INDUSTRY BRIEF *'From Food Waste to Smart Compost Formulations'* Project

Project Objectives

The project objectives were to evaluate

1. how compost in current use in global crop systems impacts yield, soil organic carbon (SOC) and nitrous oxide emissions from soil
2. how vegetable and grain crops perform with food waste compost as a nitrogen source, or with compost when blended as organo- or organo-mineral fertiliser
3. the risk of human pathogen transfer with food waste compost.

Objective 1 – Advancing compost to maximise benefits for yield and carbon storage

The international research team analysed over 2000 observations of compost use in crop systems. It was demonstrated that current use of compost as a mostly generic product carries uncertainties and variable outcomes. It was found that in:

- 6 out of 10 studies, yields were on average 10% lower with compost than with mineral fertiliser.
- 9 out of 10 studies, compost increased SOC, on average by 37%.
- 3 out of 10 studies, compost increased both yield and SOC.
- 7 out of 10 studies, compost ameliorated with mineral fertiliser increased both yield and SOC.

The team found no evidence that compost systematically increases emissions of greenhouse gas nitrous oxide from soil, but a better knowledge base would be desirable.

Predicting compost performance

The project identified 11 key predictors that together determined 80% of the effects on yield, SOC, and nitrous oxide emissions. The predictors are compost (carbon-to-nitrogen ratio, carbon-to-phosphorus ratio, pH, salt content), management (nitrogen supply) and biophysical settings (crop type, soil texture, SOC, pH, temperature, rainfall).

The top three most important drivers are: nitrogen as the most important driver for yield and SOC, followed by the pH of compost and soil, and third ranked is SOC. Using this knowledge, a framework was established to maximise benefits from compost. The framework was called 'Precision Compost Strategy'.

Figure 1 Compost Pellets from Peats Soils

Aligning compost use with target crops and growth environments can increase global food production

It was calculated that a global precision compost strategy can increase major cereal production by 4%, which is 96.3 million tonnes of grain per year. For comparison, this is double the grain yield harvested in Australia in a good year.

The team calculated that optimised compost generates most pronounced benefits in drier and warmer climates, and in soils with acidic pH, and sandy or clay texture. In these situations, compost achieves up 40% more yield than mineral fertiliser.

A global precision compost strategy can restore 19.5 billion tonnes of carbon in soil, which is 26% of current topsoil carbon (0-20 cm). This means precision compost can boost soil fertility and mitigate climate change.

The next steps require putting the precision compost strategy into action through smart compost formulations that realise all benefits. This requires collaboration of regulators, waste producers, recycling and compost industries, farmers, and scientists.

Zhao, S., Schmidt, S., Gao, H. et al. A precision compost strategy aligning composts and application methods with target crops and growth environments can increase global food production. Nat Food 3, 741–752 (2022).

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Objective 2 – Towards smart compost formulations: amending compost with organic/mineral nitrogen

In glasshouse experiments that allow tight control of nutrient supply and crop growth, the project explored smart compost design. Tested was how vegetable and grain crops perform with compost generated from food and green waste to quantify how compost

i. supplies nitrogen to fast-growing crops;
ii. can be amended with organic or mineral nitrogen to optimise crop yield;
iii. ameliorates soil for enhanced crop performance.

Using silica sand as low-nutrient growth substrate for crops and standardising nitrogen input, the team tested vegetable (summer, winter) and sorghum grain crops with

- Single-source nitrogen (N): organic recyclates compost (pellets or lose), bacterial biomass (PPB, purple phototrophic bacteria grown on liquid nutrient-rich waste streams), and chicken manure; mineral N was urea or ammonium-nitrate.
- Multi-source N: mixed N sources, e.g., 50:50 compost-mineral N
- Compost as soil ameliorant (5:95 compost:sand).

It was found that in the tested conditions

- as sole source of N, compost is unsuitable delivering low crop yields;
- compost combined with organic and/or mineral N sources delivers similar yield as mineral-N;
- crops responded differently to compost combined with organic and/or mineral N sources, confirming that crop-specific responses should inform compost formulations;
- as soil ameliorant and in the presence of organic or mineral N sources, compost produced a higher harvest index (yield/plant biomass), higher N uptake and faster ripening in one crop; but negatively affected another crop (less growth, N uptake, yield).
- as soil ameliorant, compost increased N use efficiency, a desired trait in crop systems.

Together, these experiments confirm that compost should be optimised for crop N nutrition. That compost as soil ameliorant boosted fruit ripening is noteworthy. Plausible reasons are that compost contains bioactive chemicals that boost crop performance, that it stimulates the presence of crop-beneficial microbes or improves the growth substrate in other ways. The negative effects observed in the second crop could be due to soil microbes competing for N as they are building soil organic matter.

The knowledge generated in these experiments, together with the Precision Compost Strategy, informs smart compost formulations targets of the follow-on project.

Figure 2 Compost granules part of the Precision Compost Strategy.

Objective 3 – Assessing the risk of food waste compost transfer of human pathogens

The project included a literature review, examining the risk that pathogens in food waste compost pose for food production. The literature is surprisingly limited as most research has focussed on composting facilities and worker exposure to pathogens. Most literature examines animal manure compost as source of human pathogens (e.g., Salmonella, Listeria), and the authors of these studies consider this risk higher than the risk from composts derived from non-animal derived wastes. There is much less information on food waste compost and the few studies that exist consider the risk of pathogen transfer lower than from animal-manure derived compost. These studies highlight that there is a need for systematic investigation of the pathogen load of composts – from source input to the sterilising effect of composting and beyond.

With the current, limited knowledge base, it was concluded that an inherent risk of pathogen transfer into food waste compost cannot be excluded. This topic clearly deserves investigation and potential regulation, including controlling the sources of food waste that enter compost and ensuring appropriate composting (i.e., high temperatures). Which human pathogens enter the food waste stream needs to be tested, and if pathogens survive the composting process and later use of compost in cropping.

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