Waste Management xxx (2013) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Review

Compost: Its role, mechanism and impact on reducing soil-borne plant diseases

C.M. Mehta [a,b], Uma Palni [b], I.H. Franke-Whittle [c], A.K. Sharma [a,*]

[a] Department of Biological Sciences, College of Basic Science and Humanities, G. B. P. U. A. & T. Pantnagar, U.S. Nagar, Uttarakhand, India
[b] Department of Botany, D.S.B. Campus, Kumaun University Nainital, Uttarakhand, India
[c] Leopold-Franzens University, Institute of Microbiology, Technikerstraße 25, 6020 Innsbruck, Austria

ARTICLE INFO

Article history:
Received 29 July 2013
Accepted 28 November 2013
Available online xxxx

Keywords:
Compost microbes
Plant diseases
DGGE
Disease suppression

ABSTRACT

Soil-borne plant pathogens are responsible for causing many crop plant diseases, resulting in significant economic losses. Compost application to agricultural fields is an excellent natural approach, which can be taken to fight against plant pathogens. The application of organic waste products is also an environmentally friendly alternative to chemical use, which unfortunately is the most common approach in agriculture today. This review analyses pioneering and recent compost research, and also the mechanisms and mode of action of compost microbial communities for reducing the activity of plant pathogens in agricultural crops. In addition, an approach for improving the quality of composts through the microbial communities already present in the compost is presented. Future agricultural practices will almost definitely require integrated research strategies to help combat plant diseases.

Contents

* Corresponding author. Tel.: +91 7500241561; fax: +91 5944233473.
E-mail address: anilksharma_99@yahoo.com (A.K. Sharma).

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http://dx.doi.org/10.1016/j.wasman.2013.11.012

1. Introduction

Almost a century ago, Sanford (1926) started a new era of soil-borne disease investigations. In his study, he suggested that the soil-borne pathogen *Streptomyces scabies*, which causes potato scab, could be controlled by green amendments. This control was due to the action of antagonistic soil saprophytes derived from the green amendment material. Soil-borne pathogens cause great economic losses all over the world. They are also more intractable to management and control compared to pathogens that attack the above-ground portions of the plant (Bruehl, 1987). Presently, soil-borne problems are managed by using different integrated approaches, however, these approaches do not completely eliminate the pathogens from the soil. The complex nature of soil and its environment enable these pathogens to survive for long periods in the field.

Soil organisms that have the potential to be plant pathogens can be classified into five major groups: fungi, bacteria, viruses, nematodes and protozoans (Agrios, 2005). Some pathogens of the above ground parts of plants (leaves, stems) also survive in the soil at various stages in their life cycles. Therefore, a soil phase of a plant pathogen may be important, even if the organism does not infect roots. The majority of bacteria are less prone than fungi and nematodes to causing soil-borne diseases due to their inability to produce spores and thus their inability to survive in the soil for a very long period (Koike et al., 2003). In addition, bacteria also require a wound or natural opening for penetration into the plant and initiation of infection (Genin and Boucher, 2004; Nester et al., 2005). Insect damage can facilitate the entry of plant pathogens into plants (Agrios, 2005). Like bacteria, viruses also require a wound for plant infection and as viruses are transmitted by vectors, few viruses can infect plants. In soil, viruses can be transmitted by nematodes (Brown et al., 1995) or by zoosporic fungi such as *Olpidium* and *Polymyxa* (Campbell, 1996).

Fungi cause the majority of plant diseases in agricultural fields (Pernezny et al., 2011). Fungi are eukaryotic, filamentous, multicellular, and heterotrophic organisms that produce a network of hyphae (mycelium), which is able to absorb nutrients from the surrounding substrate (Alexopoulos et al., 1996). Members of the Oomycetes reportedly cause most soil-borne diseases (Fry and Niklaus, 2010). They produce swimming spores (zoospores) and contain cellulose in their cell walls. The mycelial structure of fungi helps it to spread up the root, internally or externally, or to spread to other roots in close proximity (Raaijmakers et al., 2009). This is the most effective fungal strategy for long time survival in plants.

Over the last few decades, much research investigating soil-borne pathogens and their effect on different crops and vegetables has been conducted. The fungal genera *Rhizoctonia*, *Fusarium*, *Verticillium*, *Phytophthora* and *Sclerotium* contain the major soil-borne plant pathogens known, these pathogens affecting a number of important crops including wheat, cotton, vegetables and temperate fruits (Koike et al., 2003; Noble and Coventry, 2005). To overcome such diseases, different approaches have been taken in the past. The most common method to control these diseases is the use of fungicides. Using fungicides against a pathogen can help to control disease in a very effective way, however, frequent and indiscriminate use of fungicides may also lead to atmospheric pollution and the development of fungicide resistance (Christopher et al., 2010). Therefore, an alternative to chemical control is much needed. Alternative approaches include solarisation (Katan, 1996), biofumigation (Kirkegaard et al., 2000), biological soil disinfestations (Blok et al., 2000) and application of biocontrol agents (Hoitink and Boehm, 1999; Ryckeboer, 2001) or organic amendments such as composts (Paulitz and Belanger, 2001; Bailey and Lazarovits, 2003).

In a biological control approach, microorganisms isolated from the soil can be directly used for the reduction of plant disease. A group of papers in the 1920s and early 1930s (Hartley, 1921; Henry, 1931) was published on the biological control of plant pathogens. Approximately 50 years later, books by Baker and Cook (1974) and Cook and Baker (1983) which collected and analysed available knowledge on the use of microorganisms for the biological control of plant diseases, have renewed research activity in the area, resulting in many laboratory scale studies, but few effective field trials. In recent years, biological control has become an increasingly promising alternative to chemical control in the management of soil-borne disease (Harman et al., 2004). Numerous studies have demonstrated reduced incidence of diseases in different crops after supplementing the soils with fungal or bacterial antagonists (Singh et al., 2002; Ahmed, 2011; Akrami et al., 2011). Different approaches for the biological control of pathogen borne diseases can be used, and composting is one such approach.

Composting is a controlled biological decomposition process by which organic materials are degraded through the activities of successive groups of microorganisms (Dees and Ghiorse, 2001). Composting transforms raw organic waste materials into biologically stable, humic substances that make excellent soil amendments (Adani et al., 1995). Composting has been used in farming to improve soil fertility and crop health for centuries, however the process was somewhat modernised in the nineteenth century in Europe, with the onset of what is known today as organic farming (Heckman, 2006). In composting processes, the most important step is the decomposition of organic matter, and this occurs via mostly aerobic decomposition, although some anaerobic decomposition also occurs (Cooperband, 2002).

Compost application can help reduce pathogen attacks and in addition, also improve the soil health and its nutrient levels. Most of the literature on the role of compost, its mechanism of action, its microbial structure and the possibilities to improve compost quality for disease suppression is scattered, and so far, these topics have been reviewed separately. Therefore, in this paper, we have reviewed pioneering as well as recent works in detail, and provide clear information about the role of compost in disease suppression, as well as the major factors and mechanisms contributing to compost quality.

2. Role of compost in disease suppression

The role of composts in disease suppression was first suggested by Hoitink et al. (1975). Inclusion of compost in the growing media as a method to suppress a wide variety of soil-borne plant pathogens like *Rhizoctonia* root rot (*Rhizoctonia solani*) on bean and cotton, *Fusarium* wilt (*F. oxysporum* f. sp. *cucumerinum*) of cucumber, *Sclerotinia* drop (*Sclerotinia sclerotium*) of lettuce etc. was studied by Lumsden et al. (1983). These studies showed the importance of composts in the biocontrol of different soil-borne plant diseases. Today, compost application is a well established commercial prac-