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Review Article

Compost: A Tool for Managing Soil Borne Plant Pathogens

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A B S T R A C T

Compost technology is a valuable tool being used for managing soil borne plant pathogens and increases yields by farmers interested in sustainable agriculture. These beneficial uses of compost can help growers to save money, reduced their use of pesticides and conserve natural resources. Control of Soil borne pathogens is difficult because these pathogens survive for many years as sclerotic in soil or as mycelium in organic matter under several environmental conditions. Control of plant diseases has commonly relied on cultural practices and on the use of fungicidal treatments. However cultural practices alone are not efficient and at the present time. Organic amendments play an important role as environmentally friendly and sustainable alternative approach to protect plants against soil borne pathogens. Soil amendments using composted agricultural wastes in this respect can be an advantaged as both in soil fertility, recycling of agricultural residues and could provide a powerful tool for management of plant diseases.

Introduction

The soil/substrate that supports plant roots and provides water and nutrients to plants is often considered a hostile environment that harbors plant pathogens. Moreover, the most common strategy used to control risk of disease from the soil is the eradication or minimization of soil pathogens regardless of the presence of other organisms. Consequently, the extensive use of physical/chemical biocides generates a soil/substrate microbiological vacuum which makes it more susceptible to infestation by pathogens, increases disease incidence and in some cases enhance fungal resistance.

Soil-borne plant pathogens like *Pythium, Phytophthora, Sclerotium. Aphanomyces, Thielaviopsis, Macrophomina, Fusarium, Ganoderma, Verticillium,* etc. frequently causes heavy losses in economically valuable crops, horticultural plants and trees throughout the world. These pathogens affect both yield and quality. In intensive agriculture, economically valuable crops are frequently or even continuously planted on the same piece of land. The population of these soil-borne plant pathogens increases with the increased years of cultivation of susceptible crops. The inoculum density of the pathogens in soil is directly proportional to the disease intensity on a crop in the field. The inoculum density of soil borne pathogens can be kept in check with various methods but the compost is one which can reduce the inoculum density of these pathogens in an ecofriendly way and this information include how composting inactivate or reduce the density of various soil borne pathogens and keep the ravages of diseases in check.

Need for management

Soil borne plant pathogen significantly reduces crop yield

These pathogens are particularly challenging because they often survive in soil for many years

Simultaneous infections from multiple soil borne pathogens sometimes results in a disease complex that can be further damage the crop

Many plant diseases caused by soil borne pathogens are difficult to predict, detect and diagnose

Soil environment is extremely complex making it a challenge to understand all aspect of diseases caused by soil borne pathogens

Compost

It is a humidified material resulting from the composting process, exhibiting amending as well fertilizing characters

Composting

It is a process of transformation of organic material (Plant matter) through decomposition in to a soil like material which is termed as compost. Invertebrates (insects and earth worms), and microorganisms (Bacteria and fungi) help in this transformation

Compost suppressiveness

Compost acts as a food source and shelter for the antagonists that compete with· plant pathogens, for those organisms that prey on and parasitize pathogens, for those beneficial that produce antibiotics and for those microorganisms that induce resistance in plants. Success or failure of any compost treatment for disease control depends on the nature of the raw product from which the compost was prepared, the maturity of the compost and the composting process used. High-quality compost should contain disease-suppressive microorganisms and mycorrhizal inoculums.

Factors influencing composting process

Certain factors can influence composting process, which must be in an optimum range if aerobic, thermophilic composting is to proceed rapidly and effectively. These are summarized as follows:

C: N ratio

During composting, micro-organisms require carbon for growth and energy, and nitrogen for protein synthesis. Rapid composting is achieved when wastes or mixtures of wastes have C: N ratios of between 15 to 35. Higher ratios can slow the rate of composting.

Moisture content

The optimum moisture content of organic wastes for rapid-aerobic, thermophilic composting ranges from 40 to 60% (by weight). Above 60%, there may be insufficient air space to sustain aerobic decomposition.

Temperature

As composting proceeds and if other factors are favourable, microbial activity causes temperature to increase from the mesophilic range (20-40 ^{0}C) into the thermophilic range

(>40^0C). Optimum temperature for rapid aerobic composting ranges from 55 to 65°C.

pH

Optimum pH for rapid composting of various wastes ranges from 5.0-9.0.

Aeration/Oxygen supply

A continuous supply of oxygen is required to ensure rapid aerobic, thermophilic composting, there should be at least 30% free space.

Particle size/texture

Grinding, shredding and blending organic wastes can enhance the rate of decomposition during composting by providing a more favourable surface to volume ratio.

Microbial activity

Disease suppressive properties of composts rely on a number of factors including microbial activity, microbial population dynamics, nutrient concentrations and other associated chemical and physical factors (Fig. 1). The mechanism suggested is that the compost enhances the activity of microorganisms introduced with the compost and stimulates those residents in the soil (Lumsden *et al.*, 1983b). High levels of microbial activity in composts were postulated as the primary factor in disease control (Phae *et al.*, 1990, Nelson 1991, Craft and Nelson 1996, Nakasaki *et al.*, 1998). Addition of mature composts prepared from tree bark (Chen et aI., 1987), municipal sewage sludge (Lumsden *et al.*, 1983a), separate cattle manure and grape pomace (Chen *et al.*, 1988) to peat mixes increases microbial activity and induces microbiostasis and suppression to Pythium root rot and damping-off (Mandelbaum *et al.*, 1988).

Composts for Plant growth

Amendment of soil with compost has shown positive and significant effects on growth parameters of a crop due to increase organic matter, better soil moisture and fertility conditions and increased microbial activity (Fig. 1). Cowpea plants grown in amended soil had greater number of nodules compared to non-amended with maximum counts in FYM amended soil, but in *P. juliflora* and *A. nilotica* compost-amended plots these were not significantly different than control. Root length did not differ significantly in amended or non-amended soil, but reduced significantly in weed compost-amended plots (Baraja *et al.*, 2010). Except *Calotropis* and weed compost-amended plots, shoot length was greater in other amended plots but significant differences with non-amended soil were recorded only in *P, juliflora, A. nilotica* and FYM amended plots. In fresh and dry shoot weights, consistent trend was not recorded in amended or non-amended plots. Better nodulation observed in the amended treatments could be ascribed to the availability of soil moisture and nutrients and these factors also enhanced population of beneficial microbes which might have contributed for a better growth of cowpea in *P. juliflora* compost-amended soil. Variations observed in growth parameters of cowpea in different composts can be assigned to differences in biological and chemical-properties of the composts (Widmer *et al.*, 1998, Abbasi *et al.*, 2002).

Improvement in Soil moisture

Soil amendment with compost also improves soil moisture conditions in those so which are otherwise poor in water holding capacity. In study carried out in sandy soils; compost amended plots held more soil moisture (30.4-35.3 nm) compared to corresponding non-amended (29.4 mm) plots, (Bareja *et al.,* 2010); There was a great variation in different composts at 20 days after planting (DAP), where available soil moisture ranged from 11.9 - 19.6 mm in amended plots compared to 20.2 mm in the non-amended control indicating that cowpea plants effectively utilized soil moisture for the initial growth in amended plots. At 4O DAP, variations in soil moisture conservation were not discernible in different treatments but again FYM amended plots held maximum soil moisture. At fourth sampling date, which coincided with the maturity of cowpea all the amended plots held more soil moisture than the non-amended control.

Improvement in seed yield

Increased seed yield in all the compost-amended treatments may be a cumulative effect of increased soil moisture retention, availability of nutrients, qualitative and quantitative improvements in microbiological properties, increased microbial activity and reduced disease incidence.

Beneficial effect of compost-amendment in reducing disease incidence and increasing seed yield has been well documented for sunflower, tomato and cluster bean (Allievi *et al.,* 1993, Lodha *et al.,* 2002). Improvement in seed yield of cowpea in the year 2003 compared to 2001 is mainly attributed to quantum and distribution of rainfall. In the year 2001, four well distributed rain events (254 mm) occurred during vegetative and flowering stage. Thereafter, no significant rain events occurred leading to severe moisture stress at pod formation stage and onwards till maturity. However, in the year 2003, there were six good evenly distributed rain events (282 mm) till pod formation stage, thus crop experienced moisture stress only after seed formation stage.

Improvement in Micronutrients

Maximum contents of Cu, Fe, and Mn were estimated in plants grown in weed compost - amended soil, while Zn content was higher in those grown in *P. juliflora* amended plots (Bareja *et al.,* 2010). Interestingly, Zn content was lower in plants grown in weed compost-amended soil. There was a great variation in Mn content in plants of amended or non-amended soil. Overall, maximum uptake of these nutrients was estimated in plants grown in weed followed by *A. nilotica* compost-amended soil.

Survival of bio-control agents

Exploitation and recycling of naturally available agricultural waste media have been used for growth and carrier medium for multiplication of various bio-control agents. Research efforts made at CAZRI have shown that utilizing pods of *P. juliflora*, an abundantly grown shrub with potato improved multiplication of *T. harzianum* in liquid broth (Lodha *et al.,* 1999). Thus, utilizing *P. juliflora* plant parts for the preparation of compost can be a better choice for fast multiplication and as a substrate for easy delivery in soil after further experimentation.

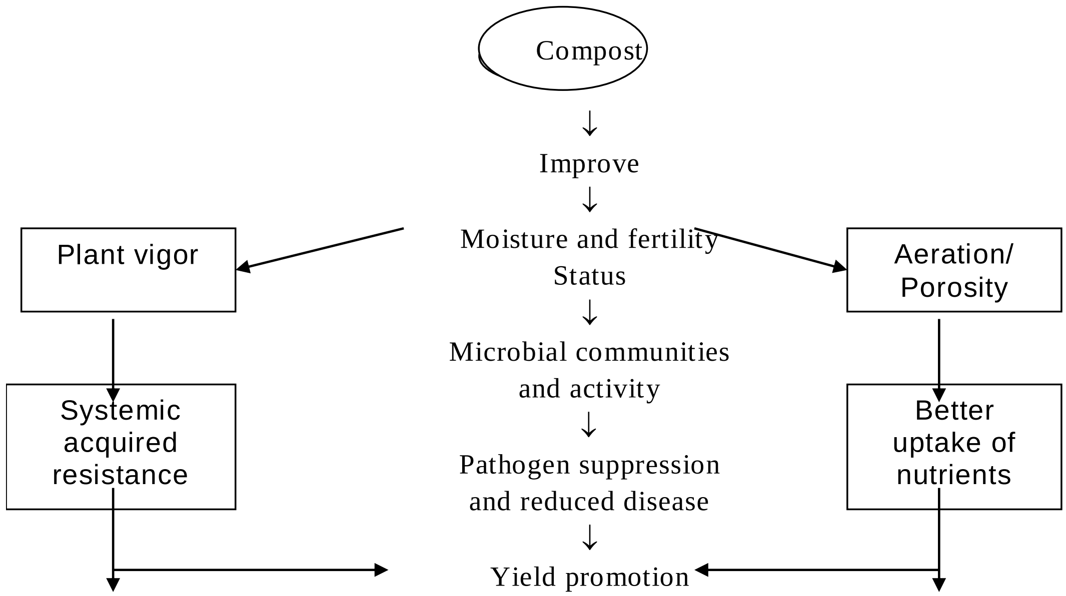
Mechanism of biological control in composts

Most compost products suppress Pythium and Phytophthora root rot naturally, while only some suppress *Rhizoctonia* and very few induce systemic resistance in plant (Zhang *et al.*, 1998).

Table.1 Main effect and reference groups studying composts as an inducer or plant disease suppression

S.No	Compost materials	Disease suppression	Observed effect	References
1.	Composted municipal waste (CMW) amendment of citrus soils	*Phytophthora nicotianae* in citrus seedlings	Disease decreased increasing proportions of one CMW (20% v/v)	Widmer *et al.*, 1998
2.	Animal manures	*Phytophthora cinnamomi* in lupine and two cut-flower species	Chicken manure compost better control than cow, horse and sheep manure. Suppression was biological in nature and populations of fluorescent *Pseudomonas* were involved in the effect	Aryantha *et al.*, 2000
3.	Peat moss amended with a range of 4 to 20% composted swine wastes at different weeks of maturity	*Pythium ultimum* and cucumber bioassay. *Rhizoctonia* pre-emergence damping off of impatients	Potting mixes amended @ of 20% with compost after 35 weeks or more of curing was more suppressive to *Rhizoctonia* and Pythium damping-off. Compost maturity and cellulose content have direct effects over *Rhizoctonia*	Diab *et al.*, 2003
4.	Compost from viticultur, organic fraction differentiated or un differentiated, municipal bio waste, cow manure & peat and differentiated municipal biowaste (1:1 v/v)	*Pythium ultimum*, *Rhizoctonia solani* and *Sclerotinia minor*	All composts performed better than peats. The best composts against *P. ultimum* were: 2, 4 and 5. The best composts against *R. solani* were 1 and 4. The best compost against S. minor was 2.	Pane *et al.*, 2011
5.	Cork compost (CC) Olive mare compost (OC) Grape marc compost (GMC) Spent mushroom compost (SMC)	*Rhizoctonia solani* (*Rhizoctonia* damping-off)	Disease incidence reduction in CC (0.5-1 year age) and in OC, GMC and SMC (1.5-3 year age) Effect of T34 in disease incidence reduction. Importance of nature of materials and age of compost	Trillas *et al.*, 2006
6.	Vegetable + animal market wastes + sewage sludge and yard wastes	*Fusarium oxysporum* f.sp. *lycopersici* (*Fusarium* wilt of tomato) Two dose of pathogen 5 x 10^4 cfu/ml and 5 x 10^4 cfu/m^3)	Compost suppressiveness is compared with peat: vermiculite mix (1:1), natural *Fusarium* Chateaurenard suppressive soil, sterilized natural soil amended with 10% compost, or with *Trichoderma* spp. Or Fo 47, BCAs	Cotxarrera *et al.*, 2002
7.	Grape marc and extracted olive press cake (GM + EPC), olive tree leaves and olive mill waste water (OL + OMW), and spent mushroom compost (SMC)	*Fusarium oryxporum* f.sp. *radicis lycopersici* in tomato plants	The three composts were highly suppressive and suppression is related to the presence of specific microorganism	Ntougias *et al.*, 2008;
8.	Compost from tomato plants and cow manure	*Fusarium osysporum* f.sp. *melonis*	These compost were very suppressive to this disease and in this study it is evaluated its effect of storage (different temperature and moisture) on suppression	Saadi *et al.*, 2010
9.	Mature biosolids compost (sewage sludge and yard waste)	*Sclerotinia rolfsii* in bean plants	Prolonged compost curing negates suppressiveness. Combination of microbial populations and the chemical environment were responsible for pathogen suppression.	Danon *et al.*, 2007
10.	Cork compost and light peat	Verticillium wilt of tomato	Cork compost was suppressive in comparison with peat. This compost had higher microbial activity and biomass. The two plant growth media differed in their carbon metabolic profiles	Borrero *et al.*, 2002
11.	18 compost from different countries	*Verticillium dahlia* (egg plants), *Rhizoctonia solani* (cauliflower and pinus), *Phytophthora nicotianae* (tomato), *Phytophthora cinamomi*) (lupin), *Cylindrocladium spathiphylli* (spathiphyllum); *Fusarium oxysporum* f.sp. *lini* (flax)	Among studied compost, the most consistent disease suppression (64 – 71%) was found against F.xoysporum and the most infrequent (4.7 – 6.5%) was against *P. cinnamomi* and *R. solani*	Termorshuizen *et al.*, 2006

Fig.1 Mechanism of action for disease suppression and yield promotion by compost



Specific disease suppression refers to a specific group of microorganisms antagonizing the pathogen. Such group may include included non-pathogenic *Fusarium* species and *fluorescent pseudomonas (Pseudomonas fluorescens*). The biological control for *Rhizoctonia solani*, by a narrow group of antagonistic microorganisms, is described as specific suppression. Edaphic microorganisms stimulated by compost amendments contribute to the suppressive activity or the amended soil through four control mechanisms: antibiosis, competition, predation hyperparasitism and the induction of systemic acquired resistance in the host plant (Lockwood, 1988).Antibiosis is the inhibition of one organisms growth by a metabolic product (such as antibiotic) being produced by another organism (Baker and Cook, 1974). Many organism, especially soil fungi and actinomycetes, produce antibiotic substances. Three diseases have been found to be controlled by antibiosis: armillaria root rot (*Armillaria mellea*) by *Trichoderma viride*, pythium and *Rhizoctonia* damping off and stem and root rot disease by *Pseudomonas fluorescens*, and crown gall (*Agrobacterium tumefaciens*) by *Agrobacterium radiobacter*. The most widely accepted commercial example is the use of strain 84 to control of crown gall, one of the most serious disease of stone fruit trees in nurseries and of many other woody plants. *Agrobacterium radiobacter* and particularly one strain, strain 84 produces large quantities of a bacteriocin, now called agrocin. Competition is when organisms compete for nutrients (particularly high-energy carbohydrates, nitrogen and iron) infection sites, and possibly certain environmental factors such as oxygen and space (Baker and Cook, 1974).Parasitic and predatory fungi are known to parasitize plant pathogens resulting in lysis or death. Such organisms may include *Rhizoctonia solanii* on species of *Pythium* (Butler, 1957), *Trichoderma viride* on *Armillaria mellea* (Duddington and Wyborn, 1972) and *Tuberculina maxima* and *Fusarium roseum* on rust (*Cronartium ribicola). Verticillium dahlae* is reported to parasitize even itself. Microorganisms including *Trichoderma* such as *T. hamatum* and *T. harzianum* are considered the predominant fungal parasites recovered from composts prepared from lignocellulosic waste (Kuter *et al.,* 1983; NeIson *et al.,* 1983) and capable of eradicating *Rhizoctonia solani* (Hoitink *et al.,* 1991). When suitable antagonists are already present in the soil or substrate but do not provide a satisfactory level of disease control, it may be desirable to intensify their activity. This may be accomplished by one or more of the listed methods: crop rotation; adding amendments to stimulate antagonists; altering soil pH to favour the antagonist, inhibit the pathogen, or both; employing tillage methods that modify soil structure and aeration; selection of a planting date to reduce disease incidence; applying organic amendments in such a way as to reduce the available nitrogen at the infection site and managing irrigation practices to maintain soil water potential favorable to antagonists at infection sites (moist for bacteria, drier for actinomycetes), and still ensure water available for the plant.

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