Nitrogen cycling in cereal stubble management systems

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Key Messages

- During the 2016 season, stubble retention practices had no significant effect on wheat grain yield and protein.
- ^{15}N stubble labelling studies have shown that at Karoonda approximately 5% of the 2015 wheat crop N was sourced from the 2014 wheat crop stubble.
- The management of cereal stubble influences the microbial activities related to cycling of C and N and its supply to the growing crop. Stubble removal resulted in lower microbial biomass C and N, N mineralization and reduced N supply in the surface soil.
- Stubble management practices had no significant effect on soilborne pathogen levels and disease incidence.

Background

In many Australian agricultural soils, carbon availability is the most limiting constraint of microbial functions hence management of biologically available C is the key to improving biological functions including those involved in N mineralization. Crop residues are one of the major sources of C for soil biota therefore stubble retention can provide benefits through changes in soil physical, chemical and biological properties which influence carbon turnover, nutrient generation and subsequent availability of nutrients to crops. Although stubble retention benefits are expected to be realised in all soil types, the magnitude and nature of change in biological functions can vary depending on type and timing of stubble management and is influenced by soil type and environmental factors (e.g. rainfall). As part of the GRDC project (CSP00186) replicated field experiments were conducted at Karoonda (South Australia), Temora (New South Wales) and Horsham (Victoria), to strengthen our knowledge on seasonal changes in the (1) biological value of stubble (2) mineralisation: immobilisation balance and (3) the direct supply of N from stubble to crops as influenced by stubble management.

Aim

To quantify the effect of stubble management on seasonal changes in the biological value of stubble, mineralisation: immobilisation balance and the direct supply of N from stubble to crops.

Results

Rainfall at the experimental site during 2016 season was well above average (decile 10) with >40mm rainfall received in each month except for Feb and April (Figure 1). This provided 25-28 days of soil moisture conditions that were optimal for microbial activity. There were no significant differences between different stubble treatments in the total amount water in the soil profile (92 to 102 mm in the profile to 1M depth) although some variation at 10-30 cm depths was observed (Figure 2).

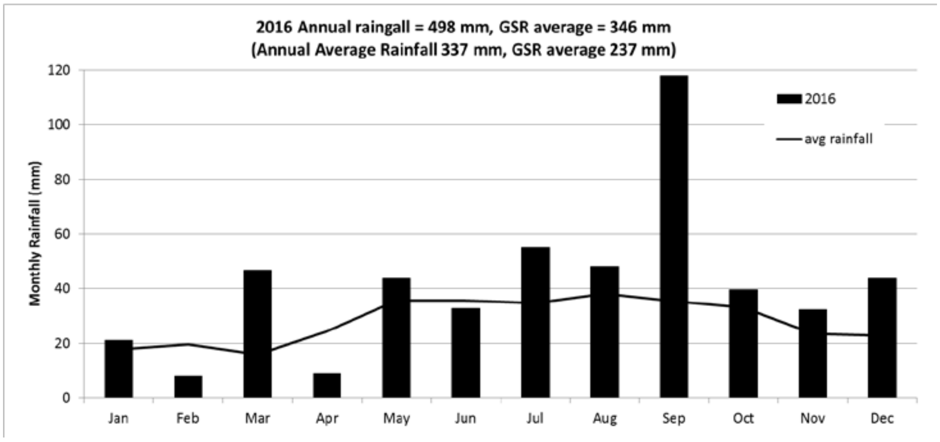
Crop performance: The different stubble management practices had no significant influence on the wheat grain yield and grain protein levels (Table 1). There was no significant difference in crop establishment across the stubble treatments and limited differences in the plant biomass at GS31 and anthesis (data not presented).

Plant pathogens and disease: Stubble retention had a limited effect on the plant pathogen inoculum levels at sowing 2016 and the risk for soilborne diseases such as Rhizoctonia, TakeAll and Fusarium crown rot was generally low in all treatments, except for the medium disease risk for Fusarium root rot and TakeAll in the *Standing* stubble and *Surface* stubble treatments, respectively (Table 2). Regular rainfall during summer and good weed control have contributed to the decline in pathogen inoculum (Gupta et al. 2015). Results from the measurement of root disease incidence at 8 weeks after sowing agreed with the inoculum data i.e. generally there was lower disease incidence and no specific significant treatment effects were observed.

Table 1. Wheat crop performance in 2016 crop season.

Treatment	Grain yield (t/ha)	Protein (%)
No-Stubble	2.05	8.00
Standing	2.11	7.85
Surface	1.94	7.60
Incorporated	2.02	7.68
F-test	*NS*	*NS*

Figure 1. Rainfall distribution at the Karoonda experimental site during 2016.



Microbial properties and N mineralization: Stubble retention significantly increased microbial biomass C, N supply potential and N immobilization potential, especially in the *Standing* and *Incorporated* stubble treatments compared to the treatment where stubble was removed at harvest (Table 3). Stubble retention influences microbial and nutrient supply properties by providing carbon (energy as MB-C) to support biological activity and could modify soil moisture levels. In the *No-stubble* treatment, root material from the previous wheat crop would have provided some of the required C source for biological activity. Stubble retention increased dissolved organic C (DOC) levels in the soil and *Standing* and *Incorporated* stubble treatments significantly increased MB C and MB N compared to No-Stubble and *Surface* stubble (Table 2). Stubble retention practices also significantly altered the catabolic diversity (i.e. ability of microbial communities to use different carbon substrates) confirming the importance of C from stubble for microbial diversity and activity (Figure 3). Wheat stubble from 2015 crop had a wide C:N ratio (>90:1) and thus stubble retention did not cause any changes in dissolved organic N. Stubble management practices alter the degree of contact between stubble and soil microorganisms thereby altering the rate of stubble decomposition. For example, previous research has shown that incorporation of stubble after harvest results in the decomposition of ~65% of stubble during summer (i.e. before the next crop is sown) provided above average summer rainfall is received, and this rate is generally higher than for *Standing* stubble. This would have contributed to the lower N-supply potential observed in the *Incorporated* treatment compared to the *Standing* stubble treatment (Table 3). Although the wider C:N ratio of stubble at Karoonda is likely to cause relatively more immobilization (tie-up) of N during the early stages of stubble decomposition, good summer rainfall in 2016 would have reduced the effect of immobilization on N availability to the seedlings.

Biological mineralization following rainfall events in summer resulted in a significant increase in mineral N especially in the top 50 cm of the soil profile in all the treatments. At sowing, soil mineral N levels to 1 m depth ranged between 57 and 82 kg N/ha whereas at harvest in December 2016 the levels were 30-39 kg N/ha, indicating treatment based differences in the N loss through crop uptake and leaching (Figure 2). For example, the amount of N lost was higher in the *No-stubble* and *Surface* stubble treatments (51 and 43 kg N / ha, respectively) compared to that in the *Standing* and *Incorporated* stubble treatments (35 and 19 kg N/ha). Lack of treatment differences in grain yield between stubble treatments suggests similar total N uptake. In-crop N mineralization measurements showed greater seasonal variation than treatment effects both in 2015 and 2016 seasons (Figure 4).

Microbial biomass acts as a buffer or temporary storage pool for nitrate N protecting it against leaching, conversely lower MB in the No-stubble and *Surface* stubble would have contributed to greater loss of N in the soil profile. The low grain protein levels suggest a lack of N supply to meet crop demand; this is supported by the significant decline in the in-crop N mineralization during later stages of crop growth (October) (Figure 4). The 2016 wheat crop was the 3rd consecutive cereal crop which may have depleted soil organic N sources for microbial mineralization in this lower soil organic matter soil (total organic C = 0.55%).

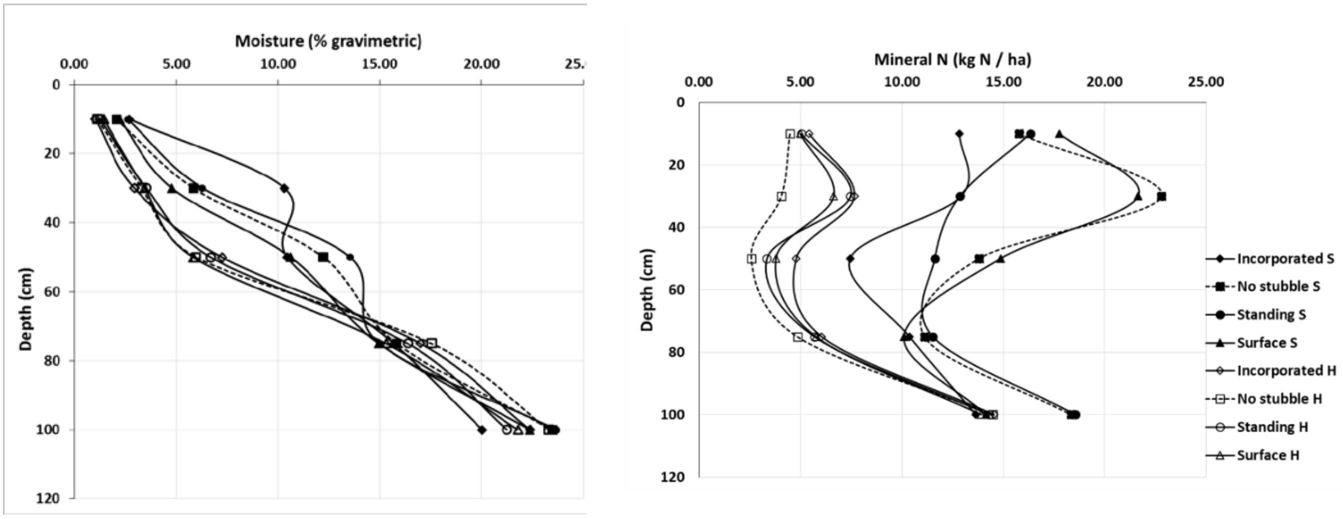


Figure 2. Moisture and mineral N levels in the soil profile at the sowing (S) and harvest (H) 2016 crop as influenced by stubble management practices.

Results from ^{15}N-labelled stubble experiments indicated that N from wheat stubble in one year contributes a small percentage of N requirement of the following crop at Karoonda (4-5%), Horsham (2-3%) and Temora (8-15%). Thus, the benefits from cereal stubble retention are likely to be from the stubble-induced changes to MB, activity and nutrient cycling processes (mineralization and immobilization) which in turn influenced the timing of N availability and plant pathogen inoculum levels.

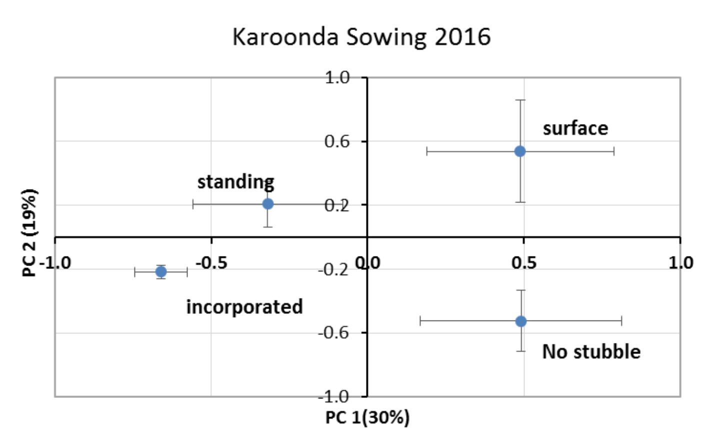


Figure 3. Principal Component Analysis (PCA) results showing the effect of stubble management practices on catabolic diversity of soil microorganisms. Data points closer are more similar than those further apart.

Conclusions and Implications

Nitrogen mineralized from the soil organic matter through microbial activity contributes substantially to crop N uptake whereas cereal stubble provides 4-5% of the N uptake by the following crop. Management strategies including stubble retention, tillage and rotations of crops (and even varieties) can help manipulate the composition and abundances of microbial communities involved in N mineralization and the size and turnover of MB, thereby influencing N availability. Therefore, N supply potential and microbial N immobilization (tie-up) estimates need to be considered together with seasonal conditions to make better N management decisions in cropping soils.

Figure 4. Net N mineralization (ave.±std error) measured *in-situ* within a wheat crop during 2015 and 2016 seasons as influenced by stubble retention practices on a Kandosol at Karoonda, SA over 10-14 day periods beginning on dates shown. PRSTM probes (www.westernag.ca) were incubated (ave. 14 days) in the surface at 10 cm depth inside open PVC cores in field experimental plots at Karoonda in SA. Stubble quantity and its contact with soil are attributed for the treatment and temporal variation.

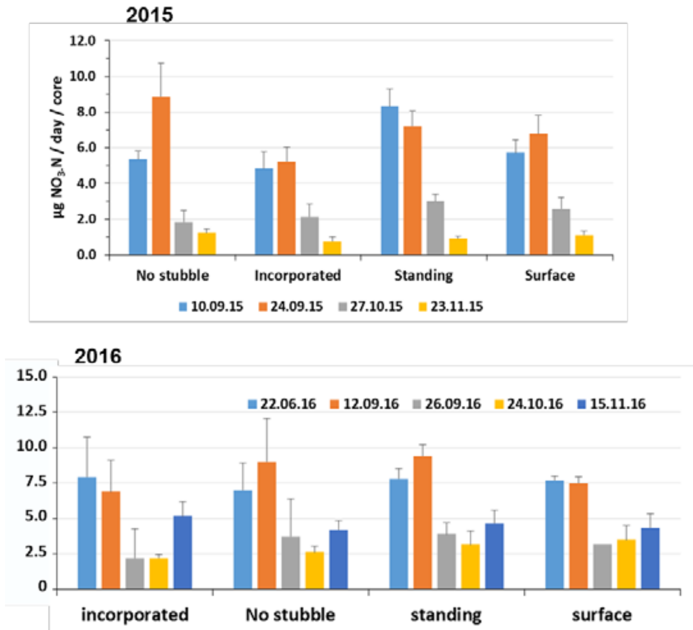


Table 2. Effect of stubble management practices on soilborne plant disease risk (disease risk categories are based on the pathogen DNA concentrations measured at sowing of 2016 wheat crop).

Treatment	*R. solani* AG8	Ggt (TakeAll)	Fusarium crown rot
No Stubble	Low	Low	Low
Standing	Low	BD	Med
Surface	Low	Med	Low
Incorporated	Low	BD	Low

Note: BD – below detection; pathogen DNA levels measured by SARDI RDTS labs

Table 3. Effect of stubble management on microbial biomass and N supply properties in the top 10 cm of soil at sowing in 2016 at Karoonda, SA.

Treatments	MB-C	MB-N	N Supply Potential#	N Immobilization Potential	DOC	DON	DOC:DON ratio
	µg / g soil		kg N / ha		µg / g soil		
No Stubble	144	20.6	29.9	13.9	29.06	2.68	10.85
Standing	165	23.6	39.3	15.9	37.01	2.56	14.43
Surface	122	17.5	38.2	11.8	34.77	3.48	9.99
Incorporated	188	26.8	25.9	18.1	34.68	2.38	14.58
F-test	0.003	0.003	0.003	0.010	NS	NS	NS
LSD	34	4.9	6.6	2.6			

 # N supply potential estimates for a decile 9 season; MB=microbial biomass; DOC=Dissolved Organic Carbon; DON= Dissolved Organic Nitrogen

Further information

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