Crop rotation and fallowing can affect the functional resilience of microbial communities in a rainfed cropping system in southern Australia

Gupta V.V.S.R.[A], Marcus Hicks[A], Stasia Kroker[A], Bill Davoren[A] and David Roget[B]
[A] CSIRO Ecosystem Sciences, [B] formerly CSIRO, PMB No. 2, Glen Osmond, SA, Australia; Email: Gupta.Vadakattu@csiro.au

Introduction

Soil biological functions in southern Australian dryland cropping soils are mainly regulated by soil moisture and the amount of biologically available carbon[3]. Therefore, regular addition of carbon sources is critical to maintain functional capability. Generally, in these soils soil biota experience boom-bust cycles of C availability and are exposed to repeated wet-dry events. The depletion of C-rich microsites can affect the distribution, diversity and metabolic status of microbial communities and can impact on the overall biological resilience[2,3]. We discuss the impact of 6 years of intensive cropping, no-till and optimum fertilizer input systems on microbial activity, diversity and resilience when compared to the traditional fallow-crop rotations.

Methods

A long-term field experiment was established, in 2002, at Paringi (Kerribee station) in New South Wales (WGS84 lon 142.37, lat -34.28). Treatments included a combination of rotations (wheat, canola, fallow and grain legumes), tillage (no-till and conventional cultivation) and fertilizer inputs (district practice and high-input) with four replicates. The climate is a Mediterranean-type, characterised by hot dry summers and a winter-dominant, average annual rainfall of only 260mm. Soil is an Alfisol (Calcic Calcarosol). Soil chemical properties (0-10 cm) at the start of the trial were pH(water) 7.6, organic C 0.68%, total N 0.06%, and clay content 10.6%. Surface soil (0-7.5 cm) samples collected prior to sowing (May) in 2008 were analysed for various microbial, biochemical and chemical properties:

- Microbial biomass (MB) C, N and C and N mineralization potentials
- C-substrate utilization profiles – modified Microresp® method[1]
- Functional gene abundance – *nif*H[6] and *amo*A[7]
- Stability of biological communities[5] (Resistance and Resilience) – a laboratory based repeated wet-dry cycle assay (Gupta et al., unpublished)

Results and Discussion

- Microbial biomass C ranged between 250 to 400 µg C / g soil and accounted for 3-5% of soil organic C levels.
- Soils from continuous crop rotations supported higher amounts of MB-C and N. MB was lower in the fallow phase, e.g. ≥25% lower than after a wheat crop. MB-N levels were highest after legume crops.
- Community level physiological profiling indicated the significant effect of cropping systems i.e. catabolic diversity in soils from fallow-based rotations was different to that in soils from intensive cropping treatments (Figure 1).

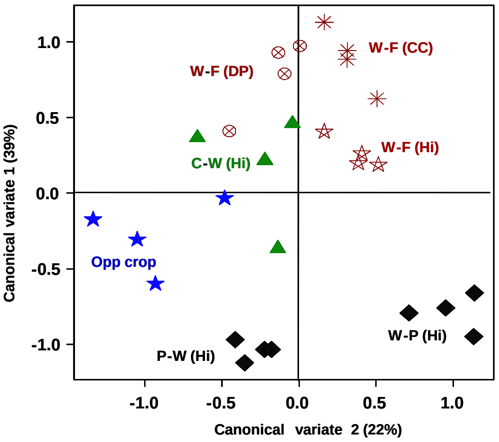

Figure 1: Canonical variate analysis of catabolic diversity profiles for microbial communities in surface soils after 6 years of different cropping systems. W=Wheat, F=Fallow, C=Canola, P=Peas, DP=District Practice (lower fertilizer inputs) Hi=High inputs, Opp crop=Opportunity cropping i.e. crop type is selected based on seasonal conditions at the time of sowing.

Long-term cropping systems experiment at Paringi in New South Wales, Australia

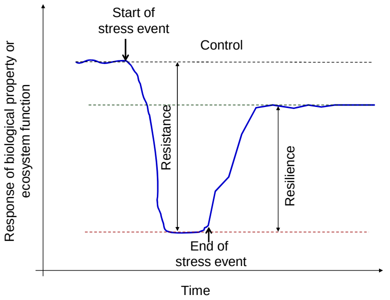

Figure 2: A conceptual diagram for measurement of stability of ecosystem function. While the resistance prevents further decline in ecosystem function, resilience allows its recovery[2,4].

Knowledge of a soil's resilience assists in the development of systems or practices that promote the recovery of degraded soils.

Measurement of resilience involves quantifying short-term changes in specific biological properties (e.g. activity, diversity and population levels of soil biota) following an exposure to disturbance or stresses (e.g. wet-dry or freeze-thaw cycles or chemical applications).

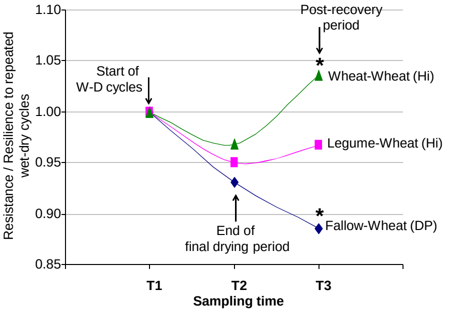

Figure 3: Microbial activity values normalised using data from samples that were not exposed to stress events.

- Both resistance and resilience are significantly lower (*, $P<0.05$) in soils from fallow-wheat rotation; resilience was highest in soils from intensive wheat rotation.
- Lower biological resilience under legume based rotations could be attributed to:
  - i. Lower amounts of C inputs compared to cereals
  - ii. Higher N content in the legume residues results in faster degradation and depletion of C rich microsites
- Fallowing in a crop rotation can cause a significant decline in particulate organic matter levels in soil[3].

- Quantities of *amo*A and *nif*H genes were lowest in fallow-wheat soils and the effects of wet-dry cycles varied for the two functional genes.

Table 1: Abundance of functional genes as influenced by cropping system treatments and exposure to stress events.

Cropping system Treatment	Initial	Not exposed to Wet-Dry cycles		Exposed to Wet-Dry cycles	
	T1	T2	T3	T2	T3
			***amo*A gene copy number**		
Fallow – Wheat (DP)	805 ± 465	3589 ± 445	1610 ± 339	3079 ± 639	3266 ± 587
Legume-Wheat (Hi)	1723 ± 855	5056 ± 742	1997 ± 241	3327 ± 440	2026 ± 217
Wheat – Wheat (Hi)	3372 ± 1087	5447 ± 1155	2316 ± 325	4025 ± 633	3563 ± 976
			***nif*H gene copy number**		
Fallow – Wheat (DP)	99 ± 52		823 ± 102		1010 ± 250
Legume-Wheat (Hi)	166 ± 101		697 ± 26		1142 ± 126
Wheat – Wheat (Hi)	576 ± 116		921 ± 116		917 ± 132

Conclusions

- Crop management practices that increased above and below ground C inputs improved microbial functions and biological resilience.
- Repeated wetting and drying events that are common in Mediterranean environments during summer have the potential to impact on the stability (resistance and resilience) of biological functions, especially under lower available C conditions.

References

1. Campbell et al. (2003) Applied and Environmental Microbiology 69, 3593-9
2. Griffith et al. (2004) Microbial Ecology 47, 104-13
3. Gupta et al. (2008) In: Global Issues, Paddock Action, Unkovich, M. (Ed.), The Regional Institute Ltd, Gosford, NSW, Australia
4. Herrick (2000) Applied Soil Ecology 15, 75-83
5. Orwin KH and Wardle DA (2004) Soil Biology and Biochemistry 36, 1907-12
6. Rosch et al. (2002) Applied and Environmental Microbiology 68, 3818-29
7. Rotthauwe et al. (1997) Applied and Environmental Microbiology 63, 4704-12

Acknowledgements

Financial support was provided by the CSIRO, Mallee Sustainable Farming Inc. and Grains R & D Corporation.

Authors also acknowledge Rick Llewellyn and Anthony Whitbread for field-based advice.

Further information

contact: V.V.S.R. Gupta
phone: +61 8 8303 8579
email: Gupta.Vadakattu@csiro.au
web: http://www.csiro.au/org/Entomology.html

www.csiro.au