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Editorial: Upcycling organic waste for the sustainable management of soilborne pests and pathogens in agri-food systems

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Editorial on the Research Topic
Upcycling organic waste for the sustainable management of soilborne pests and pathogens in agri-food systems

Introduction

Agricultural and food supply systems face the challenge to meet a delicate balance between supporting the increasing demand for food and minimizing their environmental impact. Two main challenges dominate these impacts. First, the accumulation of organic wastes at each stage of the whole food chain process. Second, to protect crops against pests and pathogens without applying hazardous chemicals. This is translated in stricter regulation. Organic wastes are being banned from landfill disposal (i.e., California Senate Bill 1383 or Directive EU 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste); and hazardous chemicals such as methyl bromide are being banned worldwide (i.e., Montreal protocol). To guarantee the success of these regulations without disrupting the demanding growing population economy and environment, the development of novel technologies to upcycle organic residues is an urgent need. This aligns with the increasing consumer's demand for sustainable food products, which offers a unique opportunity to develop more sustainable agricultural practices by revalorizing agri-food by-products. Composting, soil bio-fumigation, biosolarization and anaerobic soil disinfestation (ASD) are some of the practices included in this topic that can turn agri-food by-products into substitutes for chemical fumigants as well as improve soil health. This Research Topic covers a

TABLE 1 Summarizing table of key information of the Research Topic articles.

Topic reference	Technology	Organic wastes	Soilborne pests and pathogens	Cropping system
Axelrod et al.	Biosolarization	Insect compost		Lettuce
Gandariasbeitia et al.	Soil biodisinfestation	Beer bagasse Defatted rapeseed cake Fresh cow manure	*Meloidogyne incognita*	Lettuce
Guerrero et al.	Soil biodisinfestation	Wheat husk Fresh sheep manure Sunflower pellets	*Phytophthora capsici*	Bell pepper
Khadka and Miller	ASD*	Wheat bran Molasses Chicken manure Mustard greens	*Rhizoctonia solani*	Radish
Larregla et al.		Fresh sheep manure Poultry manure	*Phytophthora capsici*	Protected pepper crops
Muramoto et al.	Integrated Soil Health Management	NA		Strawberries
Serrano Perez et al.	Biofumigation	Brassica carinata	*Phytophthora nicotianae*	Paprika Pepper
Vincent et al.	ASD	Molasses Composted poultry litter	NA	Tomato
Shrestha et al.	ASD	Molasses Soybean hulls Wheat bran Corn starch	NA	Bell pepper Tomato Eggplant
Swilling et al.	ASD	NA	*Sclerotium rolfsii*	NA
Testen et al.	ASD	Corn gluten meal Distillers dried grains Soybean meal Wheat bran Dry sweet whey Cover crops	*Pyrenochaeta lycopersici, Colletotrichum coccodes, Verticillium dahliae, Meloidogyne spp.*	Tomato
Avidov, Varma, Saadi, Hanan, et al. Avidov, Varma, Saadi, Khoury, et al.	Composting	Broiler litter	*Salmonella*	NA

*Anaerobic Soil Disinfestation.

wide range of articles dealing with the challenges of organic by-products amendment-based approaches to understand the main mechanisms of soilborne pests and pathogens inactivation. Table 1 summarizes the wide diversity of by-products, pathogens, and crop systems where these technologies can be applied, highlighting their potential impact. Being technologies based on the biological degradation of exogenous labile organic matter, many of the published articles focused on the characterization of the microbial communities. Realistically, up to now, there is no silver bullet. Therefore, Muramoto et al., explores the concept of Integrated Soil Health Management (ISHM) to better address management strategies for soil-borne disease and overall soil and plant health.

Outcomes and challenges on organic wastes

There is no one stop solution for managing organic waste meaning a constant optimization process is needed. Despite the consensus regarding their adverse effects, landfilling and incineration are still the waste disposal techniques most used around the world (Siddiqua et al., 2022). In the European Union, incineration is considered adequate only if it delivers the best environmental outcome possible, such as energy recovering (Directive 2008/98/EC on waste). The term "organic waste" being phased out and replaced by "recycled organic resources" should be the short/mid-term inspiring goal.

Scientific research is the basis for any future implementation of new solutions, and the rapid advancement in the areas of big data, artificial intelligence, "omics" should also lead the way in organic waste upcycling. An ecological approach should be considered as the way to move forward, where farms becomes a "niche" that must be balanced in term of inputs and outputs of resources (Oren et al., 2018). Replacing hazardous chemicals by sustainable biological treatments is a priority. The challenge is that often agrochemicals, including synthetic soil fumigants are cheaper and more reliable than biological solutions. In this Research Topic readers can identify the diversity of by-products employed to face agronomical challenges (Table 1) and their potential application as future "weapons" in the constant "arms race" against soilborne pests and pathogens.

Outcomes and challenges on mechanisms of soilborne pests and pathogens management

The present Research Topic also describes some biological, chemical and physical mechanisms involved in pest inactivation. A better understanding of their mode of action can contribute to improve the efficacy. This includes understanding how abiotic factors such as soil temperature, pH, redox conditions directly or indirectly affect pests and pathogens or increase their susceptibility to bioactive compounds. High soil temperature is one of the most direct mechanisms in pests/pathogens inactivation particularly during solarization and biosolarization (Dahlquist et al., 2007). Higher temperatures also have shown to make weeds more susceptible to organic acids (Fernández-Bayo et al., 2020). Understanding the role temperature plays is particularly important to manage pathogens in regions or seasons characterized by milder temperatures (Henry et al., 2020; Vecchia et al., 2020). The temporary development of anaerobic conditions is also key to manage soil borne pest and pathogens directly due to the lack of oxygen (Khadka et al.). Indirectly, anaerobic conditions promote the shift of soil microbiome (Hewavitharana et al., 2019); the reduction of metal ions such as Fe^{2+} and Mn^{2+} (Momma, 2015); or the fermentation of the added labile organic carbon and the generation of organic acids (Momma, 2008; Fernández-Bayo et al., 2020). One goal should be therefore maximizing the generation of well-established bioactive compounds such as volatile fatty acids (Momma e al., 2006), glucosinolates (Gimsing and Kirkegaard, 2009), and other compounds that need to be studied. In this context, understanding the soil biological activity is key. On the one hand, there is a need to understand the short-term interactions of the soil microbial community with the exogenous microorganisms and nutrients applied with the organic by-products (Fernández-Bayo et al., 2019). On the other hand, microbes can also directly suppress the target pest and pathogen (Mazzola, 2007). This requires understanding microbial community changes and their resilience and legacy effect in the soil post-treatment. Ultimately, only treatments capable of preventing pathogen recolonization in the long-term (Rosskopf et al., 2020) will guarantee the sustainability of these technologies and their adoption by farmers. Among these mechanisms, this Research Topic highlights some promising information on the promotion of soil suppressiveness after ASD (i.e. Gandariasbeitia et al.) as well as the key role of organic acids on pest inactivation (i.e. Swilling et at.).

Trends on sustainable soilborne pests and pathogens management

The use of organic amendments for the management of soilborne pests and pathogens has a long history; however, only after the phase out of methyl bromide, we have seen a renewed interest and a more consistent research effort toward the development of biological soil disinfestation methods (Rosskopf et al., 2020). The present Research Topic introduces the importance of employing ISHM strategies and provides important updates on some of the most promising amendment-based biological techniques available for the management of soil health with a focus on the management of soilborne pests and pathogens. The updated state of the art on the development and optimization of soil managements biotechnologies such as ASD, biosolarization, biofumigation and composting presented in this Research Topic contributes to disclose the great potential of employing by-products of the agri-food industry, otherwise considered waste, as a resource for the management of soilborne pests and pathogens. The evaluation of the performance of such biotechnologies employing a variety of organic by-products to manage different pathosystems under different environmental conditions, is proof of a new trend and of a renewed research effort aimed at developing more sustainable soil health management practices. However, none of this will be successfully implemented without proper involvement and training of farmers. Furthermore, the enhanced capacity to analyze the soil microbiome, is greatly expanding our understanding of the key role the soil microbiome plays in determining soil health in an agroecosystem. The possibility to characterize the soil microbiome and correlate shift of the soil microbial communities to specific soil inputs and to the suppression of specific pathosystems represents a great opportunity for the advancement of the biotechnologies considered in this Research Topic. The gain of such perspective further highlights the risks associated with the employment of soil disinfestation practices that indiscriminately reduce the soil microbial population. Overall, this Research Topic contributes to enhance our awareness of the need for more sustainable and integrated soil health management practices.

Author contributions

JF-B has led, written and reviewed this manuscript. YA, MG, and FD have written and reviewed this manuscript. All authors contributed to the article and approved the submitted version.

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