THE IMPACT OF ROTATION, STUBBLE MANAGEMENT AND TILLAGE ON THE RELATIVE CONTRIBUTION OF BACTERIAL AND FUNGAL MICROBIAL BIOMASS.

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Abstract

The long term impact on soil microbial biomass of a range of farming systems was evaluated 18 years after the trial was initiated at a site in Wagga Wagga, NSW. The farming systems examined were stubble management, tillage, rotation and grazing. The relative contribution of fungi and bacteria to the microbial biomass was measured in the 0-5 and 5-10 cm layers of soil. Differences in microbial biomass composition were apparent in the farming systems examined as well as between depths. Mulching cf. burning favoured the fungi at both depths. Grazing with sheep cf. mowing in the sub clover phase of the wheat/sub clover (W/C) rotation encouraged fungal biomass in both depths. No-till favoured fungal biomass in the top 5 cm of wheat/lupin (W/L) rotation cf. 3 cultivations with a scarifier.

Key words: biomass, fungi, bacteria, soil, tillage, rotation, stubble

There is some evidence that the microbial biomass of the soil adapts to a particular farming system through changes in the relative proportions of the biomass contributed by fungi and bacteria (8,17). Such changes influence the decomposition of substrates, such as crop residues, added to the soil. For example, soils that have a history of no-till and residue retention have a higher proportion of their microbial biomass as fungi and efficiently decompose crop residues deposited on the soil surface (8). In contrast, a soil with a history of conventional cultivation and residue burning tends to be dominated by bacteria and may more efficiently decompose residues incorporated into the soil profile (16). The interactions between farming system, microbial biomass and residue decomposition become important when farms undergo transition from a "conventional" farming system to a "no-till" system, currently promoted as improving agricultural sustainability. This study reports the impact of the farming systems in a long term trial on the relative proportions of bacteria and fungi in the microbial biomass (b:f) in the 18th year of a long term trial.

Materials and methods

The experiment site, located at Wagga Wagga? (147?20?E, 35?05?S), was on a red earth (Gn 2.12)(15) and was established in 1979. There are 9 treatments located randomly in 6 blocks. Each phase of the rotations were replicated 3 times each year in alternate blocks. All measurements were taken from the 3 replicates in the wheat phase. The 9 treatments are described in *Table 1*. For more information on treatment management and design see Heenan *et al* (10).

Samples were collected during the spring of 1996. Soil samples were collected from 0-5 cm and 5-10 cm, during anthesis of the wheat crop once soil temperatures reached 20 ?C and following rain. Each sample was then sieved, subsampled and stored at 4 ?C . Water content was measured and individual solutions were made up to supply water, glucose and antibiotic to each soil sample per gram of dry soil. The mass of CO_2 was assessed using the method by Parkinson and Paul (16) and the biomass was derived using a modified Anderson and Domsch (1) SIR method using streptomycin and cycloheximide to inhibit bacterial and fungal respiration. The relative contributions of bacteria and fungi to the microbial biomass were estimated using the formula derived by Anderson and Domsch (1). Data was analysed by ANOVA using GENSTAT 5.

Results

In most treatments, bacteria contributed more to soil microbial biomass than fungi by as much as 3.3:1. The exceptions were treatment (T) 1 and T8 at 0-5 cm and T7 at both depths. B:f was greater at 5-10 cm than at 0-5 cm, in all treatments except T2 where there was little difference between depths.

When the treatments were ranked in order of increasing ratio of b:f (Table 1) differences between stubble management treatments became apparent. At the 0-5 cm depth of soil, the five treatments which included mulching (T7, T1, T8, T2 and T9) are ranked lower in b:f than the four treatments in which stubble was burnt (T3, T4, T6 and T5). A similar rank order was obtained at 5-10 cm depth with the mulched treatments lowest and the burnt treatments highest, although the order was slightly different from the surface layer and there was some overlap of the middle ranked treatments (T4 and T9).

Rotation appeared to have a less consistent effect than stubble management on the treatment rankings. However, continuous wheat irrespective of N application (T5 and T6) had the highest and W/C-grazed (T7) the lowest ratio of b:f at both soil depths.

There was no clear effect of tillage on the treatment rankings, 3 pass tillage ranked highest and lowest at both soil depths. At 0-5 cm no-till significantly increased the fungal contribution to the biomass ($P<0.05$) where stubble was retained in W/L and in mown W/C. At 5-10 cm no-till and grazing both significantly ($P<0.05$) increased the fungal contribution in the W/C rotations.

Table 1: Farming system treatments ranked in order of increasing ratio of bacterial:fungal biomass at two soil depths.

Correlations between b:f and soil pH ($r = 0.17$, lowest), total soil N, soil organic C ($r = -0.72$, highest) and wheat total dry matter were generally poor.

Discussion

The primary impact on the microbial biomass comes from a combination of soil moisture, soil temperature, aeration and substrate availability(13, 14). It is only after these primary components have acted that secondary factors start to influence the microbial biomass. These secondary factors such as tillage, stubble burning and rotation can also directly affect the primary components (14).

Cultivation favours those microbes with short generation intervals, high metabolic rate, small size and a low degree of food and habitat specialisation (11). Overall, systems using less tillage have a greater bacterial and fungal biomass (5). Cultivation physically reduces the fungal biomass through direct destruction of fungal hyphae and habitat (12). The reduction in pore numbers and pore sizes reduces the ability of fungi to colonise (6) and as the rhizosphere is dominated by bacteria (6) the opportunities for fungi to colonise root pores are reduced. The inhibiting effect of cultivation on fungi is further compounded by the loss of aggregation that the fungi would have performed (7). Bacteria respond favourably to cultivation as they lack hyphae and rely on soil mixing for contact with substrate (5).

Stubble retention with no-till particularly favours fungi as they are physically able to bridge the gap to the surface residue and withstand low water potentials on the surface (8, 12). Gupta and Roper (8) found that residue retention leads to a greater proportion of fungi. This may indicate that treatments with a ratio greater than one in Table 1 are ecologically stressed, leaving T1, T7 and T8 as the more sustainable options. The annual rate of loss of organic C and total N from the soil were lowest for T1, T7, T8 and T9 (10), which supports this hypothesis.

The positive impact of grazing on the fungal contribution to the microbial biomass was also noted by Bardgett *et al* (3). Foster (6) suggests that the presence of soil fauna, which bury faecal pellets and redistributes nutrients in its own faecal pellets, provides a readily mineralised source of nutrients for soil fungi.

Gupta and Germida (7) indicate that the optimum proportions of b:f are those where fungi dominate. This is supported by higher negative correlations between b:f and soil organic carbon. Fungi typically account for more than half of the microbial biomass and is commonly about 70% (13).

The quality of substrate input can influence b:f (13, 2). Fungi are the principle agents for the decomposition of plant carbon polymers, the by products of which are subsequently available to bacteria. Thus better quality plant residue will encourage fungal growth (13). This supports the finding that including a legume in the rotation increases the fungal contribution with continuous wheat, irrespective of N application (T5 and T6), having the highest and W/C-grazed (T7) the lowest b:f at both soil depths.

The quantity (14) and distribution (6) of substrate also influence b:f as normally the majority of the soil microbial biomass is starving, lying dormant or non viable (14) and hence dependent on and responsive to inputs.

Depth reduced the fungal contribution mainly due to reduced aeration, one of the macro environmental components of microorganisms, which leads to fungi concentrating in the surface 5 cm of the soil (4, 8).

The poor correlation between soil pH and b:f is supported by Anderson and Domsch (3,1) stating that decreasing soil pH does not alter b:f and is demonstrated by the similarity of T6 and T5 which have 0-10 cm soil pH ($CaCl_2$) values of 3.87 and 4.64, respectively. Differences in agricultural chemical use between the rotations are unlikely to have caused any changes in b:f (9).

Conclusion

The farming systems used in this experiment have had an impact on the soil microecology. No-till increased the fungal contribution to biomass in the surface 5 cm but the trend reversed in the 5-10 cm layer. The effect of no-till on fungi is increased by retaining stubble cf. burning. The inclusion of a legume in the rotation also increased the fungal contribution and this was further increased when the C was grazed v. mown. System effects become less apparent with depth. Rotation and grazing have the greatest impact of the farming systems examined.

This experiment demonstrates that soil microecology is modified by farming systems and therefore needs to be considered when management decisions are made. Targets for optimum proportions have not been identified but further study may identify b:f which maximise agricultural sustainability.

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Table 1. Farming system treatments ranked in order of increasing ratio of bacterial:fungal biomass at two soil depths.

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Treatment number	Rotation	Stubble Management	Tillage	Ratio	Treatment number	Rotation	Stubble Management	Tillage	Ratio
		0-5 cm					5-10 cm		
7	W/C - grazed	mulched	3 passes	0.59	7	W/C - grazed	mulched	3 passes	0.81
1	W/L	mulched	no-till	0.71	2	W/L	mulched	3 passes	1.33
8	W/C - mown	mulched	no-till	0.89	8	W/C- mown	mulched	no-till	1.46

2	W/L	mulched	3 passes	1.34	1	W/L	mulched	no-till	1.59
9	W/C - mown	mulched	3 passes	1.42	4	W/L	burnt	3 passes	1.86
3	W/L	burnt	no-till	1.52	9	W/C- mown	mulched	3 passes	1.91
4	W/L	burnt	3 passes	1.53	3	W/L	burnt	no-till	2.25
6	WW + 100 N	burnt	3 passes	2.32	5	WW + 0 N	burnt	3 passes	3.14
5	WW + 0 N	burnt	3 passes	2.64	6	WW + 100 N	burnt	3 passes	3.31
s.e.d.				0.11	s.e.d.				0.56

W = wheat, L = lupin, C = subterranean clover, 100 N = 100 kg N /ha/ yr