Can edible mushroom boost soil health in banana organic systems?

Walter Ocimati, Evans Were, Geofrey Ogwal, Miguel Dita, Anthony F. Tazuba, Si-Jun Zheng, G. Blomme

Contact: w.ocimati@cgiar.org
Introduction

- The increasing global demand for safe and healthy foods produced using environmentally sound approaches has propelled the importance of organic farming.
- Soil health is an integral component of this.
- Healthy soils provide regulating and supporting ecosystem functions that impact crop productivity.
- Soil health management in organic systems requires the elimination the current heavy reliance on agrochemicals for managing biotic (weeds, pests, and diseases) and abiotic constraints.
- Addition organic amendments (OA) is one of the compatible soil health management practices.
- OA use is constrained by access, availability, and the tedious and often complex preparation process.
Mushroom wastes as a manure source

- Edible mushroom production has gained importance over the past two decades
- Global annual consumption fresh mushroom increased from 1kg in 1993 to 4.7 kg in 2013 per person.
- Global mushroom production exceeded **40 m tons** in 2021 translating into **200 m tons** of spent mushroom wastes (SMW).
- SMW contain large amounts of mineral nutrients, lignocellulolytic enzymes and microbial biomass, making them suitable for agricultural use.

Source: Ocimati et al. 2019
Mushroom wastes as a manure source

- SMW have been reported to improve soil physical, biological and chemical parameters; and to suppress soil borne pests and diseases.
- SMW could be an important source of soil organic amendments for organic banana systems.

- In this review we conduct a meta-analysis of publications to determine the major trends on the use of SMW to benefit crop rhizosphere.
- We conclude by providing an outlook on potential benefits of SMW to management of key soil health challenges of organic banana systems.

Source: Ocimati et al. 2021
A total of 1,851 publications between 1936 and 2022, with limited publications between 1936 and 1996.

Increase in publications between 1996 and 2022 (Fig. A).

Fungal biology and genetics (35%), and SMW use in agriculture (24%) dominate the publications (Fig B).

Out of 427 publications on agricultural use of SMW, 69%, 16% and 15%, respectively, focused use as biofertilizers, animal feed and biocontrol agents (Fig C).
Edible mushroom waste use for suppressing plant pathogens

- Diverse genus of edible mushrooms have been shown to suppress plant pathogens (Fig. A)
- SMW use in the management of fungal pathogens (58%) dominated the publications (Fig. B).
- Others - bacterial pathogens (16%), nematodes (12%), and mycotoxin degradation (9%)
- Mechanisms of pest/pathogen suppression (Fig. C):
  ✓ secondary metabolites or enzymes (33%),
  ✓ modulation of plant defense responses (16%),
  ✓ promotion of secondary metabolites (13%) and
  ✓ plant growth promotion
<table>
<thead>
<tr>
<th>Mushroom sp.</th>
<th>Mechanism(s)</th>
<th>Target pathogen or pest and effect</th>
<th>Citation</th>
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<tbody>
<tr>
<td><em>Pleurotus</em> pulmonarius</td>
<td><strong>Nematicidal</strong> metabolites (S-coriolic acid, linoleic acid, p-anisaldehyde, p-anisyl alcohol, 1-(4-methoxyphenyl)-1,2-propanediol, and 2-hydroxy-(4'-methoxy)-propiophenone)</td>
<td>- Nematodes (<em>C. elegans</em>)&lt;br&gt;- Immobilization and shrinking of nematode head prior to infection and digestion</td>
<td>Stadler et al., 1994.</td>
</tr>
<tr>
<td><em>Hericium</em> erinaceus</td>
<td><strong>Antibacterial activity</strong> of Water, n-butanol, and ethyl acetate extracts of SMS.&lt;br&gt;- <strong>Induced expressions of plant defense genes</strong> encoding β-1,3-glucanase (GluA) and pathogenesis-related protein-1a (PR-1a) -associated with systemic acquired resistance&lt;br&gt;- <strong>Plant growth promotion</strong>&lt;br&gt;- 85% suppression of <em>R. solanacearum</em>, improved growth</td>
<td><strong>Phytopathogenic bacteria:</strong>&lt;br&gt;<em>Pectobacterium carotovorum</em> subsp. <em>carotovorum</em>, <em>Agrobacterium tumefaciens</em>, <em>Ralstonia solanacearum</em>, <em>Xanthomonas oryzae</em> pv. <em>oryzae</em>, <em>X. campestris</em> pv. <em>campestris</em>, <em>X. a. pv. citiri</em>, and <em>X. a. pv. glycine.</em></td>
<td>Kwak et al., 2015</td>
</tr>
<tr>
<td><em>Lactarius</em> rufus</td>
<td><strong>Antifungal sesquiterpene</strong>&lt;br&gt;- Growth inhibiting Rufuslactone</td>
<td>- Alternaria alternata, <em>A. brassicaceae</em>, <em>Botrytis cinerea</em> and <em>F. graminearum.</em></td>
<td>Luo et al., 2005;</td>
</tr>
<tr>
<td>SMS compost and extracts, <em>P. ostreatus</em></td>
<td>- Effect on <strong>diverse mesophilic bacteria and actinobacteria</strong>&lt;br&gt;- <strong>Increased soil carbon and organic matter</strong>&lt;br&gt;- Pleurostrin - Peptides with <strong>antifungal activity</strong></td>
<td><strong>Fusarium oxysporum</strong> f. sp. <em>melonis</em>, <em>F. oxysporum</em>, <em>Mycosphaerella arachidicola</em> and <em>Physalospora piricola</em>&lt;br&gt;- Upto100% suppression of mycelia</td>
<td>Suárez-Estrella et al., 2012, Chu et al., 2005</td>
</tr>
</tbody>
</table>
- In-vitro suppression of Foc race 1 – anti-fungal compounds
- Promotion of diverse beneficial microbes
- Screenhouse
  ✓ Plant growth promotion
  ✓ reduced corm damage in plantlets of a susceptible banana cultivar - in both sterile and naturally infested soils.

Source: Ocmait et al. 2019
Edible mushroom waste use as biofertilizer

Table 2. Sample publications on spent mushroom waste use as biofertilizers

<table>
<thead>
<tr>
<th>Benefits in the soil rhizosphere</th>
<th>Citation</th>
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<tbody>
<tr>
<td>Crop vigor and yield Improvement</td>
<td>Kadiri and Mustapha, 2010</td>
</tr>
<tr>
<td>Improves soil organic carbon and matter</td>
<td>Li et al., 2020, Becher et al., 2021</td>
</tr>
<tr>
<td>Enhances soil macro (nitrogen, phosphorus, and potassium)- and micro (iron, zinc)-nutrients</td>
<td>Lou et al., 2017, Ma et al., 2021, Jonathan et al., 2011</td>
</tr>
<tr>
<td>Regulates and maintains soil pH in range of agricultural production</td>
<td>Abreu et al., 2020, Lipiec et al., 2021</td>
</tr>
<tr>
<td>Helps improve soil structure, thus a higher and balanced air porosity</td>
<td>Courtney et al., 2009, Lipiec et al., 2021</td>
</tr>
<tr>
<td>Improves soil microbial biomass and functional diversity within the soil</td>
<td>Li et al., 2020, Frac et al., 2021</td>
</tr>
<tr>
<td>Regulates soil moisture and temperature</td>
<td>Ma et al., 2021</td>
</tr>
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</table>
Spent mushroom waste (SMW) use for managing soil health problems of organic banana systems

- **Key biotic soil health challenges of banana systems:**
  - Diverse nematode species (*Radopholus similis*, *Pratylenchus* spp., *Meloidogyne* spp., and *Helicotylenchus multicinctus*).
  - Fusarium wilt caused by *Fusarium oxysporum* f. sp. *cubense* (Foc) - a major soil borne threat to banana production.
  - Bacterial pathogens (*Xanthomonas vasicola* pv. *musacearum* and *Ralstonia* spp)

- Current review shows multiple studies (in vitro, greenhouse and field) in which multiple species of nematodes, in genera of *Fusarium*, *Xanthomonas* and *Ralstonia* to suppressed by SMW.

- Findings of Ocimati et al. (2021) further support the potential use of SMW in management of Foc in banana systems

- **Key abiotic constraints:**
  - Low soil moisture content and nutrient deficiency are major yield limiting factors for the banana.

- Studies above show SMW to improve soil structure, soil pH, levels of macro and micro elements, soil organic matter and water retention-function that could improve performance of the banana crop in organic systems.
Study recommendations

- Assessing the potential of SMW on a wider range of edible mushroom species to:
  - suppress biotic constraints (especially, *Foc*, including *Foc* TR4) and
  - Improve highlighted chemical, biological and physical properties of soils in organic banana production systems is recommended.
Acknowledgement

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Thank you for listening
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