Biological inputs

JULY 2015

Biological inputs include a wide range of products aimed at supporting soil fertility, biological activity, and plant growth. They include inocula, biostimulants, composts and compost teas, manures, and biochars. These inputs are often used with the wider aim of reducing the inputs of traditional chemical fertilisers and agro-chemicals.

Many biological inputs are rich in organic carbon and nutrients and/or contain living organisms. The benefits of increasing organic matter to maintain soil function are widely recognised, and often promoted as an important co-benefit of using biological amendments.

Evaluating biological inputs

It can be difficult to make informed decisions about the potential efficacy of biological inputs for broadacre cropping. There are several reasons for this:

1. Most trials have been conducted in the laboratory or glasshouse and focused on the response of horticultural crops.
2. Fewer replicated trials have been conducted in grain systems, and it is difficult to extrapolate the results beyond the individual location to the broader grain-cropping context.
3. There is a limited mechanistic understanding of how biological amendments interact with other soil processes, making it difficult to predict the yield outcomes.
4. Short-term trials are unlikely to capture the long-term outlook for soil condition and productivity, particularly where amendments are expected to contribute to changes in soil organic matter content over longer periods.

*'Know your soil;
know your product;
know your local evidence'*

When considering the use of a biological input for broadacre grain production, it is important to consider:

- what is limiting plant productivity and/or soil biological activity
- the types of amendments likely to address the constraints
- whether there has been local independent testing of the product

KEY POINTS

- Biological inputs can act both directly and indirectly on plant growth through one or more biological, chemical, or physical mechanisms.
- It is important to consider what is limiting plant productivity and which type of amendment is likely to address the dominant constraints. The most appropriate biological inputs will vary with region, depending on the main yield constraints.
- Improving our mechanistic understanding of how biological inputs work under different regional broadacre field conditions will improve our ability to predict yield outcomes from their use.

Biological inputs and amendments are diverse in their chemical complexity, and they remain active in the soil system for different lengths of time (Figure 1). For example:

- Simple sugars and amino acids have a rapid rate of turnover and relatively short window of activity (less than the growing season).
- Composts and manures take longer to break down, and some material is likely to remain in the soil beyond the end of the growing season.
- Biochar is very stable and likely to remain in soil for extended periods.

Figure 1: Biological amendments represent a diverse range of compounds that are likely to remain in soil for different time periods.

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Regional yield constraints

The most appropriate biological inputs will vary with region, depending on the main yield constraints, for example:

Northern Region
low water movement through saturated soil; high soil bulk density; high sodicity

Southern Region
high soil bulk density; high sodicity

Western Region
low available water capacity; soil acidity and salinity

Alleviating yield constraints by using biological inputs

Use the colour key left to match region to yield constraint, and Table 1 below to locate the appropriate biological inputs to overcome specific constraints.

Bulk density and soil compaction. High bulk density (>1.6 g/cm^3) can restrict root growth. Solid biological inputs rich in organic matter can help to decrease bulk density, thereby improving root penetration and access to water and nutrients.

Saturated hydraulic conductivity and waterlogging. Improvements in soil structure can help to increase water movement. Solid biological inputs high in organic matter can help to decrease the bulk density, increase aggregation, and improve porosity.

Solid amendments rich in organic matter include manure, compost, vermicompost and biochar. If physical constraints occur in the subsoil, they are likely to be more difficult to address, possibly requiring incorporation of amendments at depth.

Soil sodicity. An excess of sodium and can result in poor soil structure. Traditional amelioration techniques include the application of gypsum, which acts to replace the sodium with calcium. Biological amendments are more likely to act indirectly by improving soil structure rather than decreasing the sodium content.

Low available water capacity. Coarse-textured, sandy soils drain rapidly, limiting the amount of water available for plant growth. Increasing the soil organic matter content can improve the ability of soil to hold water; therefore, solid amendments high in organic matter can help to improve water retention and availability in some soils. Mycorrhizal fungi are known to bridge soil pores , potentially increasing access to limited water.

Soil acidity. Low soil pH inhibits root growth, limits availability of some key nutrients (e.g. phosphorus), and can increase the availability of toxic elements (e.g. aluminium). Biological amendments that have high carbonate content, or are alkaline in nature, can raise soil pH. Amendments containing complex forms of carbon can improve the buffering capacity of soil, and the longer term ability to buffer acidification processes. Biological amendments may form part of a pH-management plan. However, they cannot replace the use of lime because their acid-neutralising capacity is lower.

Salinity. A saline soil contains excess salt ions (soluble salts). Salinity is difficult to remediate. Any plant tolerance to salt that develops after application of a biological input is likely to be an indirect result of mechanisms that improve the overall rooting environment.

How do biological inputs work?

It is useful to consider how any biological amendment might alter the functioning of the soil system. In many cases, biological amendments may have more than one proposed mode of action, which can be broadly divided into biological, chemical, or physical mechanisms.

Biological mechanisms include direct changes to soil biological communities and their functions, such as decomposition and nutrient turnover. Many biological inputs enhance microbial activity by providing readily available carbon, nutrients, and energy. Some biostimulants contain plant-active hormones and signal molecules that may act directly on the plant.

Alternative to stimulating the inherent microbial community, microbial inocula are used to introduce organisms with specific functions and include mycorrhizal fungi, symbiotic or free-living nitrogen-fixing organisms, phosphate-solubilising organisms, and biocontrol organisms. Their effectiveness will depend on their survival and activity in the target habitat.

The use of inoculum and biostimulants is thought to improve root growth and nutrient-use efficiency (fertiliser or soilborne fertility), water-use efficiency, and drought resistance.

Physical mechanisms include direct changes to soil physical conditions, such as bulk density, pore space, and water-holding capacity. Solid, carbon-rich amendments can lower bulk density and reduce constraints to plant growth, including poor rooting depth, aeration, water-holding capacity and drainage, or limited access to water and nutrients.

Chemical mechanisms include direct changes to the soil chemical environment, such as macro- and micro-nutrient availability, pH, and cation exchange and buffering capacities. Biological amendments can be a direct source of macro- and micro-nutrients in mineral or organic form. Modifying soil pH (e.g. liming effect), buffering capacity, and/or cation exchange capacity will change nutrient availability and retention.

Indirect mechanisms include a range of knock-on effects that alter soil functions. For example, stimulation of the biological community can also result in changes to the soil physical condition by promoting soil aggregation mediated through hyphal binding (fungi) and adhesive secretions. Changes to soil pH have a strong impact on the microbial community and on many biological pathways, for example, by changing the rate of nitrogen supply. Similarly, changes to the physical habitat influence air, water, and resource availability, with consequences for community structure and function.

Table 1: Potential of different types of biological inputs to overcome particular yield constraints based on the findings of previous scientific investigations Heavy ticks indicate that one or more studies demonstrated the effect. Light ticks indicate that the effect is widely claimed

	Yield constraint potentially overcome	Inocula	Biostimulants					manure	compost	compost tea	vermi-compost	biochar
			humic substances	seaweed extracts	oligo-saccharides	amino acids	plant extracts					
biological constraints	Poor nutrient uptake	✓	✔	✔				✔	✔			✔
biological constraints	Poor root growth	✓	✔	✔		✔		✔	✔	✔	✔	✔
biological constraints	Disease	✓		✔	✔			✔	✔	✔		✔
biological constraints	Frost or cold stress			✔		✔						
biological constraints	Waterlogging		✔									
biological constraints	Drought or heat stress	✓	✔	✔		✔						
biological constraints	Salinity		✔	✔		✔	✔					
biological constraints	Low activity of microbes	✓	✓	✓	✓	✓	✓	✓	✔		✔	✔
biological constraints	Limited habitats for beneficial microbes								✓			✓
chemcial constraints	Low macronutrients			✔				✔	✔		✔	✔
chemcial constraints	Low micronutrients			✔				✔	✔		✔	
chemcial constraints	Adverse soil pH								✔			✔
chemcial constraints	Low soil CEC							✔	✔			✔
chemcial constraints	Sodicity											
physical constraints	Low water storage in soil							✔	✔			✔
physical constraints	High density of soil							✔	✔			✔
physical constraints	Low soil organic matter							✔	✔		✓	✔

PROJECT: UNDERSTANDING BIOLOGICAL FARMING INPUTS

This GRDC funded project (2014–2017) is a collaboration between CSIRO, the University of Western Australia, and five grower groups and agronomy consultants. The project will review the evidence for improved grain productivity from a range of biological inputs. The work will focus on proposed modes of action as a means of targeting the use of biological inputs to address productivity constraints. The research will take a staggered approach to screen and trial biological inputs in a range of laboratory, glasshouse, and field studies. Ultimately, the aim is to develop a framework to guide targeted, on-farm testing of biological inputs.

The most appropriate biological inputs will vary from region to region, depending on yield constraints

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Biological inputs stimulate plant/soil interactions to benefit plant growth

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