The critical role of soil biology: what we know and what we don't?

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Surface soils are home to a rich diversity of small (e.g. microflora such as bacteria and fungi) and large organisms (e.g. soil fauna) from all major taxonomic groups. With the traditional culture based methods we have been following <10% of total soil microorganisms and recent developments in DNA and RNA-based methods allow us to characterize the entire microbial community but also determine changes in the populations and activities of specific members of the community. With the current focus on security of food to feed the growing global populations through sustainable agricultural production systems there is a need to develop innovative cropping systems that are both economically and environmentally sustainable. Soil habitat structure and carbon availability can affect the functional capability of soil microbiota by influencing microbial functional diversity. Plant type can affect the functional capacity of different groups of biota in the root microbiome. Crop rotation provides options to better manage soil biological functions by modifying populations and activities of beneficial and plant pathogenic microorganisms. Spatial location of microorganisms in the heterogeneous field soil can have significant impacts on biological processes due to variation in the accessibility to energy and nutrient sources and habitability.

Soil organisms regulate a majority of ecosystem processes in soil that are essential for plant growth (nutrient availability and disease incidence), soil health (soil structure and agrochemical degradation) and sustained productivity (development and maintenance of physico-chemical properties of soil). Carbon inputs from plant roots and crop residues form the essential supply of C (energy source) and nutrients for biological activities. Therefore in most Australian agricultural soils carbon inputs through above (stubble) and below ground (roots) plant residues have a major influence on populations of biota and their activities. Composition of microbial communities play a significant part in the changes observed in different cropping systems. The quantity and quality of crop residues affects the composition and populations of various groups of microbial communities involved in nutrient cycling, disease suppression and plant growth. A majority of research on the effects of management practices on soil biota is done on specific beneficial (e.g. N fixation in legumes) and pathogenic organisms only and we have limited knowledge about a vast majority of microbial communities in soil both in the undisturbed native systems and agricultural fields.

In the rainfed cropping regions of the world, soil biota are exposed to multiple wet-dry cycles varying in duration and intensity which can have substantial effects on biota populations and functional capability. The legacy effect of drought on soil microbiota and the food web can be a direct effect on their ability to recovery or acts indirectly through loss of available carbon and nutrients and habitat integrity. Such long-lasting stress events can also influence the resistance and resilience of biota by altering the quantity and quality of carbon inputs into soil. Fungal dominated soil food-webs, generally associated with reduced till and pasture based agricultural systems, have been suggested to be more stable than the bacterial dominated food-webs generally found in intensive annual cropping and cultivated systems. However, the contribution of plant-soil feedback on the mechanisms of resistance and resilience of various members of food web and their impact on ecosystem level function is not well understood. Results from experiments in South Australia and New South Wales indicated that the response of biological functions to moisture and temperature stress differed between cropping systems with lower resilience in soils from a fallow-crop rotation than under continuous cropping. The decline in the biological resilience of soils under fallow-crop rotation could be due to the boom-bust cycles of C availability. No-till systems with stubble retention showed greater stability of microbial catabolic potential than systems with stubble removed or incorporated and this effect varied with soil type. In conclusion, a better understanding of the resilience of a system is useful to evaluate the effect of changing environment on ecosystem function.

In summary, an improved understanding of the dynamics of functional gene diversity and biological processes can assist with matching soil biological capacity to agronomic management for sustainable productivity and ecosystem health.

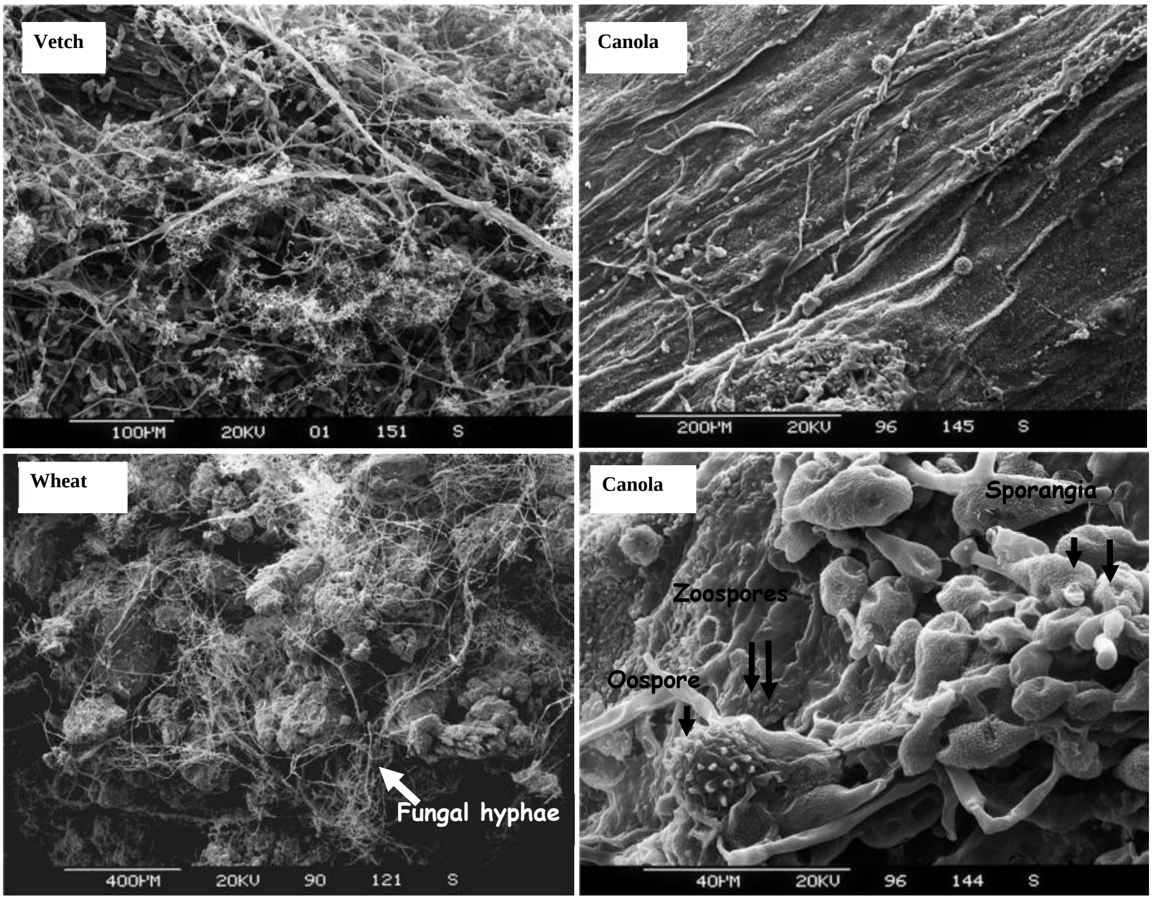

Figure 1. Photos of crop residues taken using Scanning Electron Microscope showing the various types of microorganisms colonizing different crop residues. Extensive colonisation of nitrogen rich vetch residues by bacteria and fungi. Fungi were the dominant microflora colonizing wheat residues where as fungal growth on canola residues was less and limited to specific fungi such as *Pythium* species.