated.

Cover crop soil water

Neutron moisture meter readings were taken from each plot intermittently throughout the experiment in both the cover crops and the cotton. From this, volumetric soil moisture was estimated and based on the calibration of the crop lower limit and drained upper limit. The plant available water (PAW) capacity was also calculated (Figure 1). Table 2 shows the PAW for each treatment and depth. Soil water just after sowing and at the early spray out treatment was not significantly different between treatments, indicating that the cover crops had not used a significant amount of water. When the mid spray out treatment was applied, the control and early spray out plots were equal. However, the mid and late spray out plots had used more water from the top 35 cm of the soil profile. Furthermore, the late spray out treatment had used the most water to grow the cover crop using 31.15 mm and 17.98 mm of PAW more than the early and mid-spray out treatments respectively.

Soil temperature

Following the cover crop treatment termination the soil temperature was recorded from 10 cm depth. Taken at 8:00 am on 8 October 2019 all plots averaged 19.1 °C. There were no significant differences detected at the alpha level of 0.05 between treatments. Exceeding the safe planting threshold temperature of 14 °C for cotton and having forecast average temperatures on a rising plane it was decided to plant on 9 October 2019. The bay was then irrigated on 10 October 2019 to germinate the seed. The irrigation resulted in an average soil temperature of 17.9 °C (n.s.), dropping by 1.1 °C. This

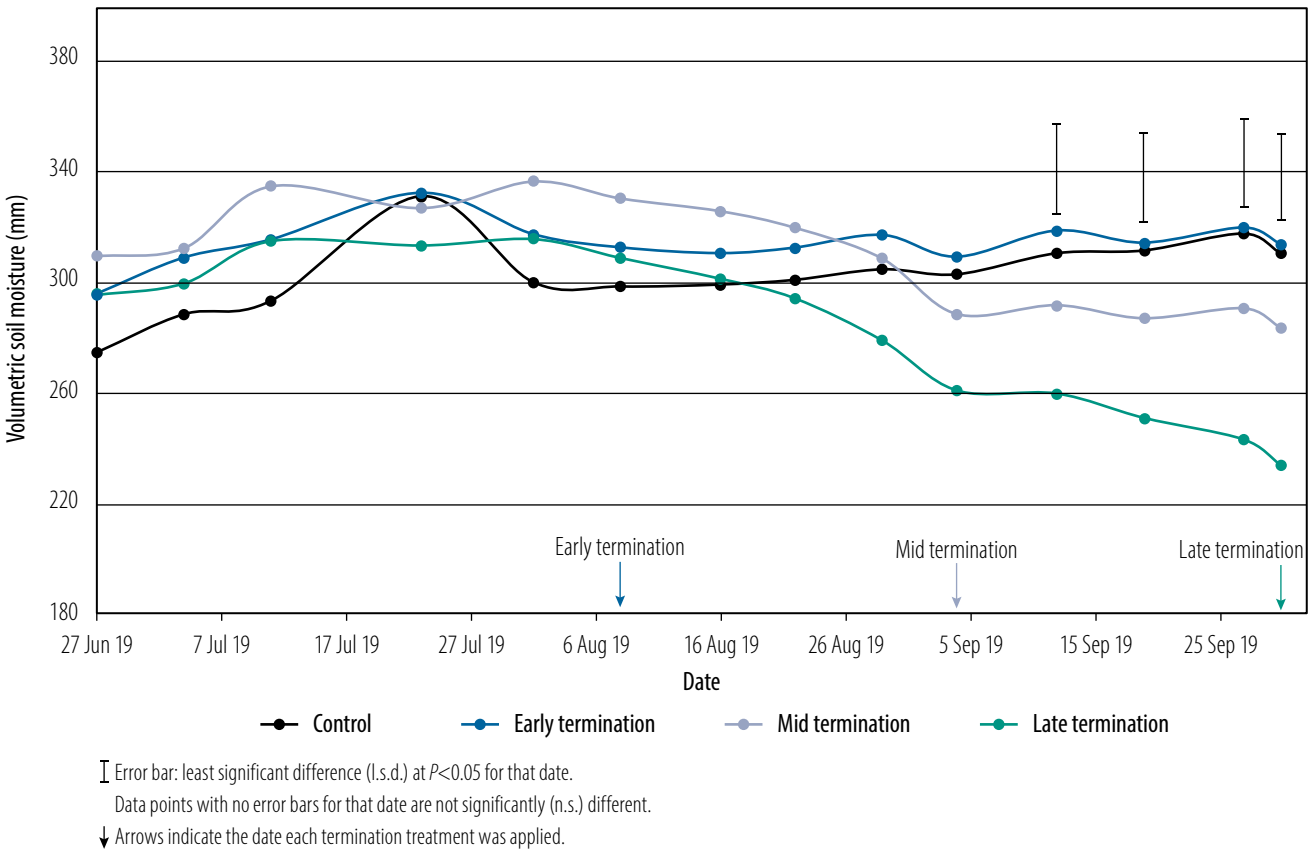
small, insignificant drop in temperature is a function of the red–brown earth lacking clay content and having the ability to heat up faster.

Water run times

At the first irrigation, the time taken for water to reach the end of each furrow was recorded and converted to speed in cm/s. The control, having no cover present in the furrows, allowed the water to travel at a speed of 1.24 cm/s. The early spray out treatment travelled at 0.93 cm/s, which was not significantly different from the control. The mid and late spray out treatments significantly slowed the water speed to 0.56 cm/s and 0.51 cm/s respectively, however, they were not significantly different from each other.

Cotton establishment

From the germination date of 10 October 2019, it took six days for the seedlings to emerge on 16 October. The control, having no cover load present, established the most plants/m^2 averaging 12.83. The early spray out treatment resulted in 11.45 plants/m^2, but was not significantly different from the control. The mid and late spray out treatments established 10.34 and 8.08 plants/m^2 respectively, which differed significantly from the control. The decrease in plant numbers with increasing cover loads is largely due to the stubble and soil moisture content affecting seed placement. The larger cover loads reduced soil water resulting in a very dry seed bed meaning seed placement was variable causing dry down and poor germination.



I Error bar: least significant difference (l.s.d.) at $P<0.05$ for that date.
Data points with no error bars for that date are not significantly (n.s.) different.
↓ Arrows indicate the date each termination treatment was applied.

Figure 1 Volumetric soil moisture of the total soil profile from 0–100 cm for the period that cover crops were growing.

Table 2 Plant available water in millimetres across depth and spray out treatments for the period that cover crops were growing.

Date	Depth (cm)	Plant available water (mm)				
		Control	Early spray out	Mid spray out	Late spray out	l.s.d.
Post sowing 27 June 2019	0–25	37.77	38.01	38.63	38.45	n.s.
	25–35	12.30	12.56	12.58	12.71	
	35–45	7.35	8.60	8.34	8.72	
	45–55	4.34	6.62	6.56	6.79	
	55–65	4.09	5.66	6.24	6.29	
	65–80	9.04	10.53	12.79	11.13	
	80–100	17.65	16.78	19.98	17.15	
	Total	93.23	99.87	105.19	100.07	n.s.
Early spray out 8 August 2019	0–25	38.96	37.46	37.43	36.34	n.s.
	25–35	13.05	12.97	13.15	12.90	
	35–45	8.72	9.11	9.49	9.34	
	45–55	5.77	7.50	8.01	8.17	
	55–65	5.08	6.78	7.63	7.32	
	65–80	10.48	12.52	14.59	12.40	
	80–100	18.82	18.23	21.40	18.09	
	Total	101.70	105.50	111.70	103.60	n.s.
Mid spray out 4 September 2019	0–25	38.55	37.54	29.37	27.98	2.882
	25–35	13.06	12.70	9.78	9.29	
	35–45	8.37	8.83	6.97	6.72	
	45–55	5.55	7.13	6.28	5.80	
	55–65	5.36	6.67	7.10	6.18	
	65–80	10.96	12.48	14.38	11.49	
	80–100	19.63	18.42	21.26	18.23	
	Total	103.33[b]	104.47[b]	95.12[ab]	85.01[a]	12.224
Late spray out 30 September 2019	0–25	37.36	37.30	26.80	23.80	2.964
	25–35	13.05	12.74	9.15	7.74	
	35–45	8.41	8.83	6.88	5.47	
	45–55	6.13	7.42	6.11	4.38	
	55–65	5.96	6.91	7.10	5.01	
	65–80	11.95	13.10	14.75	10.43	
	80–100	20.19	19.10	22.26	18.20	
	Total	105.42[bc]	105.93[c]	92.76[b]	74.78[a]	11.676

Least significant difference (l.s.d.) *P*-value <0.05 presented on the interaction between spray out treatment × depth and separately for total.
n.s. = not significant.
Letters presented on means of the total profile indicate which treatments differ significantly from each other.

Cotton biomass

Each plot was assessed for squaring date and a biomass sample taken. Across all treatments the date of first square averaged 17 December 2019 (n.s.). The biomass was heaviest for the control, achieving 687.7 kg DM/ha (Table 3). The reduced biomass recorded for the early spray out treatment was not significantly different from the control. The mid and late spray out treatments had accumulated 427.4 and 358 kg DM/ha respectively and differed significantly from the control, but not from each other.

The first flower date was recorded as 17 January 2020. The differences identified at first square mainly resulted from the established plant numbers and were still evident at flowering with almost 1200 kg DM/ha difference between the control and the late spray out treatment.

By defoliation there were no significant biomass differences between treatments and the biomass averaged 15,024 kg DM/ha. Cotton is very good at compensating growth and maximising the available space and water by producing vegetative branches. First pass defoliation was applied on 15 April 2020 and the crop required three defoliations to drop leaf and open bolls.

Table 3 First square and first flower biomass taken across each treatment.

Treatment	Biomass first square (kg DM/ha)	Biomass first flower (kg DM/ha)
Control	687.7	4600
Early spray out	544.7	4111
Mid spray out	427.4	3843
Late spray out	358.0	3410
l.s.d. (P<0.05)	147.52	711.8

l.s.d. = least significant difference.

Cotton soil water

Once the cotton was planted and flushed up, the soil water deviations seen at the end of the cover cropping period were eliminated. There were no significant differences between treatments for PAW until flowering when the crop started using large amounts of water. Both the mid and late spray out treatments measured more water in the profile compared with the control and early spray out treatments (Figure 2). This can be explained by the reduced plant stand in both treatments as there were not enough plants to extract the available moisture present in the profile. It could also be a function of the cover crop residues improving water infiltration under irrigation, however, these inferences cannot be assumed in this experiment.

Towards the end of the season the control and early spray out treatments started to extract moisture from depth more than the mid and late spray out treatments (Table 4). The higher plant stands in these treatments probably resulted in the crop depleting soil moisture sooner than the mid and late spray out treatments, forcing root growth to explore the soil profile in search of moisture.

Changes in PAW over time (Figure 3) shows the additions and depletions of soil water from sowing the cover crop to defoliating the cotton. The extraction of soil water from the spray out treatments is clearly depicted here and reflects the total soil moisture data presented in Figure 1. Once the cotton crop was irrigated to germinate the planted seed, all treatments returned to an equal level of soil moisture. Once the crop started extracting larger amounts of water it was evident that there was a treatment effect. As mentioned above, this treatment effect could be a function of improved infiltration or poor plant stand.

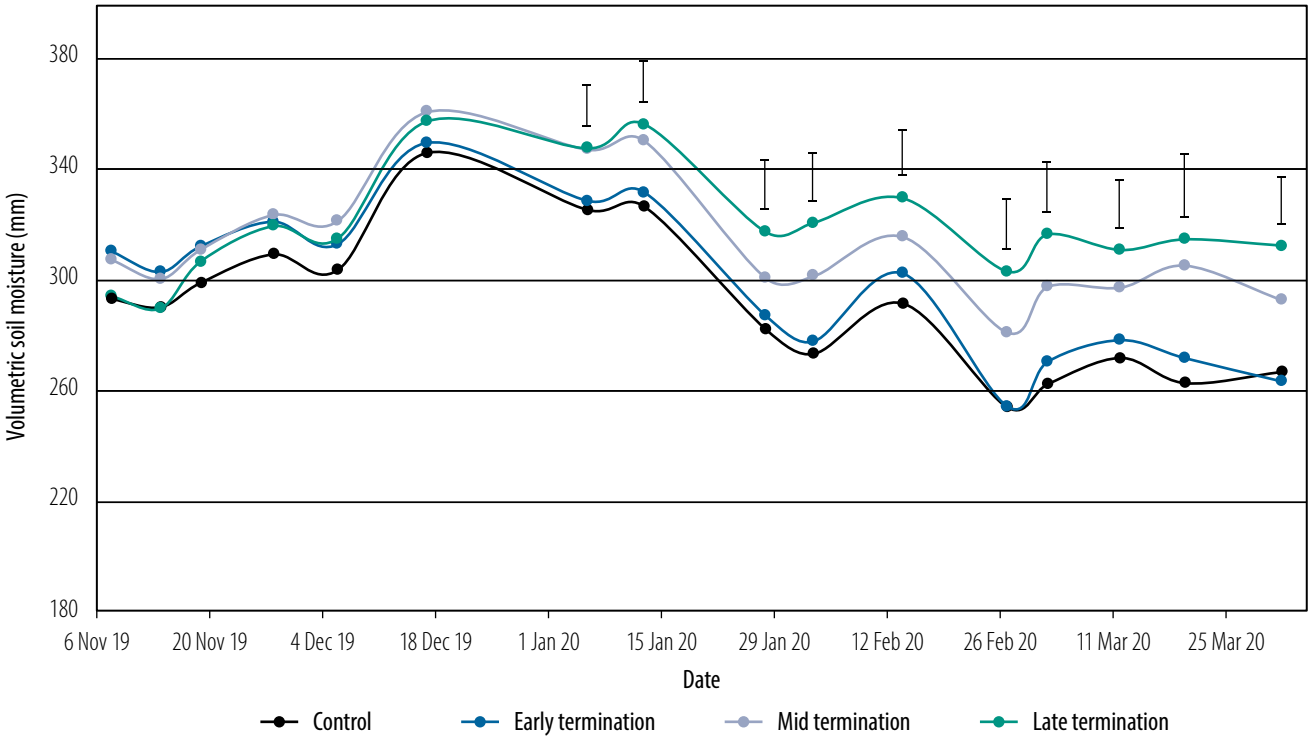


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Figure 2 Volumetric soil moisture of the total soil profile from 0–100 cm for the period that the cotton crop was growing.

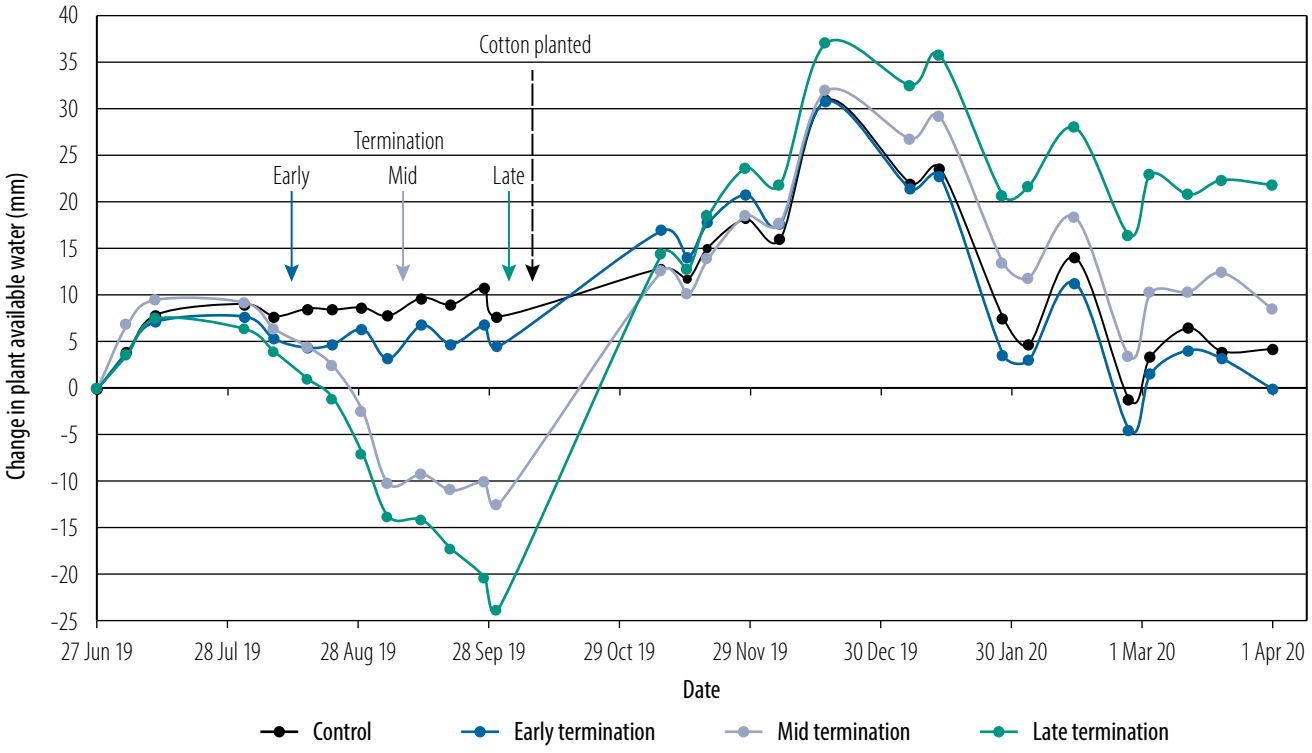

Figure 3 Change in plant available water (PAW) during the cover crop growth period and during the cotton season.

Table 4 Plant available water in millimetres across depth and spray out treatments for the period that the cotton crop was growing.

Date	Depth (cm)	Plant available water (mm)				
		Control	Early spray out	Mid spray out	Late spray out	l.s.d.
Early season growth 8 November 2019	0–25	39.20	38.59	39.53	39.93	1.268
	25–35	12.66	13.06	13.12	13.58	
	35–45	9.26	9.83	9.82	9.98	
	45–55	8.22	9.43	9.19	9.20	
	55–65	8.29	9.41	9.25	8.32	
	65–80	15.06	16.70	16.38	14.07	
	80–100	19.69	21.25	20.13	18.31	
	Total	112.7	118.4	117.6	113.0	n.s.
First square 17 December 2019	0–25	41.20	39.60	41.41	41.27	n.s.
	25–35	14.35	14.18	14.69	14.78	
	35–45	10.91	11.14	11.40	11.54	
	45–55	10.92	11.18	11.25	11.48	
	55–65	10.71	11.08	11.28	11.19	
	65–80	19.16	19.77	20.56	20.02	
	80–100	24.46	25.41	26.16	25.23	
	Total	131.6	132.4	136.8	135.5	n.s.
First flower 13 January 2020	0–25	36.04	36.93	38.65	39.75	n.s.
	25–35	12.04	12.68	13.39	14.34	
	35–45	9.88	10.17	10.76	11.38	
	45–55	10.37	10.40	11.08	11.44	
	55–65	10.33	10.70	11.16	11.57	
	65–80	19.25	19.23	20.47	20.47	
	80–100	25.42	25.71	26.19	25.95	
	Total	123.4[a]	125.4[a]	132.4[b]	134.7[b]	5.52
Defoliation 1 April 2020	0–25	37.28	37.45	38.66	40.47	n.s.
	25–35	10.44	11.34	11.92	13.02	
	35–45	6.77	8.27	8.08	9.48	
	45–55	5.73	6.81	7.13	8.80	
	55–65	7.40	7.03	7.85	8.87	
	65–80	14.39	12.66	15.84	16.81	
	80–100	21.18	20.18	22.33	22.32	
	Total	103.7[a]	102.3[a]	113.0[b]	120.0[b]	6.442

Least significant difference (l.s.d.) *P*-value <0.05 presented on the interaction between spray out treatment × depth and separately for total.
n.s. = not significant.
Letters presented on means of the total profile indicate which treatments differ significantly from each other.

Soil nitrogen

No significant difference in soil N was identified between cover crop spray out treatments. On average, there was 112 kg N/ha from 0–90 cm when the cover crops were sown. After all cover crops had been terminated, the soil was again analysed for N before cotton was planted. At this time there was 16 kg N/ha to 90 cm depth. The cotton crop was supplied with 360 kg N/ha via water run and broadcast methods and on average the soil retained 57 kg N/ha to 90 cm after crop destruction.

Yield

Machine-picked lint yields were above the district average of 11 bales/ha and, given the difficult season, the crop performed well. Lint yields harvested across all treatments had a 1.76 bale/ha decrease from the control (highest yielding) to the late spray out treatment (lowest yielding). All other treatments did not vary significantly from the control of 13.79 bales/ha (Table 5).

This negative yield response to the increased amount of biomass from a late spray out is likely to result from reduced establishment. Plant numbers per metre dropped 4.75 by spraying out late compared with the control. Similarly, the mid spray out treatment yielded statistically the same as the control and yet the number of plants established per meter in this treatment dropped by 2.49 from the control. It can be assumed that the plant compensatory growth under these circumstances can compensate for a loss of 2.5 plants/m, but fails to achieve the same yield potential with only 8.1 plants/m.

Table 5 Lint yields picked from each of the treatments expressed as 227 kg bales per hectare.

Treatment	Lint yield (bales/ha)
Control	13.79 (100) [a]
Early	13.56 (98) [a]
Mid	13.49 (98) [a]
Late	12.03 (87) [b]
l.s.d. ($P<0.05$)	1.242

Figures in parentheses indicate the percentage of control.
Letters presented indicate which treatments differ significantly from each other.

Summary

There were no benefits of cover cropping reflected in cotton yields after just one season. It is safe to assume that the improvement of soil structure and health takes longer than 12 months to have a significant influence on crop yields. The best performing treatment was the mid spray out treatment where the cover crop was terminated at growth stage Z39 and produced 3.57 t/ha of dry matter. The yields in this treatment were not significantly different from the control. It slowed the movement of water through the furrow and resulted in more PAW towards the end of the cotton season. Given the availability of water and assuming no other limiting factors, if the number of established plants per metre could be compensated for with a higher sowing rate, then the yields under this system could potentially be improved above the control.

Acknowledgements

This experiment was part of the 'Cover crops in grain and cotton farming systems' project, DAQ00211, 2018–21, a joint investment by the Cotton Research and Development Corporation (CRDC), NSW DPI, GRDC and the Queensland Department of Agriculture and Fisheries (QDAF).

Thanks to the technical assistance of Alan Boulton, John Dando and Sam Hopper.

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