

FINAL REPORT

CSO00044

Understanding biological farming inputs

PROJECT DETAILS

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PROJECT TITLE: UNDERSTANDING BIOLOGICAL FARMING INPUTS

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Summary

This project evaluated biological farming inputs for incorporation into broad acre cropping. Literature review and direct testing revealed wide variability of chemical composition of biological inputs. Screening showed little impact of any amendment on wheat growth. Field testing provided limited evidence of short-term efficacy, with 1 amendment (from 38) having significant positive impacts on yield. Whilst manures / composts may increase the rate of plant-available N/P production, biostimulants and humates did not enhance wheat N uptake. Despite testing over 60 amendments, very limited evidence that biological inputs will have short-term effects on grain yields was found.

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Conclusions

In reviewing literature, including publicly available reports with direct relevance to Australian agriculture, as well as Australian and internationally peer-reviewed literature, a vast array of biological farming inputs available to growers were found. It is also clear that whilst there has been much targeted work in the laboratory and glasshouse, less evidence is available demonstrating consistent results of biological inputs in field conditions, particularly for broad acre cropping.

The evaluation of over 60 biological inputs through chemical analysis in the laboratory echoed literature observations, in that there is a wide variation of chemical properties both within and between product classes. Further, whilst organic amendments such as composts and manures are relatively easy to compare on a "per application" basis, the wide variation in application rates for biological inputs such as biostimulants and humates makes such comparisons less meaningful. When over 50 of the amendments were compared directly to one another in a controlled glasshouse screening study, very little evidence of any impact on wheat when grown under moderate drought stress was found.

Moving to the field, the evaluation of over 30 biological inputs across eight field sites in the major grain-growing regions of Australia also provided limited evidence for positive impacts of biological inputs on grain yield across two different rainfall years. Further, only sporadic evidence was found of impacts on soil fertility or microbial community structure - potential early indicators of changes in soil function.

In further probing mechanisms by which biological inputs may impact on soil process and crop nitrogen capture there were limited impacts of biostimulants or humates on the acquisition of N by wheat from soil or an isotopically labelled legume litter. This is an important finding, given the presumption that many such biological inputs improve nutrient use efficiency. Additionally, in an incubation experiment to investigate nutrient and carbon dynamics following biological input application only those inputs containing significant quantities of nutrients increased the availability of those nutrients in soil.

Bringing all this together, it can be concluded from this research that most biological inputs available to Australian grain growers are unlikely to have a positive impact on yields or soil fertility in the short term. In addition the huge diversity of amendments and their properties makes it difficult to make broad recommendations on product suitability.

Recommendations

As a result of the research conducted in this project, the following recommendations can be made:

- Before considering the use of biological inputs in a farming system, it is important to understand the main environmental (e.g. drought, heat, waterlogging) and soil (e.g. pH, salinity, high nutrient absorption) constraints to increased production.
- Taking these constraints into consideration, it is also important to be aware of the most likely mechanisms by which biological inputs may attenuate these constraints, and over what time frame.
- Residual effects of any biological input will be strongly governed by their mode of action, method of application, and chemical composition. Biostimulants applied as a foliar spray will only impact on the current crop, whereas an organic amendment applied within the seeding furrow may remain for growing several seasons.
- Be aware that any biological input with a mode of action that includes increased nutrient use efficiency and facilitates a reduction in conventional fertiliser inputs is encouraging the potential for nutrient mining of the soil, with deleterious effects on soil organic matter stocks.
- When considering the use of biological inputs, on-farm testing in the specific situation the product is to be used is important. The practical guide and calculators produced within this project can provide guidance as to whether a certain amendment can be expected to make a profitable change to the farming system.

Outcomes

Within the Australian grain-growing sector, there has been strong interest in some quarters into how biological farming inputs may improve yields, provide opportunities to reduce conventional inputs, and increase resilience of farming systems to stresses.

Economic Outcomes: Evidence from comprehensive experimental work at the lab, glasshouse and plot scale, coupled with a deep review of the literature indicates how variable biological inputs are in terms of their chemistry. This makes their classification difficult, and in turn makes grower judgement calls on specific biological inputs difficult. Although our glasshouse and field experimentation highlights limited effects of biological inputs on wheat / barley yield in the short (1-2 years) term, it is recognised that some amendments may have cumulative effects over a longer time period that may in turn result in increased profitability. Three outputs from this project (a practical guide to on farm testing of biological inputs, and two on-line calculators) provide growers and advisors with the tools required to both target on the ground testing on farm, and to explore scenarios in which the use of a biological input may be profitable. In particular, the on-line biological inputs calculator enables the user to input costs and savings for traditional inputs, as well as the biological input in question to explore potential break-even or profitability points as a result of reduced costs or increased yields. The practical guide advocates a soil / environmental constraints approach, encouraging the reader to look at the incorporation of biological inputs into their farming system on the basis of the major constraints to production that they face, and the likelihood of target biological amendments addressing these fundamental barriers to increased production.

Environmental outcomes: Whilst not directly considered in this project, the potential of biological inputs to reduce conventional fertiliser or pesticide inputs may reduce losses to the environment. However, it must also be considered that as cropping involves the removal of nutrients from the soil in the form of the harvested crop, hence any amendment that does not contain nutrients but claims to increase nutrient uptake efficiency from the soil must be viewed with care in order that the soil organic matter resource is not unduly run down.

Social outcomes: In particular, grower groups and advisors who delivered the field experiments are now aware of limited impacts of biological inputs relative to conventional fertiliser in most situations. Project scientists have also presented data from the project to a variety of fora, including GRDC Southern Region Research Updates, and thus a wide audience has been reached.

Output 1

A plain English review published of the extent of biologically active products available, identifying recommendations of use, published performance and evidence and the mode of action, uploaded onto the GRDC soil biology web-site by 31st July 2014 and annually updated. Where practicable, the review will be regionally explicit.

Output 2

This output combines outputs 2&3 as listed in the tender.

Regionally focussed information in the form of a technical report and a summary factsheet on the performance potential of biological products based on available scientific evidence (from GRDC Programs and other sources) including a set of

questions to test product claims, by 30th September 2014.

A published and web-based practical guide for on farm biological product performance testing and economic evaluation including recommended evaluation protocols, by 30th September 2015.

Output 3

This is a combination of outputs 4&5

Provide support and advice for up to 8 regionally based sites managed by grower groups or other external parties to provide advice and training on farm trials demonstrating the protocols and measurement approaches by 31st March 2015.

By 31st March 2015 (annually delivered) provide support to grower groups or other external parties to publish and distribute the results of trials completed.

Achievement/Benefit

This project was designed to investigate the efficacy of biological farming inputs in the context of Australian broad-acre dry-land grains cropping. The definition of biological farming inputs is broad, encompassing alternative fertilisers, biostimulants, humates, microbial inocula, composts, manures and biochars - in essence, any non-conventional amendment, the purpose of which is to provide more enhancement to the farming system than just its pure nutrient value.

There are a wide range of biological inputs available within Australia, the main goal of the project was to investigate a wide gamut of amendments across the spectrum of those available. Focusing on coverage rather than in-depth investigation, the three year project chemically analysed well over 60 amendments, testing 38 of these in field experiments conducted at eight sites across the country.

Experimental and investigatory work was broken up into four discrete but complementary scientific components.:

1. A thorough review of the literature was conducted, enabling the project to set its own results in the context of wider research findings.
2. Laboratory testing and glasshouse screening was conducted in order to quantify chemical variability of biological farming inputs both within and between product classes, and to examine growth responses of wheat in a controlled environment.
3. Field testing of biological inputs was conducted across eight sites in five states, covering all three GRDC grain growing regions. A total of 38 biological input treatments were investigated (14 per site, four replicated across all sites) relative to a conventional fertiliser response curve (eight treatments). Yield, grain nutrient content, and various soil biogeochemical and microbial properties were examined in order to assess impacts of amendments.
4. Laboratory and glasshouse experiments were conducted to probe key mechanisms underlying biological input modes of action.

In addition to the investigatory research outlined, this project has provided the opportunity to collate a plain English review of biological farming inputs, accompanied by a practical guide to their on-farm testing, and two on-line calculators to examine data from on-farm experiments and economic scenarios in which biological inputs may improve farm profitability.

From the major review of nationally and internationally available literature, it was found that there was a general lack of evidence for the efficacy of biological inputs, especially within the broad-acre dry-land grains context, both within Australia and internationally. Even for more established amendments such as manures and composts, it is apparent from this review of the literature that multiple years of re-application may be required before major changes are observed. A particular barrier to the clarity with regard to biological input efficacy testing is a lack of clarity over active ingredients and mode of action, particularly with regard to biostimulants and humates. Our review highlighted the need to take a productivity or soil constraints approach to evaluating biological farming inputs, with particular emphasis on understanding both the main constraints to production, and also likely longevity of effect for any amendment applied.

Laboratory chemical testing and glasshouse screening revealed that although there is huge diversity in chemical composition, both between and within biological input classes, there were very limited responses of wheat to any of the >50

amendments tested in controlled conditions within a research glasshouse. Across the 38 biological inputs examined over two years at eight field sites, only four significant results in terms of wheat yield were observed. In the first year of trials, two significant reductions in yield were observed after application of one biostimulant and one humate treatment at the Paskeville site in South Australia. In the second year of trials, those treatments did not negatively impact yield again relative to the control. More positively, a chicken litter treatment had a significantly positive effect on grain yield at two sites in New South Wales, though this was likely related to high nitrogen availability within that particular litter. More in-depth analysis of soils from several of the treatments at each of the field sites revealed only sporadic and generally minor responses in terms of various soil health and fertility indicators, including microbial community structure.

Given the limitations of short term (1-2 year) field experiments, two mechanistic studies were conducted to investigate how biostimulants and humates impact on wheat capture of nitrogen from legume litter (simulating a previous legume rotation), and how biochars, humates, composts and manures impact on nutrient and carbon cycling and release as a function of biological input chemistry. The glasshouse experiment investigating nitrogen uptake utilised ^{15}N isotopic labelling in order to establish whether nitrogen within the plant was coming from the legume litter or the bulk soil. Intriguingly, despite conditions optimised for growth, there was no positive and indeed some negative impacts of biostimulants on capture both of bulk soil- and legume derived- nitrogen. Examination of nitrogen dynamics throughout the wheat growth period also failed to reveal any positive influence of any of the ten amendments tested on nitrogen release. Thus, it is apparent that in the short term, neither biostimulants nor humates are likely to enhance uptake of nitrogen by wheat.

The second mechanistic experiment was a laboratory incubation in which carbon and nutrient (nitrogen and carbon) fluxes were investigated over a 56 day period following biological input addition, reflective of the early growth period of grains crops. It was found that generally, only the more nutrient rich composts and manures enhanced nutrient availability relative to an unamended control soil treatment. Secondly, just previously found, amendment classes to be highly heterogeneous on the basis of their chemical composition, in addition their behaviour upon application to soil was equally variable from a nutrient and carbon release perspective. Thus, knowledge of the chemistry of biological inputs is required in order to make informed predictions about the impact of such amendments on soil nutrient cycling in the short term.

In addition to the scientific research conducted, this project has produced several key outputs for growers, advisors, and potentially policy makers. A technical report was produced at the start of the project and provided to GRDC to aid in understanding the variety of amendments available, and our project teams' approach to investigating their efficacy. A plain English review has been produced that is targeted at growers and advisors, and this collates and summarises key findings from a scientific review paper that has been submitted for publication in an international peer-reviewed journal. This plain English review reports the state-of-the-art of our understanding of biological farming inputs in the context of the Australian broad-acre dry-land grains industry.

In addition to the plain English and scientific reviews, the project produced a practical guide to on farm testing of biological inputs. This document provides a summary description of the various biological farming input product classes, and focuses the reader to consider key limitations to production, and which amendments may be most likely to exhibit the modes of action required to ameliorate production constraints in their specific situation. The second part of the guide then details how on farm field-scale testing of biological farming inputs with growers' equipment should be conducted, particularly with regard to replication.

To support the practical guide, two web-based calculators were developed. The first is a simple statistical analysis that allows for two treatments e.g. business as usual and a biological input to be compared, and provides the user with an output determining whether the treatment had a statistically significant impact on yield. The second calculator provides a tool for economic scenario analysis. It enables the user to input conventional input rates and costs, biological input rates and costs, and any expected offset against conventional inputs, and expected change in yield as a result. This then allows the user to examine under what conditions a biological input may become economically viable from a grain yield perspective. The option to investigate impacts of amendment on out years (including re-application of the biological input) is also provided.

Collectively, the research conducted in this project benefits several stakeholders. In providing an overview of the diversity of biological inputs available in Australia, and providing a framework by which known constraints to production can be used to guide selection, there is now a pathway for growers and advisers to take a targeted approach when considering the use of biological inputs. The field and mechanistic experiments, indicating minimal short-term positive impacts on yield or soil fertility, providing a background level of expected results, at least in the short term. Whilst it is acknowledged that not all

amendments available have been tested, nor have longer-term field experiments been possible within the scope of the project, we are confident in stating that the efficacy of biological inputs must be tested in situ on farm in order to reliably predict if positive economic or environmental outcomes will be seen. Secondly, this project is to our knowledge the largest controlled examination of a wide variety of biological amendments alongside one another in the Australian grain growing context, and thus it provides a valuable benchmark across the varied classes of biological amendments available within Australia. Further long-term research trials would be required in order to identify whether amendments might have significant cumulative effects in the medium term, and we do not discount this possibility where a biological input likely to have an effect beyond one growth season is re-applied annually.

Intellectual Property Summary

No commercialisable products planned or produced