TECHNICAL REPORT

Maximising Benefit From Crop Residues: Practical stubble retention practices in mixed farming systems of WA

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Summary

This project assessed the potential of innovative stubble retention practices to both enhance crop productivity through improved soil physical, chemical and biological processes and simultaneously address stabilisation of soil carbon content to improve soil health. Stubble retention with fish hydrolysate application compared to a burned control showed positive impacts on crop yield. Understanding the processes that occur beneath the soil surface with microbial biomass in soil and mycorrhizal colonisation in roots in unburned crunched stubbles with fish hydrolysate application will be key information to extend to the farming community to assist with farming management practices. Use of fish hydrolysate in crunched stubbles is a very new technique and the mechanism of action of fish hydrolysate on crunched stubbles decomposition was not studied in this trial. Therefore, a further study of these practices will support these results and add to the development of adoption-ready, locally-specific resources for farmers in the south west region of Western Australia .

Introduction

In low-rainfall dry-land agricultural cropping systems, typical in Western Australia (W.A.), a significant part of the year is associated with little or no plant growth, and microbial activity in the soil is limited by the absence of water and low readily available carbon (Hoyle and Murphy 2006 and other references stated in this manuscript). This is also due to no summer cropping and no plant cover for the remainder of the year with only stubble left remaining after crops are harvested, and due to the germination of opportunistic summer weeds. Traditionally, benefits associated with lower stubble loads such as reduced disease carry over, enhanced weed control, increased availability of nutrients, reduced soil erosion, and easy access of seeding equipment, have resulted in the adoption of stubble burning as a management tool. However, the loss of organic residues via stubble burning has also been associated with longer term nutritional and chemical imbalances in soil, which are often expressed in subsequent crops. In response to this perceived decline in soil organic matter fertility, strategies such as stubble retention and reduced tillage have evolved and become more widely adopted in W.A. farming systems to increase the amount of labile carbon in soil, and provide a suitable substrate to promote microbial growth and activity. Powlson et al. (1987) demonstrated in a long-term study that total soil organic carbon increased by only 5% despite high plant biomass returns of straw and stubble, whilst microbial biomass carbon increased by 37–45%. In contrast, Carter and Mele (1992) demonstrated no change in total soil organic carbon in retained versus burnt stubble treatments under high crop stubble loads (4–6 t/ha) in north-eastern Victoria. The capacity for changes in total soil organic carbon to occur in the low-input, rainfall-limited system of WA, particularly given that a significant proportion of the total plant biomass (14–38%) that may be contributed from below ground (i.e. roots) is actually retained at harvest (Atwell et al. 2002) has been questioned. Management strategies such as stubble retention have been shown to influence the capacity of a soil to changes in the functional diversity of the microbial community (Bending et al. 2002).

The aims of this study were therefore to assess changes in the physical, chemical and biological (microbial biomass and mycorrhizal fungi) properties and crop yield associated with (i) stubble burning and (ii) stubble retained and crunched an application of fish emulsion on a low-fertility, loamy sand soil in W.A.

Materials and Methods

This project was conducted on one farm at Boyup Brook, W.A. with a cropping rotation of barley/canola/oats. The 6 trial plots consisted of three replicates of two treatments: (1) control (C) - field burn of stubble (common practice), and (2) treatment (T) – stubble crunch (innovative practice) and retain along with fish hydrolysate application at (10 L/ha) (see Fig. 1). Before applying treatments, physical assessments such as % vegetation cover and stubble dry mass were observed, photo monitoring was undertaken and an average yield of earlier records of whole paddock crop was attained. Stubbles of barley crop of 2014 were burned for control on 22 April 2015 before canola seeded and other management practices were carried out as shown in Table 1. Canola stubbles were not burned for the control before oats seeded on 10 May 2016. Soil properties were determined by using basic methods used in Australia for soil analyses (Rayment and Lyons 2010). Soil microbial biomass was determined using the method of Vance et al. (1987). Mycorrhizal colonisation in oats root was determined by gridline intercept method (Solaiman and Abbott 2008).

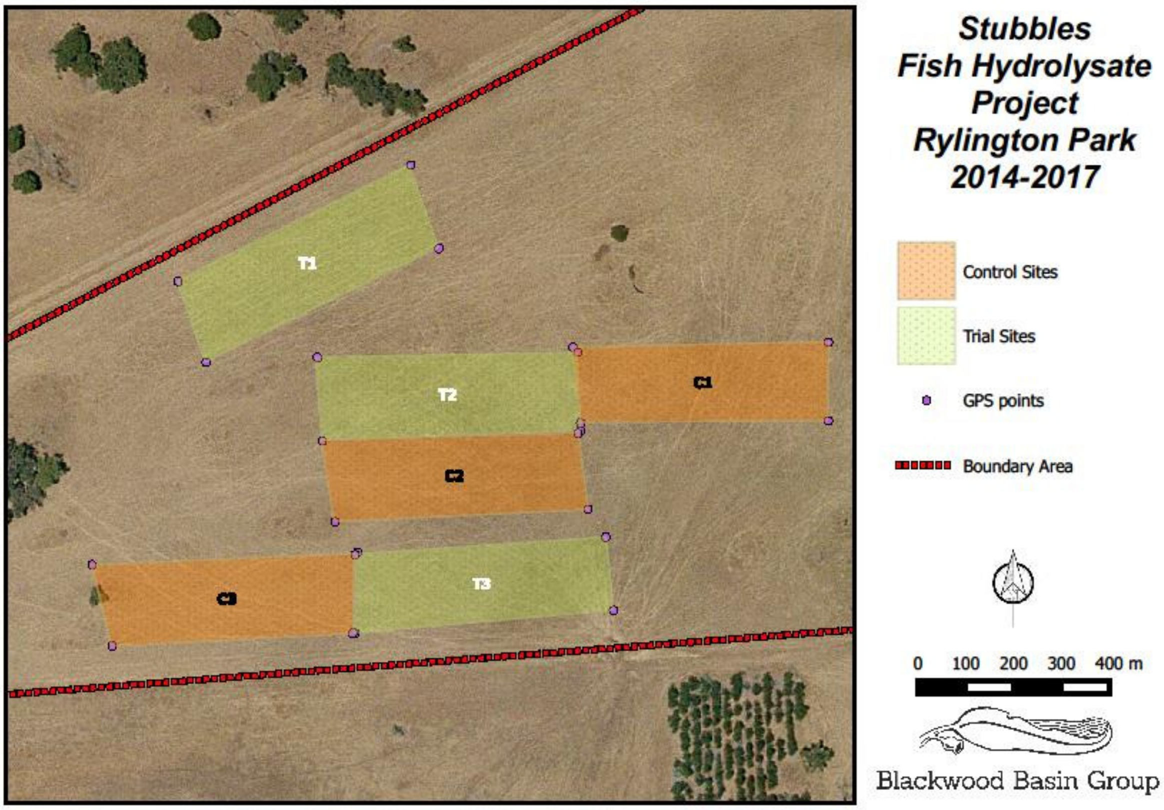


Fig. 1 Field trial layout with three replicated plots at Rylington Park, Boyup Brook, Western Australia

Table 1. Trials setup timings and management practices carried out

Timing and practices	
19/12/14	Harvested barley - approx. 3.4 - 5.1 t/ha stubble
23/12/14	Soil sampled
12/01/15	Sprayed Fish strips
19/01/15	274 Ewes into paddock
15/04/15	Ewes out
22/04/15	Burned control strips
	Spread 150 kg SoA
24/04/15	Soil Sampled
11/05/15	Sprayed Knockdown
	Seeded Canola with 80 kg Agflow Manganese
14/05/15	Sprayed Herbicide Insecticide
30/06/15	Sprayed Herbicide Insecticide
01/12/15	Canola Harvest
03/12/15	Soil Sampled
9/12/15	Sprayed Fish Strips
10/12/15	455 Ewes into paddock

04/01/16	Ewes out
21/04/16	Sprayed knockdown
22/04/16	Soil Sampled
22/04/16	Spread 150kg SoA
10/05/16	Spray pre sowing
10/05/16	Seeded Williams oats @ 100 kg/ha
30/06/16	Spray herbicide and fungicide
16-20/11/16	Cut and raked hay (not plots)
23/12/16	Harvested oats
24/12/16	Final Soil Sampling

Results

Grain yield of canola and other quality attributes (moisture, oil and protein content) did not differ between burned (control) and treatment with crunched stubbles along with fish hydrolysate (Table 2a) as well as oats grain weights, hectolitre, screenings and protein content (Table 2b). Mycorrhizal colonisation in oats roots was increased in treatment plots over control (Table 2b).

Table 2. Effect of burned and unburned stubbles on (a) canola grain weight, moisture, oil and protein content (harvested in December 2014) and oats grain weight, hectolitre, screenings and protein content (harvested in December 2016); and (b) mycorrhizal colonisation in oats root; lsd, least significant difference used for mean comparisons at $p<0.05$

(a) Canola 2015

Treatment	Grain weight (kg/ha)	Moisture (%)	Oil (%)	Protein (%)
Control	630±23	5.6±0.1	49.0±0.6	18.1±0.5
Treatment	646±54	5.4±0.1	49.3±0.1	18.1±0.2
lsd	ns	ns	ns	ns

(b) Oats 2016

Treatment	Grain weight (kg/ha)	Hectolitre (kg/hL)	Screenings (%)	Protein (%)	Mycorrhizal colonisation (%)
Control	1614±24	233±5.5	9.6±0.9	8.1±0.3	12.3±0.5
Treatment	1753±208	238±3.7	7.8±0.5	8.2±0.4	18.6±0.7
lsd	ns	ns	ns	ns	2.4

Soil physical properties did not significantly differ between burned (control) and treatment with crunched stubbles along with fish hydrolysate (Table 3a,b) in the same sampling depth, with the exception of soil moisture which was higher in treatment than control in 10-20 cm depth. All physical properties were also not significantly different between the start of experiment (December 2014) and the end of experiment (December 2016).

Table 3. Effect of burned and unburned stubbles on soil physical properties (a) before start of experiment and (b) at end of experiment; lsd, least significant difference used for mean comparisons at p<0.05

(a) December 2014

Treat	Depth cm	Moisture %	BD g/cm^3	Gravel %	Clay %	Silt %	Sand %
C1	0-10	1.5	1.2	58.4	7.2	12.0	80.8
T1	0-10	1.8	1.3	63.5	7.5	11.8	80.8
C2	10-20	2.5	1.3	65.9	7.0	8.7	84.3
T2	10-20	4.1	1.3	63.7	7.9	8.0	84.0
lsd p<0.05		0.8	0.04	3.3	1.5 ns	1.1	1.9

(b) December 2016

Treatment	Depth cm	Moisture %	BD g/cm^3	Gravel %	Clay %	Silt %	Sand %
C1	0-10	2.9	1.2	59.5	7.2	12.1	80.7
T1	0-10	2.6	1.3	57.7	7.5	10.8	81.7
C2	10-20	3.4	1.4	72.7	6.9	8.4	84.7
T2	10-20	5.0	1.3	63.4	7.9	8.6	83.5
lsd		0.6	0.1	6.6	0.4	1.3	1.2

Fractionations of soil carbon such as particulate, humus and stable carbon were differed between soil depths (Table 4). All fractions of carbon were higher in control (burned) compared to treatment plots as well as decreased from the start of experiment to the end of experiment specially humus and stable carbon fractions.

Table 4. Effect of burned and unburned stubbles on soil carbon fractions (a) before start of experiment and at (b) end of experiment; lsd, least significant difference used for mean comparisons at p<0.05

Treat	Depth	Particulate C (%)		Humus C (%)		Stable C (%)	
	(cm)	2014	2016	2014	2016	2014	2016
C1	0-10	1.9	2.1	2.6	2.0	1.4	0.8
T1	0-10	1.7	1.8	2.1	1.4	1.1	0.6
C2	10-20	1.0	0.5	1.9	0.5	0.9	0.2
T2	10-20	1.5	0.6	1.7	0.5	1.0	0.2
Lsd		0.2	0.2	0.4	0.2	0.1	0.1

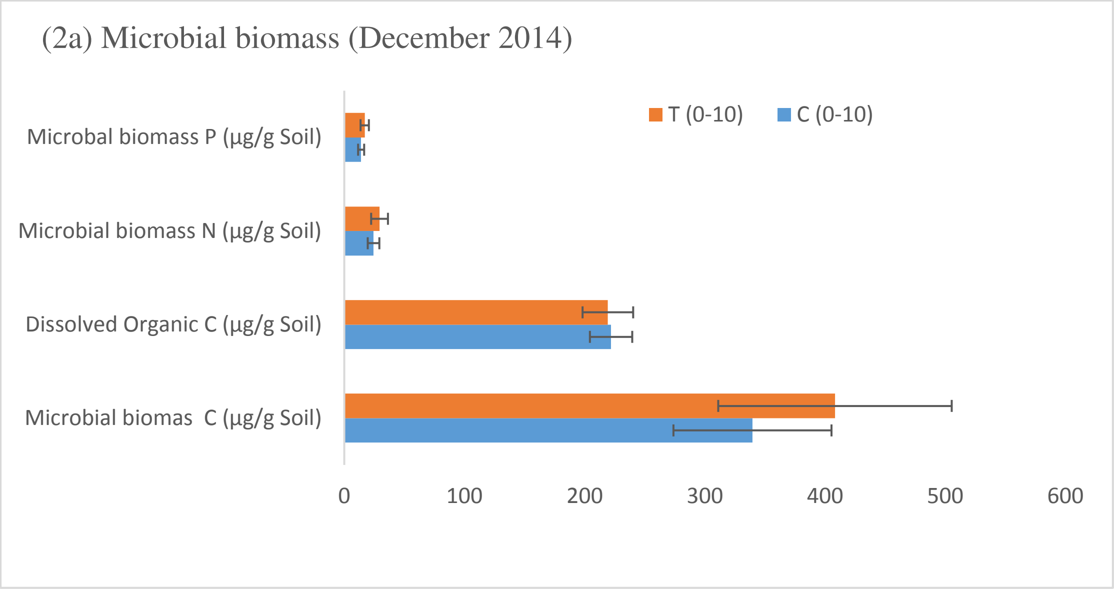
Soil pH and nutrients concentrations were not significantly different between two practices (burned and unburned) both in year 2014 and 2016 except in lower depth (10-20 cm) in 2016 where the most nutrient concentrations were lower compared to the year 2014 (Table 5).

Table 5. Effect of burned and unburned stubbles on changes of soil properties before start of treatment (December 2014) and at the end of experiment (December 2016)

Soil parameter	Soil depth (0-10 cm)				Soil depth (10-20 cm)			
	2014		2016		2014		2016	
	Treat	Control	Treat	Control	Treat	Control	Treat	Control
Soil pH (H_2O)	6.5±0.1	6.6±0.0	6.4±0.1	6.5±0.1	6.6±0.0	6.3±0.0	6.5±0.1	6.4±0.1
NO_3 (mg/kg)	18.8±3.7	17.1±2.0	12.0±2.2	11.8±0.5	12.3±3.3	12.0±2.5	2.8±0.8	3.4±0.1
NH_4 (mg/kg)	5.4±0.2	5.4±0.9	5.8±0.2	6.6±0.5	4.0±0.2	3.8±0.7	4.9±0.2	6.2±0.8
Total N (%)	0.25±0.0	0.26±0.0	0.21±0.0	0.22±0.0	0.19±0.0	0.18±0.0	0.07±0.0	0.07±0.0
Total C (%)	3.6±0.1	4.1±0.7	3.7±0.3	3.7±0.7	2.8±0.5	2.7±0.3	1.3±0.3	1.4±0.1
C/N ratio	14.7±0.3	15.1±0.5	16.1±0.3	17.5±0.3	15.6±0.1	16.3±0.6	20.1±0.2	21.0±0.6
Colwell P (mg/kg)	81.7±10.3	87.0±7.2	75.6±4.7	106.1±1.1	63.3±3.1	68.2±3.9	42.3±13.1	48.2±1.7
Colwell K (mg/kg)	91.6±8.8	84.7±3.1	90.9±4.6	130.2±7.2	67.6±11.2	68.8±7.8	43.5±7.8	47.5±4.8
Available S (mg/kg)	15.5±1.7	17.7±2.2	19.9±2.3	19.0±1.1	16.1±1.0	15.3±2.6	20.6±3.8	19.5±2.1
Exchangeable Zn (mg/kg)	2.5±0.4	2.9±0.4	2.7±0.5	3.7±0.5	2.1±0.3	1.8±0.4	1.2±0.5	1.4±0.2

Microbial biomass carbon, nitrogen and phosphorus including dissolved organic carbon were not different between selected plots for burned control (C) and treatment (T) with crunched stubbles along with fish hydrolysate (Fig. 2a, December 2014) as well as after application of both practices (C and T) before sowing of canola.

Microbial biomass carbon, nitrogen and phosphorus were higher in treatment (T) with crunched stubbles along with fish hydrolysate over burned control (C) after canola harvest (Fig. 3a, December 2015); dissolved organic carbon did not differ between practices. The effect of treatment (T) disappeared after oats were harvest in April 2016 (Fig. 3b). In contrast, control burned (C) has higher biomass nitrogen and phosphorus.



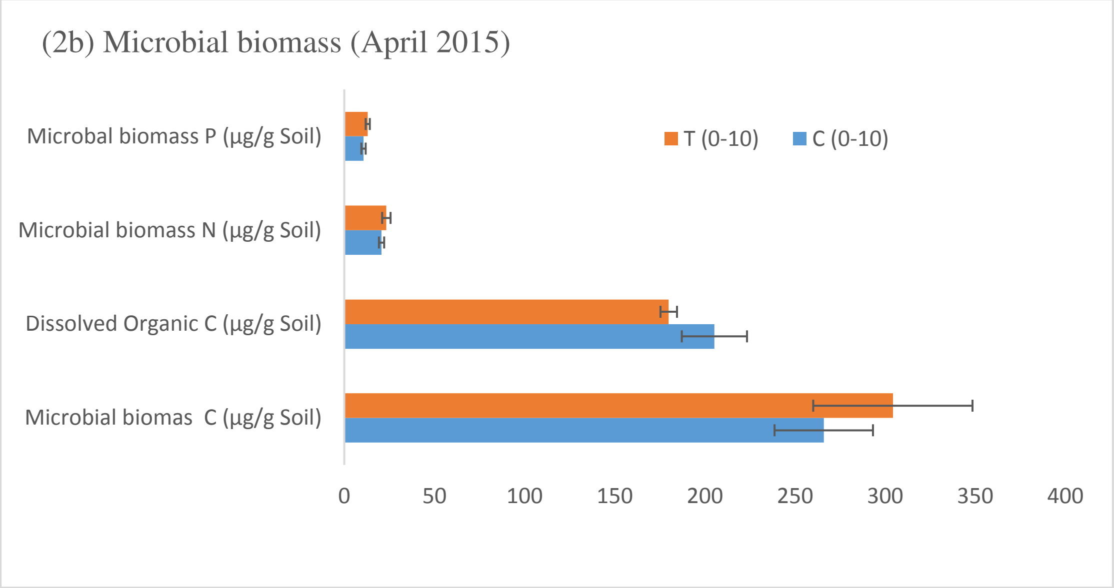


Fig. 2 Effect of burned and unburned stubbles on microbial biomass and dissolved organic carbon; (a) before start of experiment (December 2014) and (b) after applying treatment for canola cultivation (April 2015).

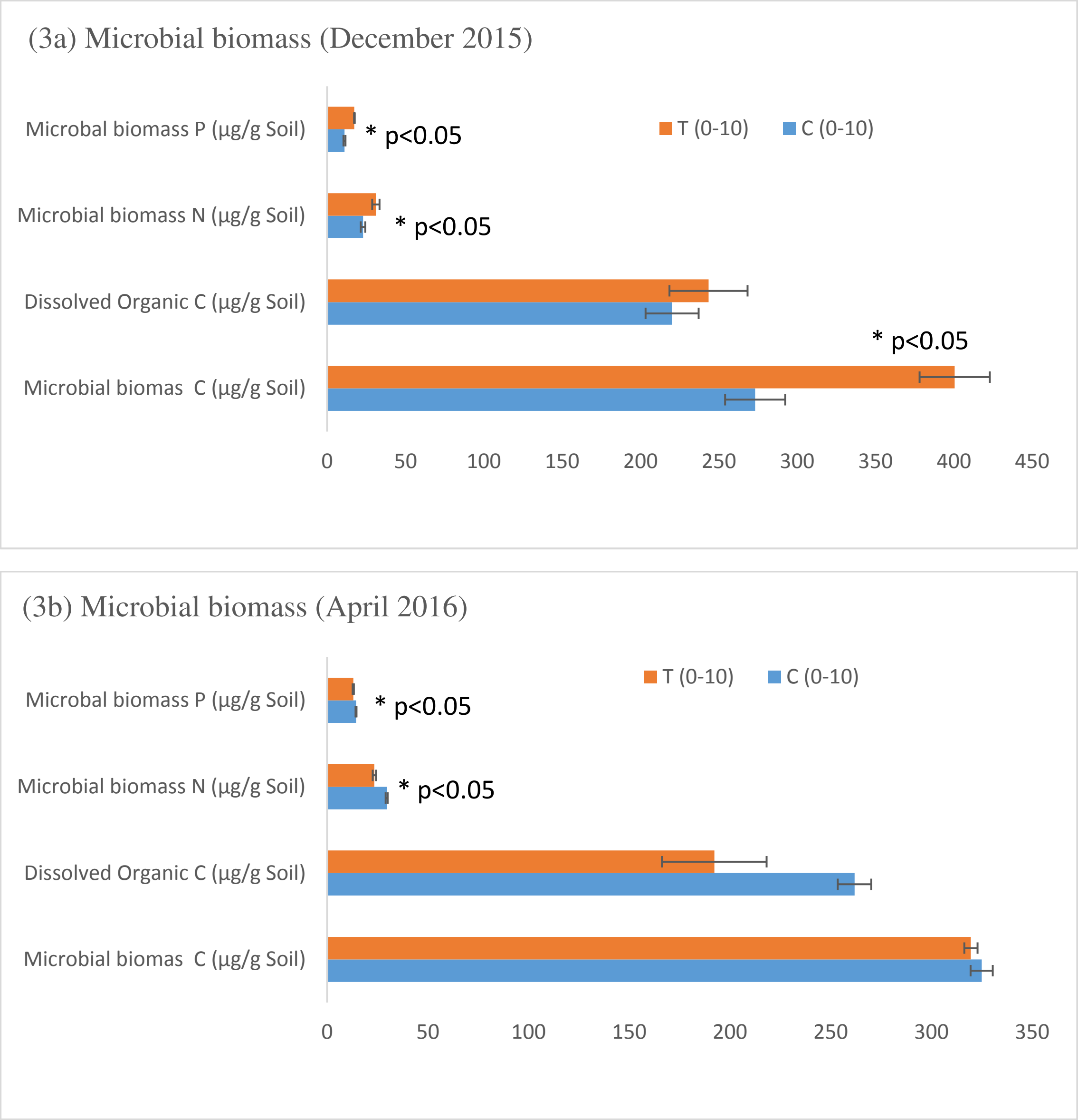


Fig. 3 Effect of burned and unburned stubbles on microbial biomass and dissolved organic carbon; (a) after canola harvest (December 2015) and (b) after oats harvest (April 2016).

Discussion

The magnitude of the stubble retention issue is demonstrated by the South West W.A. being well below state levels of 'businesses leaving or modifying crop residues through such practices as mulching'. Furthermore, there is limited robust information available specific to the local region and conditions to increase these adoption rates. Some reports stated that unburnt soils contain higher amounts of carbon and nitrogen, and much more phosphorus than burnt soils, in addition to increasing the microbial biomass (Hoyle and Murphy 2006 and others references stated in this manuscript). Hence, reducing field burning activities by increasing adoption of stubble retention methods is expected to reduce soil and nutrient loss through wind and water erosion, while improving soil condition including acidity and microbial activity through greater resource utilisation. The current field trial showed microbial biomass increase in stubble crunch along with fish hydrolysate over burned control in canola cultivated plots. When canola stubbles were not burned after harvest, microbial biomass carbon was similar in both practices. This suggests that burned control can reduce microbial biomass carbon as seen in many other reports (Hoyle and Murphy 2006 and other references cited in this manuscript). Canola grain weight and oil content were same in both practices. While these effects were also the same for the oats, mycorrhizal colonisation was increased in treatment over burned control and this has supported by an earlier study (Borie et al. 2006).

Lime was applied in April 2014 which may have had some residual effect on soil pH and total carbon concentrations. The three replicated plots layout resulted in some obvious influence on the results which showed up as lower yields, but contrastingly higher biomass carbon. This may be attributed in part to a more moisture held in the soil (helped biology) and a higher weed burden which impacted on yield.

There should have been two burns conducted in this trial. This appears to have had a significant impact on the results. Only the first burn was conducted in April 2015 on the barley stubble (pre canola crop), but not in 2016 on the canola stubble at pre oat crop (ideally this would have been a grain crop and not an oil crop in the canola rotation) as the practice of raking could not be effectively achieved in the control only. This would have led to only raked windrows being burnt rather than the entire control area. There seems to be have some difference in the microbial biomass in December 2015 data which may suggest a better outcome for the biology in the unburnt treatment immediately post canola. The microbial biomass carbon, nitrogen and phosphorus appeared to be shown higher in the unburn treatment of barley stubble than the burned barley stubble. This could be more important considering it was post canola crop which might have a fumigant effect on some soil biology. Interestingly the control recovered after canola harvest and post sheep grazing according to the April 2016 sampling which is pre oat crop. It would have been very interesting to have a December 2016 sampling for biological tests. The soil chemical properties did not show differences between two practices except some decrease value of nutrients observed in 10-20 cm depth samples at year 2016. It is suspected that the samples of 10-20 cm at 2014 may have been mixed with the topsoil as the values are higher than expected, but the 2016 data appears more realistic.

Conclusions

This project provides important information on the impacts of burned and unburned stubble practices. Learning more about what happens beneath the surface with microbial biomass in soil and mycorrhizal colonisation in roots for each of these practices is key so the farming community can factor this into their land management practices. Use of fish hydrolysate in crunched stubbles is very new technique used and the mechanism of function of fish hydrolysate on crunched stubbles decomposition was not studied in this trial. Therefore, a further study of these practices will support these results and add to the development of adoption-ready, locally-specific resources for farmers in Western Australia.

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