Chapter 1
Organic Soil Amendments: Potential Tool for Soil and Plant Health Management

Rizwan Ali Ansari, Aisha Sumbul, Rose Rizvi, and Irshad Mahmood

Abstract Utilization of organic matter as a chief substrate for agricultural crops and beneficial microorganisms is gaining interest of plant pathologists, agronomists, manufacturing and processing industries, regulators, growers, tycoons and consumers. These organic inputs provide energy and nutrients to soil leading to a considerable change in the environment which becomes appropriate for survival of crops and proliferation of microorganisms. More likely, this exercise is further reinforced by the consumers' demand as they are more conscious towards their health. Moreover, use of organic matter rather than disposal is preferred because it imparts in the market value and recycles back to the land leading towards the enhanced sustainable agricultural system. Various types of organic materials are now available and growers have been familiar with these wastes. However, efficacious nature of each organic matter is different maybe partly due to their chemical constituents, types, origin and duration of decomposition. Henceforth, the results of these natural products are inconsistent from site to site as well as from field to field. Similarly, there is no single mechanism which can advocate the queries prudently pertaining to disease management caused by various soilborne plant pathogens. Some common instances have, however, been exemplified like secretion of pathogen toxic compounds, alteration in soil physico-chemical properties, enhanced microbial activities and induction of host resistance against wide spectrum of soilborne pathogens. Moreover, soil is indistinct part of the ecosystem which may regulate the plants response. Application of low rate of organics is suggested as this will be affordable to the growers. In our opinion, this may be possible through appropriate site selection, formulation, storage and handling as well as consortia of organic matter with other compatible modules. Major problem in the adoption of this technology is insufficient supply of ready-made organics which needs a prudent optimization in order to attain sustainable agriculture.

Keywords Soil · Organic inputs · Microorganisms · Physico-chemical properties · Disease suppression · Growth enhancer

R. A. Ansari (✉) · A. Sumbul · R. Rizvi · I. Mahmood
Section of Plant Pathology and Nematology, Department of Botany, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

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1.1 Introduction

Organic soil amendments such as animal manures composts, green manures, cover crops, crop residues, straws, etc. are used to augment soil and plant health that leads to sustainable agriculture (Ansari et al. 2017a; Akram et al. 2016; Rizvi et al. 2015; Hadar et al. 1992; Muchovej and Pacovsky 1997; Trankner 1992). There were no synthetic pesticides, insecticides, inorganic fertilizers for application to the field during the beginning of the agriculture. The agriculture practices were totally dependent on cultural practices such as organic inputs, crop rotation, soil solarisation, deep ploughing, etc. Besides, agriculture as an occupation provided very important basic necessities of human being – food, shelter and clothes. However, in the nineteenth century, pesticides, inorganic fertilizer and pest-resistant varieties had replaced the classical practices almost in toto which results in a considerable breakage of the link between organic fertilizers and soil fertility (Hoitink and Boehm 1999; van Diepeningen et al. 2006; Willer et al. 2010). Consequently, organic matters like animal manure, green manure, industrial wastes (after treatments), households waste, etc. transformed into solid wastes. Long-term storage of such wastes started to cause soil, air and water pollution. Various plant diseases caused by soilborne pathogens become more aggressive to the crop plants. Henceforth, public concern and adverse effects of inorganic fertilizers on human health have received attention in organic fertilizers (Lazarovits 2001). In addition, new emerging technologies are being added in order to fulfil the ever-growing demand for food due to significant increase in population. Organic inputs grant the energy and become the ample source of nutrients to soil which creates suitable environment for the proliferation of microorganisms (Drinkwater et al. 1995). A wide range of biofertilizers has been used to control the different soilborne diseases including plant parasitic nematodes (Ansari et al. 2017b; Khan et al. 2014; Akhtar and Malik 2000; Rodríguez-Kábana 1986). Moreover, composts derived from various sources are also being used in the management of various plant pathogens (Hadar and Mandelbaum. 1992; Hoitink et al. 1993). Organic matter is used as soil amendments in order to maintain good health of soil which create conducive environment to the plant. Also, incorporation of organic inputs into soil with or without any beneficial microorganisms offers pollution-free environments (Jindo et al. 2016).

Soil is an intimate part of ecosystem but its conservation in the present scenario has been a big challenge. Moreover, it has the capability to interact with a wide spectrum of organisms in order to maintain better quality and conducive environment for microflora and rhizospheric organisms. Generally, soil quality is quickly deteriorated due to improper intensification of agricultural systems. However, proper management strategies, if applied, improve soil quality in terms of physical, chemical and biological characteristics. Interestingly, organic matter application in the soil plays a very important role in the maintenance of soil ecosystem. Organic matter becomes the substrate for the decomposers which in turn provides nutrients to the soil and plant (Abiven et al. 2009). More likely, proper incorporation of organic matter also increases the soil suppressiveness against wide range of phytopathogenic propagules (Bonanomi et al. 2010) and minimizes toxicity level of heavy metals (Park et al. 2011). Moreover, a number of organic matters, viz. compost, keep much importance in the ameliorations of soil structure (Scotti et al. 2013), biological activity (Ross et al. 2003; Ansari and Mahmood 2017; Franco-Andreu et al. 2016) and reductions in soilborne pathogens (Pane et al. 2016). Besides, depletion of soil organic carbon is directly correlated between the organic inputs and amount of organic matter present in the soil. These are mainly regulated by some environmental factors such as temperature and available water content. Generally, it has been noticed that plant debris amendments to soil contain high amount of organic. This type of organics when amended into the soil decomposes very rapidly and almost disappears within a few months (Bonanomi et al. 2013). Moreover, such organic input provides marginal contributions for the sustenance of soil organic C sink. In addition, transport of such organic C with high biochemical quality may be stimulated through microbial activities (Steiner et al. 2007; Fontaine et al. 2007).

Moreover, it is known worldwide that phytopathogens are responsible for many diseases of crop plants that exert physical as well as mental stress on farmers (Anonymous 2017). Around 50% of plant diseases of main crops in the United States were caused by soilborne phytopathogens (Lewis and Papavizas 1991). Awareness towards the maintenance of harmonious environment pertaining to agriculture has given an impetus to search out alternative to conventional agriculture. Now farmers and researchers have began to use organic matter as fertilizers in order to meet out the goal of sustainable agriculture. There is a wide range of organic matter which is being used in the sustainable agriculture, where compost is considered to be one of the best organic fertilizers. Moreover, composting has been the chief tactics in order to minimize the nutrient loss and rapid decomposition. Subsequently, microbial activities are enhanced providing a balanced nutrients to the soil and ultimately to the crop plants. This way, organic matters are transformed into valuable assets that remain embedded in the soil. Therefore, present collection of literature has been designed in order to explore the recent development in organic soil amendments.

1.2 Possible Sources of Organics

Integration of organic matter to ameliorate soil physical, chemical and biological properties dates back since beginning of the agriculture. It has been extracted from literature that Greeks and Roman had applied animal manures to soil for better yield of crop plants (Goss et al. 2013). A wide range of organic matters such as seashells, vegetable waste, farmyard manure and other waste products are used to enhance plant growth and productivity. There are various types of organic materials and difficult to mention in a short passage. Applications of such organic input vary and controlled by various significant factors. Some important organic materials have been used more commonly such as animal manure, compost, different types of shells, saw dusts, straws, green manures, crop residue, phytoextracts, etc. They are used first hand as plant growth enhancer while on the other hand, considerable amount of disease suppression (Tiyagi et al. 2015). However, the same time an appropriate treatment (such as municipal solid waste) prior to application is given to rescue the environment from pollution. Nowadays, compost is the most common organic matter used as plant growth enhancer (Jouquet et al. 2011). Soil application of compost derived from various sources not only strengthens the plants but also induces resistance in host against wide range of phytopathogens. Besides, animal manures, peat moss, wood chips, straw and municipal wastes are also used to strengthen the plants against various soilborne pathogens leading to enhanced crop productivity (Misra et al. 2016; Smith et al. 2016).

1.3 Types of Organic Amendments Applied to Soils

Various forms of organic matter as soil amendments have been noticed to promote crop productivity and maintain the soil health. They have been categorized in six major categories (Goss et al. 2013).

1.3.1 Animal Manure

Most of the manure produced is applied in land to enhance the soil fertility, plant growth and yield attributes. In the 1950s removal of manure along with water was started to reduce labour cost and improve hygiene. Later on, these liquid manures were applied in the field for the enhancement of crop yield. Generally, beef and dairy systems generate the highest amount of manures followed by pork industry, while poultry farm contributes very small amount as compared to cattle or pig. Later on, these manures are applied in land in different manners such as 84% in croplands and 16% grassland (Beusen et al. 2008). Nature of manures, however, is inconsistent and varies from time to time and depends upon the storage duration prior to its application to the land. Moreover, liquid or slurry manures may have number of layers, and property of each layers vary considerably with each other in terms of space and time (Patni and Jui 1987). More broadly, organic manures aerobic decomposition results in the generation of CO_2 and wide spectrum of organic compounds, while anaerobic decompositions begin in the stored manures. In the absentia of free oxygen, the organic inputs are converted to C compound having low molecular weight chiefly volatile organic substances and eventually CH_4 is released (Lazarovits 2001). In addition to these organic C and volatile substances, breaking down of the proteins may lead to the generation of H_2S. Likewise, generation of volatile fatty acids due to organic matter breakdown leads to reduced pH of the manure which is readily available to microbes as C sources (Lazarovits 2001). Moreover, the rate of breaking down process in aerobic conditions is faster than the anaerobic one. Likewise, disintegration of organic matter under aerobic conditions is much faster than the anaerobic conditions. Besides, liquid swine manure incorporations in the dried soil was more effective than the moist soil, apparently, because active chemical constituents were diluted in the moist (Lazarovits 2001) (Fig. 1.1).

1.3.2 Municipal Biosolids and Septage

Municipal wastes after proper treatment are applied in agricultural land in order to promote crop productivity. But, prior to application of municipal waste (solid or liquid), are subjected to pass through regulatory norms (Kumar 2016). Generally organic inputs are separated through sedimentation (primary treatment) following to digestion of easily metabolized fractions by microorganisms (secondary treatments) and, lastly, removal of N and P (tertiary treatments) (Goss et al. 2013). In addition, stabilization of the materials by heating and drying process is carried out. The stabilization is performed to eliminate the propagules of wide range of phytopathogens. However, not all European countries are applying the municipal wastes into the agricultural land. But, recently a figure has come out such as during 1996–1998 France used 60%, Spain and the United Kingdom 46%, Germany 40% and Italy 16% (Epstein 2003). It has also been observed that around 50–70% of sewage solids are applied into agricultural lands. Many rural areas of the world do not have proper sewage systems, however, they have established a holding tank which is essential to be pumped out periodically. There are many jurisdictions in the application of municipal biosolids; nevertheless, many people have started to use these untreated materials directly to the fields. Such application of municipal waste may create an environmental perturbation. Henceforth prior to application to the agricultural land, certain confirmatory test as per prescription made by the Pollution Control Board is needed to carry out to avoid ambiguity amongst the researchers or growers of the crop plants.

Fig. 1.1 Types of organics used in organic agriculture

1.3.3 Green Manures and Crop Residues

Green manures are grown to augment the nutrient status of the soil leading to improved plant health. Generally, legumes are grown in the agricultural land because they fix atmospheric N and leave some amount of it for the succeeding crop (Reddy 2008). A wide spectrum of green manures has been identified throughout the world. Green manuring have exerted a beneficial impact on soil health through various improved ways like chemical (Ebelhar et al. 1984) and biological properties (Fageria et al. 2005). Incorporation of green manure has enhanced plant growth in terms of higher biomass production. Application of green manures into soil provides good habitat for beneficial microorganisms. In addition, some properties of soil such as water holding capacity, infiltration of water and percolation of water were considerably increased (Raimbault and Vyn 1991).

Green manure crops grown in summer remain on the field for a short period of time, whereas warm seasons cover crops may be utilized to replenish the niche in crop rotation, to keep fragile soil from weathering, to prepare land for a perineal crop or to supply extra animal feeds. Some examples of summer green crops may be seen which are being grown in our surroundings such as *Vigna unguiculata* (Singh et al. 2010), *Glycine max* (Creamer and Baldwin 2000), *Melilotus indicus* (Sarrantonio and Gallandt 2003), *Sesbania* spp. (Sugumaran et al. 2016), *Crotalaria* spp. (Wortmann et al. 2009) and *Mucuna pruriens* (Whitbread et al. 2004). These crops add N along with organic matter to soil. Most of the beneficial impacts expected from the green manuring come from the aerial parts of the plant (Goss et al. 2013).

1.3.4 Food Residues and Wastes

The foods which are discarded or lost uneaten is called as food wastes or food discharges. Fresh produce from the supermarket or other sources of materials from urban centres that have not been sold timely or unusable – food discharges. Later on they are eventually applied to agricultural land after composting (Muchovej and Obreza 2001; Obreza and O'Connor 2003). There are numerous reasons of food wastes and found at the stage of food production, processing, retaining and also on consumption (Galanakis 2015). Total food wastes world widely have been estimated to be around 1.3 billion tonnes (F.A.O. 2011). In developing countries 400–500 calories per day per person are wasted, while in developed countries this figure has significantly enhanced and been found to be 1500 calories per day per person (Kim 2014). Likewise, around 30–50% (1.2–2 billion tonnes or 1.8×10^9 long tonnes or 1.32×10^9–2.20×10^9 short tonnes) of all produced food remain unconsumed (Fox and Fimeche 2013). Country wise, Singapore wasted 788,600 tonnes of food wastes in 2014 (http://www.straitstimes.com/print-edition), the United Kingdom 6,700,000 tonnes (Jowit 2007, https://www.theguardian.com/

environment/2007/oct/28/food.foodanddrink), the United States 30% of food valuing 162 billion US dollar (Elizabeth 2014) and Denmark 700,000 tonnes per year of food wastes (Juul 2016). To tackle with food wastes problems, there are some ways through which these food wastes can be recycled such as use of fertilizers after decomposition (https://en.wikipedia.org/wiki/Food_waste). Moreover, food wastes can be biodegraded after composting and recycled the nutrients into soil (https://www.usda.gov/oce/foodwaste/resources/recycle.htm).

1.3.5 Wastes from Manufacturing Processes

Organic matter may also include the residual organic matter obtained from various manufacturing industries as discharge (Dotaniya et al. 2016). Biosolids are produced in large amounts annually as residues in paper making industries, but only a small amount of these wastes products are used in agricultural system (Thacker 2007). Some examples of manufacturing waste are very common which are used to support the crop production such as sugar extracts from sugar beet (*Beta vulgaris* L.) and distillery waste (Douglas et al. 2003; Hachicha et al. 2012; Kumar et al. 2009). In addition, use of wastes of sugarcane processing industries has been found to be beneficial in agricultural system as this has improved the soil physico-chemical properties leading to enhanced plant biomass (Dotaniya et al. 2016). Several other industries are discharging its wastes in significant amount and started to use in crop production (Arvanitoyannis et al. 2006). Exclusively, waste collected from wine industries can be potentially used as soil conditioners as well as fertilizers (Ferrer et al. 2001). Moreover, different types of wastes have been determined such as grape pomace characterized by abundant phenolics due to poor extraction during the wine preparations. Henceforth, their utilization in cultivable land supports crop production leading to improved sustainable agriculture (Kammerer et al. 2004). Likewise, different types of wastes from sugarcane industries are characterized by soft, spongy, amorphous and brown to black in colour containing higher amount of nutrients of wide spectrum (Ghulam et al. 2012; Dotaniya et al. 2016). Moreover, press mud is generated during sugar purification through various processes like sulphitation and carbonation (Dotaniya et al. 2016). Press mud is a good source of organic matter and provides sufficient nutrient to plant and also improves soil health (Bokhtiar et al. 2001; Razzaq 2001). Similarly, bagasse is another discharge generated by the sugarcane industries which can be used to support agricultural system. Constituent wise, bagasse contains cellulose (47–52%), hemicelluloses (25–28%), lignin (20–21%) and other compounds (0.8–3%) (Rocha et al. 2011). Henceforth, it can be concluded that bagasse may be used to support crop production. As far as molasses are concerned, it is generated when raw juice is used to produce sugar. They are viscous liquid in nature and may separate through massecuite. Molasses are having various types of nutrients which contain enhanced microbial activities being utilized for alcohol production (Dotaniya et al. 2016; Sardar et al. 2013). More broadly, raw spent wash are acidic in nature and produced after fermentation and distillation and leaving unpleasant smell especially just after its generation. Later on, these raw spent wash are treated for its further use in various sectors of agriculture. Biomethanation is considered to be most reliable process which can purify such organically rich wastes. Biomethanated spent wash are rich in various nutrients and enhance the microbial activity when applied in the field as liquid manure (Dotaniya et al. 2016).

1.3.6 Compost

Composts derived from wide range of sources have been top ranked amongst the organic inputs being used in the various agricultural sectors (Goldstein et al. 2000; Martínez-Blanco et al. 2013; Cesaro et al. 2015; Alsanius et al. 2016; Oliveira et al. 2017). It has generally been observed a significant loss of C during the decomposition maybe because of significant displacement of fungal microbes to bacterial-rich microflora (Hu et al. 2017). Generally, organic wastes having highest amount of C:N ratio are allowed to mix with wastes which are rich in N; however, final products of the compost have comparatively lower C:N ratio. Normally, fast activities of microbes in the mixture of composts trigger a significant rise in temperature. Mixing of such materials maintain the temperature which are appropriate for composting for long time. It is assumed that all materials are needed to pass through increased temperature in order to eliminate harmful microbes and propagules of weeds (Al-Turki 2010; Sanmanee 2011). Such significant rise in temperature may sometime hamper the activity of beneficial microbes if water is not properly added (Allison et al. 2010). Moreover, there is a significant loss of N during composting which is a matter of considerable deliberations (Handa et al. 2014; Chan et al. 2011; Chan et al. 2016). In this regard, Kirchmann and Lundvall (1993) recommended not using aerobic process for decomposition of organic matter containing high amount of NH_4^+–N because there is a significant loss of N. Similarly, Ramaswamy et al. (2010) also reported a figure of 60% loss of N and 2% C from loose piled poultry manure. Furthermore, significant loss of N as N_2O from the households organics during composting along with a considerable loss of CH_4 has been observed (Beck-Friis et al. 2000). Another interesting fact has come out from the research that if composting is done in open, a significant loss through leaching may be recorded. Likewise, if windrowing of manure is done without covering, a considerable loss in N and K content may be obtained (Lampkin 1990). In addition, considerable amounts of reduction in antibiotic concentration have been observed in the soil due to composting process (Dolliver et al. 2008).

1.4 Role of Organic Amendments in Soil Health Improvement

There is huge burden on soil in terms of biotic as well as abiotic stress. Also, heavy load of pesticides, insecticides, weedicides, inorganic fertilizers, etc. has accelerated the rate of extinction of a wide range of flora and fauna. Henceforth, to obviate the soil from these stresses, it is essential to frame a module which is conducive to the soil ecosystem. Organic soil amendments are considered to be the chief option for the soil management (Zhang et al. 2015a, b; Shahbaz et al. 2017). Generally, all kind of organic matter helps to impoverish the soil health (Tejada et al. 2001; Jindo et al. 2016). A wide range of organic matters are integrated into soil and different methods for their processing are being used. Compost are mostly used to enhance the soil C stock providing essential nutrients like N and P and also help in the augmentation of microbial activities. It is presumed that quality and quantity of organic inputs directly affects the soil physical, chemical, biological features (Albiach et al. 2000; Saison et al. 2006; Bonilla et al. 2012a, b). Impact of organic soil amendments in microbiota of soil has been correlated to the suppressiveness of the soil for many plant diseases (Weller et al. 2002; Mazzola 2004; Steinberg et al. 2007; Van Bruggen and Finckh 2016).

1.4.1 Physical Properties

Incorporation of organic inputs into soil not only increases organic matter content but also improves soil physical property (Thangarajan et al. 2013; Khaliq and Abbasi 2015; Williams et al. 2017). For instance, some physical properties such as soil aggregate stability, water holding capacity and soil porosity are considerably enhanced (Celik et al. 2004; Leroy et al. 2008). Consortium of compost and wood scraps under intensive farming system enhanced pore size by formation of organo-mineral aggregates which have beneficial impacts on soil structure and soil aeration (Scotti et al. 2013). Moreover, soil integration with cow manure, sheep manure, reeds, wheat straw and rice husk enhanced soil aggregation stability and reduced bulk density (Karami et al. 2012). In another study, farmyard manure and straw application exerted decreased soil bulk density and increased soil organic C and porosity (Zhao et al. 2009). Henceforth, it is concluded that soil organic C is inversely proportional to soil bulk density after application of soil organic matter (Bauer and Black 1994). Organics generated from various types of by-products, like biochar, affect directly the particle size distribution and aggregate stability. Application of biochar improves the soil structure by increasing the soil aggregation significantly (Liu et al. 2014). However, it has also come to notice that organic soil amendments having higher contents of bioavailable C encroached from cellulose help in the proliferation of fungal colonies harbouring in the soil. It also helps in the soil aggregation and promotion of soil microbial activities which ultimately maintain good health of soil (Lucas et al. 2014).

Similarly, as far as C sequestration is concerned, organic soil amendments improve C sequestration process considerably (Müller-Lindenlauf 2009). Organic amendments promote agroforestry systems and augment C sequestration leading to enhanced plant growth and biomass production (Geier 2007; Twarog 2008; Johnson et al. 2007; Berthrong et al. 2013; Bowles et al. 2015; Bhowmik et al. 2016, 2017). In addition, organic agriculture also minimizes the biomass burning contributing a huge amount of CO_2 which impart in global warming (Müller-Lindenlauf 2009). In grassland ecosystem C sequestration was enhanced when organic inputs are amended in a considerable amount (Liebig et al. 2005; Acharya et al. 2012). Moreover, crop rotations and less deep ploughing ameliorate soil organic matter and accelerate C sequestration (Niggli et al. 2009).

1.4.2 Chemical Properties

Without appropriate organic input in the agricultural land, restoration of soil health will remain just a dream of the researchers. It is because use of chemical fertilizers not only changes the physico-chemical properties of the soil but also produces deleterious effects on soil enzymes and microbial diversity and increases soil salinity (Bonanomi et al. 2011a; Wang et al. 2017). Research under different agroclimatic conditions has revealed that organic matter is a potential tool for the replenishment of soil organic C stock (Hargreaves et al. 2008; Zhang et al. 2015a, b). Interestingly, only few studies have revealed the importance of organic amendments under plastic tunnel system so far. For instance, there were no significant differences in organic C recovery stock after 3 consecutive years of application of composts which may be due to rapid mineralization (Morra et al. 2010; Iovieno et al. 2009). Plants require a limited amount of minerals to satisfy their demands. Generally, microbial population rely on substrate derived from organic matter relatively in a fixed manner; however, the microbial activity is hampered when C/N ratio is above threshold, and the threshold values are ~25–30. The rate of organic matter decomposition is significantly decreased when the C/N ratio reaches above the thresholds which allow long-term C storage. Besides, incorporation of organic inputs containing high C/N ratio into soil and mobilization of nutrients are temporarily suspended leading to enervated plant growth and yield attributes (Hodge et al. 2000). No doubt, suspension of N mobilization is unacceptable under intensive agriculture where plant nutrition is regulated to meet the crops demand. To satisfy the demand of a healthy soil, it is needed to identify organic amendments which can balance the trade-off between organic C recovery and mineralization of nutrients. Eventually, after reaching into soil, the organic C retainability not only depends upon biochemical quality but also certain features of soil minerals such as sand, silt, clay, carbonate and organic C contents (Piccolo 1996; Clough and Skjemstad 2000; Scotti et al. 2015). Moreover, soil having low organic content and high clay fraction absorbs exogenously applied organic inputs faster and easier and makes them not easily available to microbial attack (Bonanomi et al. 2014a, b). In addition, sandy soil having high C content is adverse to microbial population because most of the mineral particles are unable to make proper and appropriate interaction. This improper reaction gives much more compounds which are enough to devastate beneficial microbial colonies.

Likewise, rampant use of chemical pesticides accelerates mineral N release; however, in contrast, organic incorporation triggers lower mineral N release for a long time (Claassen and Carey 2006; Weber et al. 2007). It is apparent that mineralization of N in slow mode under organically derived compost ameliorates soil biology (Weber et al. 2007). Generally, there is a significant increase in humic/fulvic acids in soil amended with composts which may be partly due to presence of humic acids in composts that dominate over fulvic acids. In such soil, humic acids are always significantly greater than fulvic acids (Weber et al. 2007). Besides, use of composts as soil amendments promotes the nitrification process leading to reduction in contamination of groundwater (Montemurro et al. 2007). Broadly, application of organic inputs increases some important variables pertaining to soil health such as organic C stock and soil cation exchange capacity. Maximum values of cation exchange capacity permit to retain essential nutrients cation and make possible for them to be available for crop productions (Bulluck lii et al. 2002). Similarly, anions are found to increase subsequent to organic inputs application (Zaccardelli et al. 2013b; Scotti et al. 2015). But, a significant challenge has come out in the use of organic matter especially compost derived from municipal solid waste. Municipal solid waste-derived compost increases the electrical conductivity into soil and subsequently salinity, and solidity increases which impacts negatively on crop yield (Mass and Hoffman 1977; Bonanomi et al. 2014b) and also on soil biological activity (Rietz and Haynes 2003). Such MSW-derived compost increases the soil salinity especially in the soil cultivated under plastic film due to limitation in soil leaching (Bonanomi et al. 2011a, b).

1.4.3 Biological Properties

Organic matter decomposition is the result of considerable work performed by microbes (Thangarajan et al. 2013; De Baets et al. 2016). They play a very crucial role in making soil fertile and help in the organic C mineralization (Burauel and BaBmann 2005; Whitman et al. 2016; Zheng et al. 2017). Amended organic matter into soil favours in proliferation of microbial population; hence, there is a strong correlation between organic C, soil biological activity and enzymatic activities (Chakraborty et al. 2011; Tejada et al. 2001). However, biological properties of soil are considered to be a good indicator of soil health due to their rapid responses to environmental perturbations (Nannipieri et al. 1990; Paz-Ferreiro et al. 2009). Soil with no input of organic matter exhibited a significant reduction in the soil microbial biomass, enzymatic activity and beneficial fungal colonies under intensive agricultural system (Bonanomi et al. 2011a). Use of compost as soil amendments surprisingly enhanced soil fertility such as soil enzymes and microbial activities (Thangarajan et al. 2013). A quick response in enzymatic activities such as dehydrogenase, phosphomonoesterase and β-glucosidase has been obtained after organic amendments. This specific quality of organic inputs has accelerated the repeated use of organic amendments which has subsequently enhanced the microbial population and leading to improved soil fertility (Scotti et al. 2015; Zaccardelli et al. 2013a). Use of seed meals derived from *Brassica carinata* and *Helianthus annuus* as an organic amendment enhanced the soil enzymatic activity like phosphomonoesterase, dehydrogenase, fluorescein diacetate hydrolase, arylsulphatase and β-glucosidase, thereby improving soil biology (Zaccardelli et al. 2013b). Incorporation of composts obviates the stress caused by high saline content and improves the biological fertility of soil (Lakhdar et al. 2009). Likewise, application of compost derived from municipal solid waste and palms waste at different doses such as 0, 50, 100 and 150 T/ha registered a significant improvement in the microbial activities. But, hindrances were observed at the dose level of 150 T/ha; it may be due to the presence of the heavy trace elements in municipal solid wastes (Ouni et al. 2013; Garcia-Gill et al. 2000; Crecchio et al. 2004).

Acceleration in microbial activities and biomass has been the chief aim of some cultural practices like integration of organic matter in the soil ecosystem (Janvier et al. 2007). Various types of organic amendments into agricultural land have been helpful in the enhancement of the microbial biomass than non-amended soil or inorganic fertilizers (Bonilla et al. 2012a, b; Tiquia et al. 2002; Peacock et al. 2001). Many earlier studies have revealed that compost, composted almond shells and composted yard wastes have enhanced the heterotrophic bacterial population (Saison et al. 2006; Perez-Piqueres et al. 2006; Boniall et al. 2012a, b). Soil amendments with manures, yard wastes and compost influence the microbial diversity (Yang et al. 2003; Bonilla et al. 2012a, b). It is pertinent that microbial diversity is a very complex component. Henceforth, measurement of microbial diversity quantitatively and qualitatively is needed to ventilate the unexplored reasons. Measurement through diversity index may give haphazard information; therefore, qualitative community structure analysis is more reliable than other sampling procedures. Moreover, many reports have revealed the impact of organic soil amendments which involved a significant influence on some enzymes such as urease, β-galactosidase, protease, phosphatase or dehydrogenase. In other words enzymatic activities of soil are directly correlated with level of soil organic matter incorporated, which is why soil amendments are considered as an appropriate soil indicator (Garcia et al. 1994; Ros et al. 2003; Tejada et al. 2006; Pascaud et al. 2017). Besides, single enzymes activity cannot reveal complete structure of information pertaining to nutrients status. However, organically rich soils are more complex and depend on soil physico-chemical nature (Albiach et al. 2000; Goyal et al. 1999). Such soil is characterized by abundant heterogeneous populations of microbes. Also, they are difficult to identify up to the last hierarchy level. Therefore, some advanced approaches pertaining to identification of various species are needed. In this context, terminal restriction fragment length polymorphisms (T-RFLP) have now been proven to be a milestone in the characterization of bacterial and fungal communities isolated from various localities (Pérez-Piqueres et al. 2006). Similarly, many researchers have shown that organic amendments may influence the bacterial and fungal communities; however, further verifications are needed by using advanced techniques like direct extraction of lipids (PLFA) and nucleic acids (T-RFLP, ARISA, ARDRA, DGGE) (Bonilla et al. 2012a, b; Tiquia et al. 2002; Peacock et al. 2001; Edel-Hermann et al. 2004; Dimitrov et al. 2017). These novel approaches have been adopted by various researchers globally so far (Van Elsas and Costa 2007).

1.5 Significance of Organic Amendments in Plant Health Amelioration

1.5.1 Plant Biomass Promotion

Researchers have focussed their study on environment protection prompting the research on nutrient management strategies and lowering down the use of chemical pesticides (Ghimire et al. 2017). Moreover, utilization of resistant varieties and pesticides is unable to eliminate the soilborne fungal propagules from the agricultural system. Therefore, proper management modules having high efficacious nature and low costs are needed for contemporary agriculture (Martin 2003). Effect of wide spectrum of organic amendments on different crop yield in various studies has been investigated (Sumbul et al. 2015; Horrocks et al. 2016). For instance, single application of olive pomace at 10 or 20 Mg per hectare enhanced wheat yield by 50%, by increasing of kernel weight and their number (Brunetti et al. 2005). Long-term application of soil organic amendments has increased the growth and yield attributes (Johnston et al. 2009; Xie et al. 2016). Organic integration into soil not only improves physico-chemical feature but also plays beneficial role on crop productivity. Broadly, organic soil amendments are the best option available in many developing countries for compensation of soil nutrients (Lal 2005; Kaur and Verma 2016). Moreover, application of certain easily available organic inputs such as buckwheat (*F. esculentum* L.), millet (*Echinochloa crus-galli* L.), colza (*Brassica campestris* cv. *oleifera* L.), clover (*Trifolium pratense* L.) and mustard (*Brassica hirta* Moench) has successfully improved the yield (N'Davyegamiya and Tran 2001). Besides, different industrial wastes have been applied in order to predict their response on crop yield. Wastes generated from sugarcane industries have been applied in the land and increased crop biomass recorded (Dotaniya et al. 2016). Consortium of N fertilizers and sugar press mud (derived from sugarcane industrial wastes) increased plant growth attributes such as dry matter, cane, sugar yield, etc. (Bangar et al. 2000). Likewise, in another experiment, 25 t ha^{-1} sugar press mud significantly improved the sugarcane yield (Venkatakrishnan and Ravichandran 2013). In addition, application of press mud enhanced the sugarcane quality and biomass-related attributes providing sufficient nutrients by ameliorating soil health (Sarwar et al. 2010).

Bagasse (another generated by-product) is being judiciously used in agricultural crop production system to reduce the application of inorganic fertilizers (Dotaniya et al. 2016). Properly chopped bagasse, applied 1 month before sowing is very sound for the proper decomposition that leads to production of organic acids and mobilization of insoluble phosphorus from soil to soil solution in labile form (Rocha et al. 2011; Dotaniya et al. 2016; Hofsetz and Silva 2012). Moreover, incorporation of 3000 kg ha^{-1} enhanced the crop growth attributes significantly and that may be due to enough P supplementation (Ferrer et al. 2001). Some wastes, derived from tomato, cork residue, olive husk and tannery sludge, improved the crop growth and yield variables (Vallini et al. 1983).

1.5.2 Plant Disease Management

Application of organic amendments like composts derived from various sources, manures, etc. is well studied in context of suppression of pest pathogens and plant diseases (Bailey and Lazarovits 2003; Bonilla et al. 2012a, b; Noble 2011; Noble and Coventry 2005; Van Elsas and Postma 2007; Faye 2017). Organic incorporation has frequently been found to reduce wide range of soilborne diseases infesting different agricultural plants (Aviles et al. 2011; Bonilla et al. 2012a, b; Hadar and Papadopoulou 2012; Noble 2011; Yogev et al. 2006). Generally, compost amendments are found to be associated with soilborne diseases reduction; however, there are certain dependent factors (Bonanomi et al. 2010; Noble and Coventry 2005). Wide ranges of compost were evaluated against various plant pathogens and plant diseases and resulting in significant diseases management (Termorshuizen et al. 2006; Mishra et al. 2017). Generally, it has been seen in various studies that compost has the ability to reduce the disease with a figure of 55% of disease. Some important factors such as compost material, age and quality keep prime importance determining whether compost will be suppressive or not (Bonanomi et al. 2010; Hoitink and Boehm 1999; Noble and Coventry 2005; Termorshuizen et al. 2006).

In a trial, composted dairy manure as a soil amendment along with other composts significantly enhanced microbial populations (Bernard et al. 2014; Zhang et al. 2015a, b). Some reports have suggested that crop yields are increased, but there is no considerable reduction in pathogen population (Bernard et al. 2014). Henceforth, any compost before applying in a large scale should be tested under a small level of field to avoid environmental perturbation (Ansari et al. 2017a, b). Some organic manure in non-composted form has shown inhibitory effects against many phytopathogens; however, results showed inconsistency (Bononomi et al. 2007). For instance, more than 50% of the trials have shown inhibitory effects by un-composted manure and industrial by-products against soilborne diseases, while less than 12% attributed to increase the disease incidence (Bononomi et al. 2011b). The reason behind such inconsistency may be the nature of organic inputs such as quantity, quality, origin, etc. affecting soil physico-chemical properties leading to changed microbial diversity. There are some abiotic factors that have been found associated with disease management practice. Many eminent researchers have stressed their studies to dig out the actual mechanisms pertaining to disease suppression (Bonanomi et al. 2010; Noble 2011). But ample studies have revealed that disease suppression is related to overall enhancement in microbial population and activity developing deleterious environment to the plant pathogens (Bonilla et al. 2012a, b; Bonanomi et al. 2010). This is further advocated that diseases suppression is of biological origin, because suppression nature of organic matter is lost when it is sterilized (Bonilla et al. 2012a, b). For example, incorporation of a wide array of organic manure and organic wastes were highly suppressive to *Verticillium* sp., but this result was inconsistent for site to site (Lazarovits 2001; Lazarovits and Subbarao 2010). Similarly, organic soil amendments reduced soilborne pathogens by forming ammonia or nitrous acid which is lethal to pathogens (Lazarovits 2001). Likewise, liquid swine manure minimized the disease incidence by forming volatile fatty acids in acidic soil (Lazarovits 2001; Lazarovits and Subbarao 2010). In addition, composted teas, water-based compost, contain diverse types of constituents found to be having disease-suppressive nature (Schuerell and Mahaffee 2002; Lazarovits 2010; St. Martin and Brathwaite 2012).

Ample studies have revealed that organic amendments can combat plant diseases caused by various plant pathogens such as bacteria, fungi and phytonematodes (Hoitink and Boehm 1999; Bailey and Lazarovits 2003; Ansari et al. 2017a, b). Composted materials are found showing pernicious effects on root rots as compared to non-composted materials (Hoitink and Boehm 1999). Yogev et al. (2006) found that compost derived from plant waste residue reduces disease caused by different formae speciales of *Fusarium oxysporum*. In another such incident, *Phytophthora cinnamomi* causing avocado root rots was suppressed by application of vegetable produced compost (Downer et al. 2001). Generally, composted materials have constantly been shown to be suppressive on various soilborne diseases including damping off and root rots (*Pythium ultimum*, *Rhizoctonia solani*, *Rosellinia necatrix*, *Phytophthora* spp.) and wilts (*Fusarium oxysporum* and *Verticillium dahlia*) infecting wide range of crop plants (Lazarovits 2001; Yogev et al. 2006; Yogev et al. 2010; Malandraki et al. 2008; Erhart et al. 1999; Pane et al. 2011; Tamm et al. 2010; Bender et al. 1992). Some other pathogens have been significantly controlled by organic matter application that are *Gaeumannomyces graminis* f. sp. *tritici* (Tilston et al. 2002), *Fusarium* spp. (Borrero et al. 2004), *Pythium* spp. (Erhart et al. 1999), *Rhizoctonia solani* (Pérez-Piqueres et al. 2006), *Phytophthora* spp. (Szczech and Smolińska 2001), *Verticillium dahliae* (Paplomatas et al. 2005) and *Sclerotinia minor* (Pane et al. 2011). Nevertheless, the suppressing quality varies greatly depending on organic matter type, plant hosts and pathogens spp. involved, etc. Few reports related to negative impacts of organic amendments have also been documented such as enhanced phytotoxicity and disease severity (Smolinska 2000; Tilson et al. 2002; Scheurell et al. 2005; Delgado et al. 2010). Termorshuizen et al. (2007) showed that organic amendments caused disease suppression in 54%, no considerable suppression in 42.7% and enhancement of disease in 3.3%. Similarly, Bonanomi et al. (2010) found suppressiveness of organic amendments in 45% of the cases, no significant suppressiveness in 35% cases but enhancement of the disease in 20% of the cases studied. Due to such inconsistent results, practical application of composts for disease suppression is still a matter of debate. Moreover, facts to be analysed regarding organic soil amendments derived from wide spectrum of animal and plant residue, composting methods, feedstock origin (municipal wastes, plant pruning, crop residues, animal manures, etc.), rate of application (Serra-Whittling et al. 1996) and level of maturity (Tuitert et al. 1998).

1.6 Mechanisms Implicated in Action of Organic Amendments on Soil and Plant

Amendment of soil with organic matter boosts up soil physical, chemical, biological properties leading to improved plant health (Bonanomi et al. 2010; Lazarovits 2010). No single mechanism can be implicated in such a concerted effort of ameliorating soil health with nutrients and enhancement of plant growth attributes. The quantity and quality of organic matter amended in the soil impose its impact on soil physico-chemical as well as on biological activities (Mazolla 2004; Abbasi et al. 2002; Bulluck and Ristaino 2002; Stark et al. 2008; Saison et al. 2006; Bonilla et al. 2012a, b; Gomez et al. 2006; Ceja-Navarro et al. 2010). Physico-chemical and biological properties of soil collectively make a soil suppressive which may result inhibitory to soilborne plant pathogens and stimulatory to multiplication of beneficial microorganism (Huang et al. 2015). Baker and Cook (1974) described suppressiveness of soil where in suppressive soil disease, severity or incidence remains low in spite of the presence of a virulent pathogen, a susceptible host plant and climatic conditions favourable for disease development (Hiddink et al. 2005; Janvier et al. 2007). Various mechanisms of disease suppression by organic soil amendments have been proposed that include biological control (Abbasi et al. 2007; Fu et al. 2017), stimulation of systemic resistance in plants (Hoitink and Boehm 1999; Alkooranee et al. 2017) and production of compounds lethal to plant pathogens such as ammonia, nitrous acid and volatile fatty acids (VFAs) (Mazzola 2002, 2004; El-Abbassi et al. 2017).

A number of physico-chemical parameters like soil pH, N, C and organic C content, various cations and oligoelements have been found to be associated with plant disease suppression (Bonilla et al. 2012a, b). Emphasis has been given to find out the role of physico-chemical properties in the soil and plant health improvement. Moreover, conservation of C reservoir in agricultural soil system is much helpful in nutrient delivery (Tian et al. 1992), amelioration of soil structure (Abiven et al. 2009), enhancing microbial activities (Mäder et al. 2002) and sustaining the soil suppressiveness for soilborne pathogens (Bonanomi et al. 2010; Scotti et al. 2013). Besides, enhanced soil organic matter content, soil pH alteration, type of clay and improved soil texture on microbial populations maintain soil suppressiveness (Alabouvette 1999; Fang et al, 2005; Mazzola 2002). Soil amended with high nitrogen containing organic inputs such as chicken manure, meat and bone meal, chitin and chitosan, neem and soy meals resulted in N compounds such as ammonia and nitrous acid (Lazarovits et al. 2005). Plethora of the mechanisms is involved through which organic amendments suppress the plant diseases leading to enhanced soil and plant health. To understand the web of mechanisms, a high level of instrumentation and expertise is needed. However, current assay has helped us to elucidate the possible mechanisms involved in the plant biomass enhancement as well as the plant disease suppression (Fig. 1.2). In addition, various complementary mechanisms have been proposed so far to illustrate the suppression capacity of an organic matter, for instance, (i) enhanced rhizospheric microbial activities (Hoitink and Boehm 1999; Li et al. 2017), (ii) food competition amongst the microbes (Lockwood 1990), (iii) secretion of pathotoxic compounds from decomposed organic matter (Tenuta and Lazarovits 2002) and (iv) systemic resistance induction in host plants (Zhang et al. 1996; Pharand et al. 2002; Keswani et al. 2017). Lazarovits (2001) reported that decomposition of organic matter leads to the production of nitrogenous compounds.

Generally, soil microorganisms rapidly start degrading high nitrogenous organic input leading to production of N in its different forms and more than sufficient for microorganism proliferations. The excess amount of N is localized to soil solution as ammonia (NH_3) (Lazarovits 2001). Eventually, this is swiftly converted to ammonia (NH_4^+), and pH of soil significantly enhanced. Likewise, as soon as pH rises, some amount of NH_4^+ converted back to NH_3. Interestingly, ammonia is very toxic even at very low levels, while no such pernicious effect of ammonium has been observed (Warren 1962). However, NH_3 is generated when the soil pH is significantly increased and reaches above 8.5, but this occurs in some special soil (Lazarovits 2001). Similarly parallel mechanism to former is proposed look to be more considerable. Ammonium conversion leads to formation of nitrite (NO_2^-) and subsequently nitrate (NO_3^-) by the bacterial nitrification. Such mechanisms lead to drastic reduction in the pH attaining 5.5. As soon as pH drops to 5.5, NO_2^- converts to HNO_2. NO_2^- is non-toxic, while HNO_2 is highly toxic to a wide range of soil-borne pathogens (Lazarovits 2001). In addition, soil pH is the driving factor that reduces the quantity of toxic (NH_3 or HNO_2) and non-toxic (NH_4^+ or NO_2^-) compounds (Lazarovits 2001). In addition, liquid swine manure is rich in various nutrients essential for the growth of crop plans. Various fractions are found in the liquid swine manure, but specifically, acetic acid is the chief organic compounds playing crucial role in disease suppression (Lazarovits 2001). The existence of effective biocidal products depends highly on composition of the organic amendment added to the soil, pH of the soil and soil buffering capacity (Tenuta and Lazarovits 2002). It is a well-established fact that adding fresh organic amendments to soil transiently enhances ammonium concentration and pH, followed by increased nitrification and a fall in ammonium and pH (Zelenev et al. 2005).

Moreover, volatile fatty acids (VFAs) that can be injurious to some pathogens in low pH soils are produced by the decomposition of certain organic amendments such as liquid swine manure (Conn et al. 2005). Besides, VFAs can also be achieved by adding fresh organic matter like broccoli (*Brassica oleracea* L. Convar. Botrytis (L.)

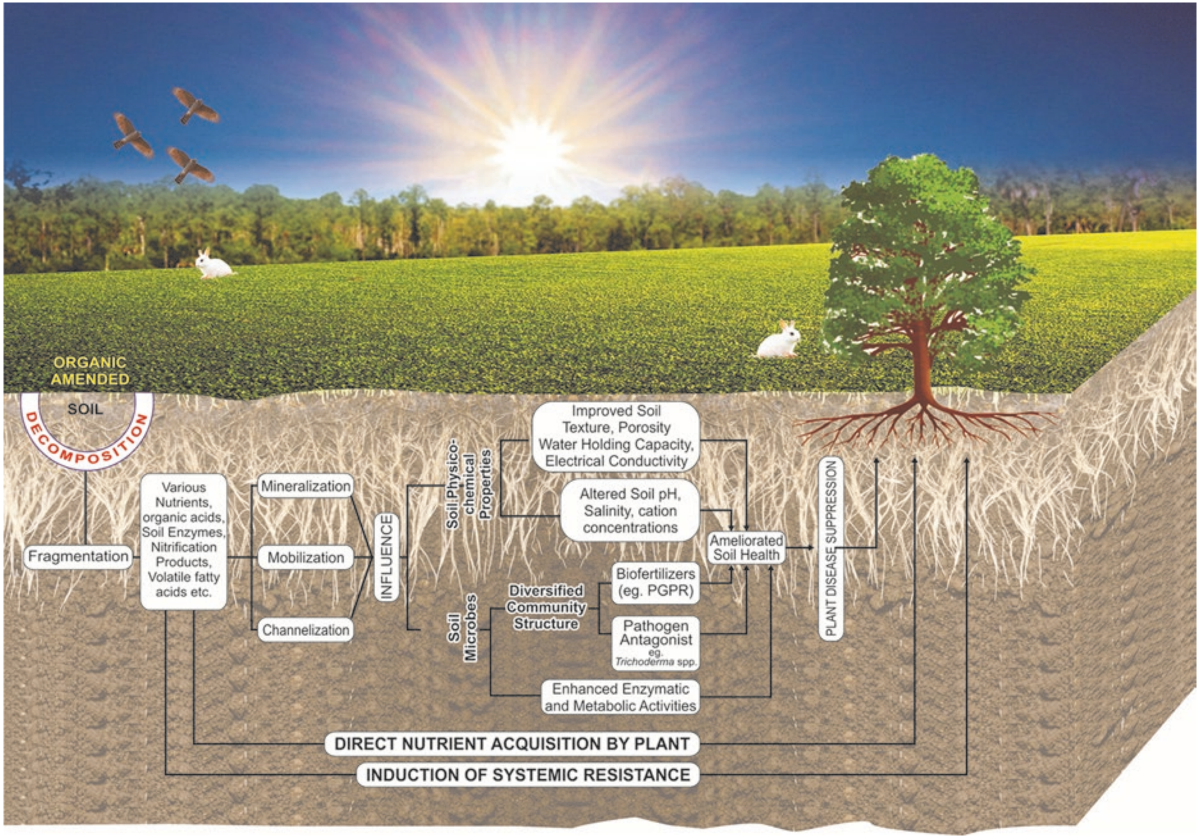

Fig. 1.2 A possible mechanism of soil and plant health ameliorations via organic matter decomposition (a hypothetical view)

Alef var. Cymosa Duch.) or perennial ryegrass (*Lolium perenne* L.) (Blok et al. 2000). Besides, concentration of calcium in the soil has also been implicated showing negative effect on wide spectrum of soilborne pathogens. Heyman et al. (2007) reported that *Aphanomyce*s root rot of pea was affected to varying extent by various calcium-containing compounds, and this was directly correlated with water-soluble Ca in soil. Similarly, Bonanomi et al. (2010) revealed that pH of amendment was not correlated to disease suppression except in the case of *Fusarium* species. Borrero et al. (2004) showed that high soil pH was effective in reducing *Fusarium* wilt of tomato. Also, there is inconsistence report related to physiological parameters pertaining to plant disease control (Janvier et al. 2007). Thus physiological issues have been found less informative in terms of plant disease suppression as compared to enzymatic and microbiological variables (Bonanomi et al. 2010; Castano et al. 2011).

Moreover, amendments of soil with organic matter generate soil suppressiveness against wide range of soilborne pathogens (Klein 2011; Sumbul et al. 2015). The impact of organic amendments on soil suppressiveness has commonly been associated with a general suppression mechanism. Incorporation of organic matter is responsible for enhancement of total microbial biomass and activity in soil, leading to impediment of the pathogen through competition for resources or by other direct forms of antagonism (Mazolla 2002). Alabouvette (1999) propounded that suppressiveness of soil for *F. oxysporum* f. sp. *lini* depends on partially competition for carbon amongst the pathogen and the microorganisms present in soil. Moreover, dissolved organic carbon is the readily available carbon sources which are consistently used, discharged upon cell death. Thereafter, eventually this organic C is reused by rapidly multiplying microorganisms creating competitive environment for plant pathogens thriving in the rhizosphere, and eventually root disease development gets hampered (Zelenev et al. 2005; Raaijmakers et al. 2009). Besides, microbes are united tightly generating an environment unfavourable to plant pathogens and later on disease development (Hoitink and Boehm 1999; Weller et al. 2002; Penton et al. 2014). Moreover, in order to ascertain the amendment suitable for specific disease suppression, it is necessary to determine a particular amendment instigating the microbial population leading to suppressed disease (Steinberg et al. 2007; Bonilla 2012a, b; Penton et al. 2014). Appropriate alteration in microbial community structure is shown to be widely associated with suppression of plant diseases. Thus, enhanced diversity of microbes provoked by organic soil amendment is responsible for successful suppression of pathogen (Cohen et al. 2005; Pérez-Piqueres et al. 2006). Moreover, *Gaeumannomyces graminis* var. *tritici* causing wheat take-all disease was found to be reduced by various strains of *Pseudomonas* spp. both in greenhouse and field experiments (Weller and Cook 1983). Besides, in Western Australia, *Trichoderma* spp. that form a major proportion of total microbial community have been implicated in the control of the wheat take-all disease (Simon and Sivasithamparam 1989). However, the recognition of a particular microbe surely involved in disease suppression does not indicate the sole responsibility of that microbe in the process, but a number of other factors both biotic and abiotic may also play partial role in disease suppression. In addition, different types of organic amendments instigate a different array of microbial community, found to be responsible for their specific efficacy against different pathogens. Such impact of organic amendment on soil suppressiveness may also vary with time, level of decomposition and environment change leading to newly evolved microbial communities (Alabouvette et al. 2004; Bonanomi et al. 2010). Besides, the concept of disease suppression may also be associated with particular activities or functions performed by microorganisms rather than only the presence or abundance of a specific population in soil.

Another aspect related to the suppressiveness of organic amendment may be attributed to the alterations efficiency of microbes in the metabolic and enzymatic activities. Multivariate analysis of this facet has been successfully carried out, but only a few cases proved to be the actual reason behind the soil suppressiveness (Gomez et al. 2006), allowing discrimination between suppressive and conductive soils (Pérez-Piqueres et al. 2006; Pane et al. 2011). For instance, take-all decline of wheat was recorded where fluorescent *Pseudomonas* spp. were found to be related to the production of phenazine (Thomashow et al. 1990) and particularly to 2,4-diacetylphloroglucinol (Raaijmakers and Weller 1998). Thus, the presence and abundance of fluorescent *Pseudomonas* in a soil are considered to be suppressive to take-all disease of wheat (Raaijmakers et al. 1997). Besides, *Trichoderma* spp. reduce take-all disease of wheat by antibiotic production, particularly pyrone compounds, however, non pyrone producing strains of *Trichoderma* are also shown to suppress disease, suggesting other mechanisms being run simultaneously. Moreover, certain other pathways of disease suppression include competition for resources and niches, incitement of plant defences, parasitism and predation, and also hydrolytic activities like chitinases and glucanases have also been reported (Mukhopadhyay 2016). Chitinase and glucanase activities have invariably been associated with soil suppressiveness and biocontrol of soilborne pathogens. Chitin, the main component of fungal cell walls, plays a pivotal role in such kind of disease suppression. Chitinolytic microorganisms instigated by specific organic amendment effectively control fungal pathogens in the soil (Bouizgarne 2013). For instance, chitin compost consisting of crab shell at 30% was used against *Phytophthora capsici* and found reduced pathogen population (Chae et al. 2006). Also, the number of chitinase-producing bacteria in the rhizosphere and the enzymatic activities like chitinase and β-1,3-glucanase were greater in plants amended with the chitin compost than unamended. Overall, no single mechanism is involved in disease suppression, plant and soil health improvement in organic rich soil. It is generally hypothesized that biological activities instigated by organic input are mainly responsible for plant and soil health amelioration. Physico-chemical variables can have an impact on growth and activities of soil microbes leading to improved soil and plant health.

1.7 Conclusions and Future Prospects

The inference can be drawn from above literatures that applications of soil organic amendments have been beneficial to the growers not only in the developed countries but also in underdeveloped one. Moreover, incorporation of wide range of organic matters into soil has culminated the cost burden especially on small landholders. Organic inputs into soil have augmented the soil biology and health. Some important variables pertaining to soil health like microbial activity, microbial diversity, pH, soil respiration, electrical conductivity, etc. have significantly influenced the soil environment. Moreover, it is assumed that as decomposition starts secretion of some organic compounds such as humic/fulvic acids, VFAs and N in its various forms begin simultaneously. These nutrients and volatile substances become ultimately a source providing sufficient nitrogen to microbes and crops. Some organic compounds are secreted by organic matter upon decomposition which are lethal to wide spectrum of soilborne pathogens. On the other hand, microbial activity especially rhizobacterial activity is considerably increased leading to enhanced systemic resistance against various phytopathogens. Moreover, responses of host plants are inconsistent due to diverse nature of organic inputs. Each organic matter differs in terms of their chemical constituents, contents, period of retention, origin, etc. Henceforth, prior to recommendation of any organic matter, a long-term application of targeted organic matter should be screened under various agroclimatic conditions. Besides, physico-chemical properties of the soil like electrical conductivity, porosity, pH, C, C:N ratio, etc. may influence the plant growth. Overall, organic soil amendments may have a lot of beneficial role in microbial activities. A genuine question arises, why farmers are refraining to adopt organic amendments? Prudently, the answer may be unawareness of inorganic fertilizers pertaining to its negative impacts on human health. Also long-term processing of organic matters before its application into the field which charges a heavy labour cost and less appropriate in perspective of cost-benefit ratio. To address these issues, a considerable number of research at various station houses are needed under various agroclimatic conditions. Scientific interaction with landholders, farmers and growers pertaining to use of organic matter into land may indeed support the use of organic inputs into agricultural system. A focus should also be on the identification of different agroclimatic circumstances where it can be best applied. Finally it may be added that organic farming is preferable than that of using chemicals in agriculture.

References

Abbasi, P. A., Al-Dahmani, J., Sahin, F., Hoitink, H. A. J., & Miller, S. A. (2002). Effect of compost amendments on disease severity and yield of tomato in conventional and organic production systems. *Plant Disease, 86*(2), 156–161.

Abbasi, M. K., Zafar, M., & Khan, S. R. (2007). Influence of different land-cover types on the changes of selected soil properties in the mountain region of Rawalakot Azad Jammu and Kashmir. *Nutrient Cycling in Agroecosystems, 78*(1), 97–110.

Abiven, S., Menassero, S., & Chenu, C. (2009). The effect of organic inputs over time on soil aggregate stability – A literature analysis. *Soil Biology and Biochemistry, 41*, 1–12.

Acharya, B. S., Rasmussen, J., & Eriksen, J. (2012). Grassland carbon sequestration and emissions following cultivation in a mixed crop rotation. *Agriculture, Ecosystems & Environment, 153*, 33–39.

Akhtar, M., & Malik, A. (2000). Roles of organic soil amendments and soil organisms in the biological control of plant-parasitic nematodes: A review. *Bioresource Technology, 74*, 5–47.

Akram, M., Rizvi, R., Sumbul, A., Ansari, R. A., & Mahmood, I. (2016). Potential role of bioinoculants and organic matter for the management of root-knot nematode infesting chickpea. *Cogent Food & Agriculture, 2*(1), 1183457.

Alabouvette, C. (1999). Fusarium wilt suppressive soils: An example of disease-suppressive soils. *Australasian Plant Pathology, 28*, 57–64. https://doi.org/10.1071/AP99008.

Alabouvette, C., Backhouse, D., Steinberg, C., Donovan, N. J., Edel-Hermann, V., & Burgess, L. W. (2004). Microbial diversity in soil: Effects on crop health. In P. Schjonning, S. Elmholt, & B. T. Christensen (Eds.), *Managing soil quality: Challenges in modern agriculture* (pp. 121–138). Wallingford: CAB International.

Albiach, R., Canet, R., Pomares, F., & Ingelmo, F. (2000). Microbial biomass content and enzymatic activities after the application of organic amendments to a horticultural soil. *Bioresource Technology, 75*, 43–48.

Alkooranee, J. T., Aledan, T. R., Ali, A. K., Lu, G., Zhang, X., Wu, J., Fu, C., & Li, M. (2017). Detecting the hormonal pathways in oilseed rape behind induced systemic resistance by *Trichoderma harzianum* TH12 to *Sclerotinia sclerotiorum*. *PLoS One, 12*(1), 1–21.

Allison, S. D., Wallenstein, M. D., & Bradford, M. A. (2010). Soil-carbon response to warming dependent on microbial physiology. *Nature Geoscience, 3*(5), 336–340.

Alsanius, B. W., Blok, C., Cuijpers, W. J., França, S. C., Fuchs, J. G., Janmaat, L., Raviv, M., Streminska, M. A., Termorshuizen, A. J., & van der Wurff, A. W. (2016). *Handbook for composting and compost use in organic horticulture*. Bio Greenhouse COST Action FA 1105.

Al-Turki, A. I. (2010). Quality assessment of commercially produced composts in Saudi Arabia market. *International Journal of Agricultural Research, 5*, 70–79.

Anonymous. (2017). *Pests eat away 35% of total crop yield, says ICAR scientist*. http://www.thehindu.com/news/national/pests-eat-away-35-of-total-crop-yield-says-icar-scientist/article17368426.ece

Ansari, R. A., & Mahmood, I. (2017). Optimization of organic and bio-organic fertilizers on soil properties and growth of pigeon pea. *Scientia Horticulturae, 226,* 1–9.

Ansari, R. A., Mahmood, I., Rizvi, R., Sumbul, A., & Safiuddin. (2017a). Siderophores: Augmentation of soil health and crop productivity. In V. Kumar, M. Kumar, S. Sharma, & R. Prasad (Eds.), *Probiotics in agroecosystem*. Singapore: Springer. (in press).

Ansari, R. A., Rizvi, R., Sumbul, A., & Mahmood, I. (2017b). PGPR: Current vogue in sustainable crop production. In V. Kumar, M. Kumar, S. Sharma, & R. Prasad (Eds.), *Probiotics and plant health*. Singapore: Springer. (in press).

Arvanitoyannis, I. S., Ladas, D., & Mavromatis, A. (2006). Potential uses and applications of treated wine waste: A review. *The International Journal of Food Science & Technology, 41*(5), 475–487.

Aviles, M., Borrero, C., & Trillas, M. I. (2011). Review on compost as an inducer of disease suppression in plants grown in soilless culture. *Dynamic Soil, Dynamic Plant, 5*, 1–11.

Bailey, K. L., & Lazarovits, G. (2003). Suppressing soil-borne diseases with residue management and organic amendments. *Soil and Tillage Research, 72*, 169–180.

Baker, R., & Cook, J. (1974). *Biological control of plant pathogens*. San Francisco: W.H. Freeman, 433p.

Bangar, K. S., Parmar, B. B., & Maini, A. (2000). Effect of nitrogen and press mud application on yield and uptake of N, P and K by sugarcane (*Saccharum officinarum* L.). *Crop Research, 19*(2), 198–203.

Bauer, A., & Black, A. L. (1994). Quantification of the effect of soil organic matter content on soil productivity. *Soil Science Society of America Journal, 58*(1), 185–193.

Beck-Friis, B., Pell, M., Sonesson, U., Jönsson, H., & Kirchmann, H. (2000). Formation and emission of N2O and CH4 from compost heaps of organic household waste. *Environmental Monitoring and Assessment, 62*, 317–331.

Bender, G. S., Casale, W. L., & Rahimian, M. (1992). *Use of worm-composted sludge as a soil amendment for avocados in Phytophthora-infested soil*. In Proceeding of Second World Avocado Congress, Orange, CA, USA, p. 143.

Bernard, E., Larkin, R. P., Tavantzis, S., Erich, M. S., Alyokhin, A., & Gross, S. (2014). Rapeseed rotation, compost, and biocontrol amendments reduce soilborne diseases and increase tuber yield in organic and conventional potato production systems. *Plant and Soil, 374*, 611–627.

Berthrong, S. T., Buckley, D. H., & Drinkwater, L. E. (2013). Agricultural management and labile carbon additions affect soil microbial community structure and interact with carbon and nitrogen cycling. *Microbial Ecology, 66*, 158–170.

Beusen, A. H. W., Bouwman, A. F., Heuberger, P. S. C., Van Drecht, G., & Van Der Hoek, K. W. (2008). Bottom-up uncertainty estimates of global ammonia emissions from global agricultural production systems. *Atmospheric Environment, 42*, 6067–6077.

Bhowmik, A., Fortuna, A. M., Cihacek, L., Bary, A., & Cogger, C. G. (2016). Use of biological indicators of soil health to estimate reactive nitrogen dynamics in long-term organic vegetable and pasture systems. *Soil Biology and Biochemistry, 103*, 308–319.

Bhowmik, A., Fortuna, A. M., Cihacek, L. J., Bary, A. I., Carr, P. M., & Cogger, C. G. (2017). Potential carbon sequestration and nitrogen cycling in long-term organic management systems. *Renewable Agriculture and Food Systems*, 1–13. https://doi.org/10.1017/S1742170516000429

Blok, W. J., Lamers, J. G., Termorshuizen, A. J., & Bollen, G. J. (2000). Control of soilborne plant pathogens by incorporating fresh organic amendments followed by tarping. *Phytopathology, 90*, 253–259.

Bokhtiar, S. M., Paul, G. C., Rashid, M. A., & Rahman, A. B. M. (2001). Effect of press mud and organic nitrogen on soil fertility and yield of sugarcane grown in high Ganges river flood plain soils of Bangladesh. *Indian Sugar, 51*(4), 235–240.

Bonanomi, G., Antignani, V., Capodilupo, M., & Scala, F. (2010). Identifying the characteristics of organic amendments that suppress soilborne plant diseases. *Soil Biology and Biochemistry, 42*, 136–144.

Bonanomi, G., D'Ascoli, R., Antignani, V., Capodilupo, M., Cozzolino, L., Marzaioli, R., Puopolo, G., Rutigliano, F. A., Scelza, R., Scotti, R., Rao, M. A., & Zoina, A. (2011a). Assessing soil quality under intensive cultivation and tree orchards in Southern Italy. *Applied Soil Ecology, 47*, 187–194.

Bonanomi, G., Antignani, V., Barile, E., Lanzotti, V., & Scala, F. (2011b). Decomposition of *Medicago sativa* residues affects phytotoxicity, fungal growth and soil-borne pathogen diseases. *Journal of Plant Pathology, 93*, 57–69.

Bonanomi, G., Incerti, G., Giannino, F., Mingo, A., Lanzotti, V., & Mazzoleni, S. (2013). Litter quality assessed by solid state 13 C NMR spectroscopy predicts decay rate better than C/N and Lignin/N ratios. *Soil Biology and Biochemistry, 56*, 40–48.

Bonanomi, G., Capodilupo, M., Incerti, G., & Mazzoleni, S. (2014a). Nitrogen transfer in litter mixture enhances decomposition rate, temperature sensitivity, and C quality changes. *Plant and Soil, 381*, 307–321.

Bonanomi, G., D'Ascoli, R., Scotti, R., Gaglione, S. A., Caceres, M. G., Sultana, S., Scelza, R., Rao, M. A., & Zoina, A. (2014b). Soil quality recovery and crop yield enhancement by combined application of compost and wood to vegetables grown under plastic tunnels. *Agriculture, Ecosystems & Environment, 192*, 1–7.

Bonilla, N., Cazorla, F. M., Martínez-Alonso, M., Hermoso, J. M., González-Fernández, J., Gaju, N., Landa, B. B., & de Vicente, A. (2012a). Organic amendments and land management affect bacterial community composition, diversity and biomass in avocado crop soils. *Plant and Soil, 357*, 215–226.

Bonilla, N., Gutierrez-Barranquero, J. A., de Vicente, A., & Cazorla, F. M. (2012b). Enhancing soil quality and plant health through suppressive organic amendments. *Diversity, 4*, 475–491.

Borrero, C., Trillas, M. I., Ordovás, J., Tello, J. C., & Avilés, M. (2004). Predictive factors for the suppression of Fusarium wilt of tomato in plant growth media. *Phytopathology, 94*, 1094–1101.

Bouizgarne, B. (2013). Bacteria for plant growth promotion and disease management. In *Bacteria in agrobiology: Disease management* (pp. 15–47). Berlin/Heidelberg: Springer.

Bowles, T. M., Hollander, A. D., Steenwerth, K., & Jackson, L. E. (2015). Tightly-coupled plant-soil nitrogen cycling: Comparison of organic farms across an agricultural landscape. *PLoS One, 10*(6), e0131888. https://doi.org/10.1371/journal.pone.0131888.

Brunetti, G., Plaza, C., & Senesi, N. (2005). Olive pomace amendment in Mediterranean conditions: Effect on soil and humic acid properties and wheat (*Triticum turgidum* L.) yield. *Journal of Agricultural and Food Chemistry, 53*(17), 6730–6737.

Bulluck, L. R., III, & Ristaino, J. B. (2002). Effect of synthetic and organic soil fertility amendments on southern blight, soil microbial communities, and yield of processing tomatoes. *Phytopathology, 92*(2), 181–189.

Bulluck Iii, L. R., Brosius, M., Evanylo, G. K., & Ristaino, J. B. (2002). Organic and synthetic fertility amendments influence soil microbial, physical and chemical properties on organic and conventional farms. *Applied Soil Ecology, 19*, 147–160.

Burauel, P., & BaBmann, F. (2005). Soils as filter and buffer for pesticides-experimental concepts to understand soil functions. *Environmental Pollution, 133*, 11–16.

Castano, R., Borrero, C., & Aviles, M. (2011). Organic matter fractions by SP-MAS C-13 NMR and microbial communities involved in the suppression of Fusarium wilt in organic growth media. *Biological Control, 58*, 286–293.

Ceja-Navarro, J. A., Rivera-Orduña, F. N., Patiño-Zúñiga, L., Vila-Sanjurjo, A., Crossa, J., Govaerts, B., & Dendooven, L. (2010). Phylogenetic and multivariate analyses to determine the effects of different tillage and residue management practices on soil bacterial communities. *Applied and Environmental Microbiology, 76*, 3685–3691. https://doi.org/10.1128/AEM.02726-09.

Celik, I., Ortas, I., & Kilic, S. (2004). Effects of compost, mycorrhiza, manure and fertilizer on some physical properties of a Chromoxerert soil. *Soil and Tillage Research, 78*(1), 59–67.

Cesaro, A., Belgiorno, V., & Guida, M. (2015). Compost from organic solid waste: Quality assessment and European regulations for its sustainable use. *Resources, Conservation and Recycling, 94*, 72–79.

Chae, D. H., Jin, R. D., Hwangbo, H., Kim, Y. H., Kim, Y. W., Park, R. D., Krishnan, H. B., & Kim, K. Y. (2006). Control of late blight (*Phytophthora capsici*) in pepper plant with a compost containing multitude of chitinase-producing bacteria. *BioControl, 51*, 339–351.

Chakraborty, A., Chakrabarti, K., Chakraborty, A., & Ghosh, S. (2011). Effect of long-term fertilizers and manure application on microbial biomass and microbial activity of a tropical agricultural soil. *Biology and Fertility of Soils, 47*, 227–233.

Chan, Y. C., Sinha, R. K., & Wang, W. (2011). Emission of greenhouse gases from home aerobic composting, anaerobic digestion and vermicomposting of household wastes in Brisbane (Australia). *Waste Management and Research, 29*(5), 540–548.

Chan, M. T., Selvam, A., & Wong, J. W. (2016). Reducing nitrogen loss and salinity during 'struvite' food waste composting by zeolite amendment. *Bioresource Technology, 200*, 838–844.

Claassen, V. P., & Carey, J. L. (2006). Comparison of slow-release nitrogen yield from organic soil amendments and chemical fertilizers and implications for regeneration of disturbed sites. *Land Degradation and Development, 18*, 119–132.

Clough, A., & Skjemstad, J. O. (2000). Physical and chemical protection of soil organic carbon in three agricultural soils with different contents of calcium carbonate. *Australian Journal of Soil Research, 38*, 1005–1016.

Cohen, M. F., Yamasaki, H., & Mazzola, M. (2005). Brassica napus seed meal soil amendment modifies microbial community structure, nitric oxide production and incidence of *Rhizoctonia* root rot. *Soil Biology and Biochemistry, 37*, 1215–1227. https://doi.org/10.1016/j.soilbio.2004.11.027.

Conn, K. L., Tenuta, M., & Lazarovits, G. (2005). Liquid swine manure can kill Verticillium dahliae microsclerotia in soil by volatile fatty acid, nitrous acid, and ammonia toxicity. *Phytopathology, 95*(1), 28–35.

Creamer, N. G., & Baldwin, K. R. (2000). An evaluation of summer cover crops for use in vegetable production systems in North Carolina. *Hortscience, 35*(4), 600–603.

Crecchio, C., Curci, M., Mininni, R., Ricciuti, P., & Ruggiero, P. (2004). Effects of municipal solid waste compost amendments on soil enzyme activities and bacterial genetic diversity. *Soil Biology and Biochemistry, 36*, 1595–1605.

De Baets, S., Van de Weg, M. J., Lewis, R., Steinberg, N., Meersmans, J., Quine, T. A., Shaver, G. R., & Hartley, I. P. (2016). Investigating the controls on soil organic matter decomposition in tussock tundra soil and permafrost after fire. *Soil Biology and Biochemistry, 99*, 108–116.

Delgado, M. M., Martin, J. V., De Imperial, R. M., León-Cófreces, C., & García, M. C. (2010). Phytotoxicity of uncomposted and composted poultry manure. *African Journal of Plant Science, 4*(5), 151–159.

Dimitrov, M. R., Veraart, A. J., de Hollander, M., Smidt, H., van Veen, J. A., & Kuramae, E. E. (2017). Successive DNA extractions improve characterization of soil microbial communities. *PeerJ, 5*, e2915. https://doi.org/10.7717/peerj.2915.

Dolliver, H., Gupta, S., & Noll, S. (2008). Antibiotic degradation during manure composting. *Journal of Environmental Quality, 37*, 1245–1253.

Dotaniya, M. L., Datta, S. C., Biswas, D. R., Dotaniya, C. K., Meena, B. L., Rajendiran, S., & Lata, M. (2016). Use of sugarcane industrial by-products for improving sugarcane productivity and soil health. *The International Journal of Recycling of Organic Waste in Agriculture, 5*(3), 185–194.

Douglas, J. T., Aitken, M. N., & Smith, C. A. (2003). Effects of five non-agricultural organic wastes on soil composition, and on the yield and nitrogen recovery of Italian ryegrass. *Soil Use and Management, 19*, 135–138.

Downer, A. J., Menge, J. A., & Pond, E. (2001). Association of cellulytic enzyme activities in eucalyptus mulches with biological control of *Phytophthora cinnamomi*. *Phytopathology, 91*(9), 847–855.

Drinkwater, L. E., Letourneau, D. K., Workneh, F., van Bruggen, A. H. C., & Shennan, C. (1995). Fundamental differences between conventional and organic tomato agroecosystems in California. *Ecological Applications, 5*, 1098–1112.

Edel-Hermann, V., Dreumont, C., Pérez-Piqueres, A., & Steinberg, C. (2004). Terminal restriction fragment length polymorphism analysis of ribosomal RNA genes to assess changes in fungal community structure in soils. *FEMS Microbiology Ecology, 47*, 397–404.

Ebelhar, S. A., Frye, W. W., & Blevins, R. L. (1984). Nitrogen from legume cover crops for no-tillage corn 1. *Agronomy Journal, 76*(1), 51–55.

El-Abbassi, A., Saadaoui, N., Kiai, H., Raiti, J., & Hafidi, A. (2017). Potential applications of olive mill wastewater as biopesticide for crops protection. *Science of the Total Environment, 576*, 10–21.

Elizabeth, R. (2014). *One-third of food is lost or wasted: what can be done*. National geographic. http://news.nationalgeographic.com/news/2014/10/141013-food-waste-national-security-environment-science-ngfood/

Epstein, E. (2003). *Land application of sewage sludge and biosolids*. Boca Raton: Lewis Publishers/CRC Press.

Erhart, E., Burian, K., Hartl, W., & Stich, K. (1999). Suppression of *Pythium ultimum* by biowaste composts in relation to compost microbial biomass, activity and content of phenolic compounds. *Journal of Phytopathology, 147*, 299–305.

F.A.O. (2011). *Global food losses and food waste – Extent, causes and prevention*. Rome: FAO. http://www.fao.org/3/a-i2697e.pdf.

Fageria, N. K., Baligar, V. C., & Bailey, B. A. (2005). Role of cover crops in improving soil and row crop productivity. *Communications in Soil Science and Plant Analysis, 36*(19–20), 2733–2757.

Fang, C., Smith, P., Moncrieff, J. B., & Smith, J. U. (2005). Similar response of labile and resistant soil organic matter pools to changes in temperature. *Nature, 433*, 57e59.

Faye, J. M. (2017). *Evaluation of organic amendments for the management of root-knot nematodes (Meloidogyne* spp.*) of tomato (Solanum Lycopersicum L.)*. Doctoral dissertation. Department of crop and soil sciences, Kwame Nkrumah University of Science and Technology.

Ferrer, J., Páez, G., Mármol, Z., Ramones, E., Chandler, C., Marın, M., & Ferrer, A. (2001). Agronomic use of biotechnologically processed grape wastes. *Bioresource Technology, 76*(1), 39–44.

Fontaine, S., Barot, S., Barré, P., Bdioui, N., Mary, B., & Rumpel, C. (2007). Stability of organic carbon in deep soil layers controlled by fresh carbon supply. *Nature, 450*, 277–280.

Fox, T., & Fimeche, C. (2013, January). *Global food: Waste not, want not*. Institute of Mechanical Engineers, London. https://www.imeche.org/policy-and-press/reports/detail/global-food-waste-not-want-not

Franco-Andreu, L., Gómez, I., Parrado, J., García, C., Hernández, T., & Tejada, M. (2016). Soil biology changes as a consequence of organic amendments subjected to a severe drought. *Land Degradation & Development, 28*(3), 897–905.

Fu, L., Penton, C. R., Ruan, Y., Shen, Z., Xue, C., Li, R., & Shen, Q. (2017). Inducing the rhizosphere microbiome by biofertilizer application to suppress banana Fusarium wilt disease. *Soil Biology and Biochemistry, 104*, 39–48.

Galanakis, C. M. (2015). *Food waste recovery: Processing technologies and industrial techniques*. London: Academic.

Garcia, C., Hernandez, T., Costa, F., & Ceccanti, B. (1994). Biochemical parameters in soils regenerated by the addition of organic wastes. *Waste Management and Research, 12*(6), 457–466.

Garcıa-Gil, J. C., Plaza, C., Soler-Rovira, P., & Polo, A. (2000). Long-term effects of municipal solid waste compost application on soil enzyme activities and microbial biomass. *Soil Biology and Biochemistry, 32*, 1907–1913.

Geier, B. (2007). IFOAM and the history of the international organic movement. In*Organic farming: An international history* (pp. 175–186). Wallingford: CAB International.

Ghimire, R., Lamichhane, S., Acharya, B. S., Bista, P., & Sainju, U. M. (2017). Tillage, crop residue, and nutrient management effects on soil organic carbon in rice-based cropping systems: A review. *Journal of Integrative Agriculture, 16*(1), 1–15.

Ghulam, S., Khan, M. J., Usman, K., & Shakeebullah. (2012). Effect of different rates of press mud on plant growth and yield of lentil in calcareous soil. *Sarhad Journal of Agriculture, 28*(2), 249–252.

Goldstein, J., Pincus, I., & Rynk, R. (2000). Compost use in agriculture. *Compost Science & Utilization, 11*(2), 94–96.

Gomez, E., Ferreras, L., & Toresani, S. (2006). Soil bacterial functional diversity as influenced by organic amendment application. *Bioresource Technology, 97*, 1484–1489. https://doi.org/10.1016/j.biortech.2005.06.021.

Goss, M. J., Tubeileh, A., & Goorahoo, D. (2013). A review of the use of organic amendments and the risk to human health. *Advances in Agronomy, 120*, 275–379.

Goyal, S., Chander, K., Mundra, M., & Kapoor, K. (1999). Influence of inorganic fertilizers and organic amendments on soil organic matter and soil microbial properties under tropical conditions. *Biology and Fertility of Soils, 29*, 196–200.

Hachicha, R., Rekik, O., Hachicha, S., Ferchichi, M., Woodward, S., Moncef, N., Cegarra, J., & Mechichi, T. (2012). Co-composting of spent coffee ground with olive mill wastewater sludge and poultry manure and effect of Trametes versicolor inoculation on the compost maturity. *Chemosphere, 88*, 677–682.

Hadar, Y., & Mandelbaum, R. (1992). Suppressive compost for biocontrol of soilborne plant pathogens. *Phytoparasitica, 20*(1), S113–S116.

Hadar, Y., & Papadopoulou, K. K. (2012). Suppressive composts: Microbial ecology links between abiotic environments and healthy plants. *Annual Review of Phytopathology, 50*, 133–153.

Hader, Y., Mandelbaum, R., & Gorodecki, B. (1992). Biological control of soilborne plant pathogens by suppressive compost. In E. S. Tjamos, G. C. Papavizas, & R. J. Cook (Eds.), *Biological control of plant diseases* (pp. 79–83). New York: Plenum Press.

Handa, I. T., Aerts, R., Berendse, F., Berg, M. P., Bruder, A., Butenschoen, O., Chauvet, E., Gessner, M. O., Jabiol, J., Makkonen, M., & McKie, B. G. (2014). Consequences of biodiversity loss for litter decomposition across biomes. *Nature, 509*(7499), 218–221.

Hargreaves, J. C., Adl, M. S., & Warman, P. R. (2008). A review of the use of composted municipal solid waste in agriculture. *Agriculture, Ecosystems & Environment, 123*, 1–14.

Heyman, F., Lindahl, B., Persson, L., Wikström, M., & Stenlid, J. (2007). Calcium concentrations of soil affect suppressiveness against Aphanomyces root rot of pea. *Soil Biology and Biochemistry, 39*, 2222–2229.

Hiddink, G. A., van Bruggen, A. H. C., Termorshuizen, A. J., Raaijmakers, J. M., & Semenov, A. V. (2005). Effect of organic management of soils on suppressiveness to *Gaeumannomyces graminis* var. *tritici* and its antagonist, *Pseudomonas fluorescens*. *European Journal of Plant Pathology, 113*, 417–435.

Hodge, A., Robinson, D., & Fitter, A. H. (2000). Are microorganisms more effective than plants at competing for nitrogen? *Trends in Plant Science, 5*, 304–308.

Hofsetz, K., & Silva, M. A. (2012). Brazilian sugarcane bagasse: Energy and non-energy consumption. *Biomass & Bioenergy, 4*(6), 564–573.

Hoitink, H. A. J., & Boehm, M. J. (1999). Biocontrol within the context of soil microbial communities: A substrate-dependent phenomenon. *Annual Review of Phytopathology, 37*, 427–446.

Hoitink, H. A. J., Boehm, M. J., & Hadar, Y. (1993). Mechanisms of suppression of soilborne plant pathogens in compost-amended substrates. In H. A. J. Hoitink & H. M. Keener (Eds.), *Science and engineering of composting* (pp. 601–621). Worthington: Renaissance Publication.

Horrocks, A., Curtin, D., Tregurtha, C., & Meenken, E. (2016). Municipal compost as a nutrient source for organic crop production in New Zealand. *Agronomy, 6*(2), 35.

Hu, Z., Xu, C., McDowell, N. G., Johnson, D. J., Wang, M., Luo, Y., Zhou, X., & Huang, Z. (2017). Linking microbial community composition to C loss rates during wood decomposition. *Soil Biology and Biochemistry, 104*, 108–116.

Huang, X., Wen, T., Zhang, J., Meng, L., Zhu, T., & Cai, Z. (2015). Toxic organic acids produced in biological soil disinfestation mainly caused the suppression of *Fusarium oxysporum* f. sp. cubense. *BioControl, 60*(1), 113–124.

Iovieno, P., Morra, L., Leone, A., Pagano, L., & Alfani, A. (2009). Effect of organic and mineral fertilizers on soil respiration and enzyme activities of two Mediterranean horticultural soils. *Biology and Fertility of Soils, 45*, 555–561.

Janvier, C., Villeneuve, F., Alabouvette, C., Edel-Hermann, V., Mateille, T., & Steinberg, C. (2007). Soil health through soil disease suppression: Which strategy from descriptors to indicators? *Soil Biology and Biochemistry, 39*(1), 1–23.

Jindo, K., Chocano, C., Melgares de Aguilar, J., González, D., Hernandez, T., & García, C. (2016). Impact of compost application during 5 years on crop production, soil microbial activity, carbon fraction, and humification process. *Communications in Soil Science and Plant Analysis, 47*(16), 1907–1919.

Johnson, J. M. F., Franzluebbers, A. J., Weyers, S. L., & Reicosky, D. C. (2007). Agricultural opportunities to mitigate greenhouse gas emissions. *Environmental Pollution, 150*, 107–124.

Johnston, A. E., Poulton, P. R., & Coleman, K. (2009). Soil organic matter: Its importance in sustainable agriculture and carbon dioxide fluxes. *Advances in Agronomy, 101*, 1–57.

Jouquet, E. P., Bloquel, E., Doan, T. T., Ricoy, M., Orange, D., Rumpel, C., & Duc, T. T. (2011). Do compost and vermicompost improve macronutrient retention and plant growth in degraded tropical soils? *Compost Science & Utilization, 19*(1), 15–24.

Jowit, J. (2007). *Call to use leftovers and cut food waste*. https://www.theguardian.com/environment/2007/oct/28/food.foodanddrink?CMP=share_btn_tw

Juul, S. (2016). Will Denmark win the global race against food waste? *The Huffington Post*. http://www.huffingtonpost.com/selina-juul/will-denmark-become-a-wor_b_9703260.html

Kammerer, D., Claus, A., Carle, R., & Schieber, A. (2004). Polyphenol screening of pomace from red and white grape varieties (*Vitis vinifera* L.) by HPLC-DAD-MS/MS. *Journal of Agricultural and Food Chemistry, 52*, 4360–4367.

Karami, A., Homaee, M., Afzalinia, S., Ruhipour, H., & Basirat, S. (2012). Organic resource management: Impacts on soil aggregate stability and other soil physico-chemical properties. *Agriculture, Ecosystems & Environment, 148*, 22–28.

Kaur, C., & Verma, G. (2016). Effect of different organic sources and their combinations on weed growth and yield of wheat (*Triticum aestivum*). *The Indian Journal of Agricultural Sciences, 50*(5), 491–494.

Keswani, C., Bisen, K., Chitara, M. K., Sarma, B. K., & Singh, H. B. (2017). Exploring the role of secondary metabolites of *Trichoderma* in tripartite interaction with plant and pathogens. In *Agro-environmental sustainability* (pp. 63–79). Cham: Springer International Publishing.

Khaliq, A., & Abbasi, M. K. (2015). Improvements in the physical and chemical characteristics of degraded soils supplemented with organic–inorganic amendments in the Himalayan region of Kashmir, Pakistan. *Catena, 126*, 209–219.

Khan, M. R., Jain, R. K., Ghule, T. M., & Pal, S. (2014). *Root knot nematodes in India*. A comprehensive monograph. All India Co-ordinated Research Project on Plant Parasitic Nematodes with Integrated Approach for their control. Indian Agricultural Research Institute, New Delhi, pp 78.

Kim, J. Y. (2014). *Food waste – A bigger problem than you thought*. http://www.huffingtonpost.com/jim-yong-kim/food-waste%2D%2D-a-bigger-pro_b_5000462.html?ncid=engmodushpmg00000004

Kirchmann, H., & Lundvall, A. (1993). Relationship between N immobilization and volatile fatty acids in soil after application of pig and cattle slurry. *Biology and Fertility of Soils, 15*, 161–164.

Klein, E. (2011). Soil suppressiveness to Fusarium disease following organic amendments and solarization. *Plant Disease, 95*(9), 1116–1123. https://doi.org/10.1094/PDIS-01-11-0065.

Kumar, S. (2016). *Municipal solid waste management in developing countries*. Boca Raton: CRC Press, Taylor and Francis Group.

Kumar, K., Rosen, C. J., Gupta, S. C., & McNearney, M. (2009). Land application of sugar beet by-products: Effects on nitrogen mineralization and crop yields. *Journal of Environmental Quality, 38*, 319–328.

Lakhdar, A., Rabhi, M., Ghnaya, T., Montemurro, F., Jedidi, N., & Abdelly, C. (2009). Effectiveness of compost use in salt-affected soil. *Journal of Hazardous Materials, 171*, 29–37.

Lal, R. (2005). Enhancing crop yields in the developing countries through restoration of the soil organic carbon pool in agricultural lands. *Land Degradation and Development, 17*, 197–209.

Lampkin, N. (1990). *Organic farming*. Ipswich: Farming Press Books.

Lazarovits, G. (2001). Management of soil-borne plant pathogens with organic amendments: A disease control strategy salvaged from the past. *Canadian Journal of Plant Pathology, 23*, 1–7.

Lazarovits, G. (2010). Managing soilborne disease of potatoes using ecologically based approaches. *The American Journal of Potato Research, 87*(5), 401–411.

Lazarovits, G., & Subbarao, K. (2010). Challenges in controlling Verticillium wilt by the use of nonchemical methods. In U. Gisi, I. Chet, & L. Gullino (Eds.), *Recent developments in management of plant diseases* (pp. 247–264). Dordrecht: Springer.

Lazarovits, G., Conn, K. L., Abbasi, P. A., & Tenuta, M. (2005). Understanding the mode of action of organic soil amendments provides the way for improved management of soilborne plant pathogens. *Acta Horticulturae, 698*, 215.

Leroy, B. L. M., Herath, H. M. S. K., Sleutel, S., De Neve, S., Gabriels, D., Reheul, D., & Moens, M. (2008). The quality of exogenous organic matter: Short-term effects on soil physical properties and soil organic matter fractions. *Soil Use and Management, 24*(2), 139–147.

Lewis, J. A., & Papavizas, G. C. (1991). Biocontrol of plant diseases: The approach for tomorrow. *Crop Protection, 10*(2), 95–105.

Li, R., Tao, R., Ling, N., & Chu, G. (2017). Chemical, organic and bio-fertilizer management practices effect on soil physicochemical property and antagonistic bacteria abundance of a cotton field: Implications for soil biological quality. *Soil & Tillage Research, 167*, 30–38.

Liu, Z., Chen, X., Jing, Y., Li, Q., Zhang, J., & Huang, Q. (2014). Effects of biochar amendment on rapeseed and sweet potato yields and water stable aggregate in upland red soil. *Catena, 123*, 45–51.

Liebig, M. A., Morgan, J. A., Reeder, J. D., Ellert, B. H., Gollany, H. T., & Schuman, G. E. (2005). Greenhouse gas contributions and mitigation potential of agricultural practices in northwestern USA and western Canada. *Soil and Tillage Research, 83*(1), 25–52.

Lockwood, J. L. (1990). Relation of energy stress to behaviour of soilborne plant pathogens and to disease development. In D. Hornby (Ed.), *Biological control of soilborne plant pathogens* (pp. 197–214). Wallingford: CAB International.

Lucas, S. T., D'Angelo, E. M., & Williams, M. A. (2014). Improving soil structure by promoting fungal abundance with organic soil amendments. *Applied Soil Ecology, 75*, 13–23.

Maas, E. V., & Hoffman, G. J. (1977). Crop salt tolerance-current assessment. *Journal of Irrigation and Drainage, 103*, 115–134.

Mäder, P., Flieβbach, A., Dubois, D., Gunst, L., Fried, P., & Niggli, U. (2002). Soil fertility and biodiversity in organic farming. *Science, 296*, 1694–1697.

Malandraki, I., Tjamos, S. E., Pantelides, I. S., & Paplomatas, E. J. (2008). Thermal inactivation of compost suppressiveness implicates possible biological factors in disease management. *Biological Control, 44*(2), 180–187.

Martin, F. N. (2003). Development of alternative strategies for management of soilborne pathogens currently controlled with methyl bromide. *Annual Review of Phytopathology, 41*, 325–350.

Martínez-Blanco, J., Lazcano, C., Christensen, T. H., Muñoz, P., Rieradevall, J., Møller, J., Antón, A., & Boldrin, A. (2013). Compost benefits for agriculture evaluated by life cycle assessment: A review. *Agronomy for Sustainable Development, 33*(4), 721–732.

Mazzola, M. (2002). Mechanisms of natural soil suppressiveness to soilborne diseases. *Antonie Van Leeuwenhoek, 81*, 557–564, Kluwer Academic Publishers, Netherlands.

Mazzola, M. (2004). Assessment and management of soil microbial community structure for disease suppression. *Annual Review of Phytopathology, 42*, 35–59.

Mishra, S., Wang, K. H., Sipes, B., & Tian, M. (2017). Suppression of root-knot nematode by vermicompost tea prepared from different curing ages of vermicompost. *Plant Disease* (ja). https://doi.org/10.1094/PDIS-07-16-1068-RE.

Misra, R. V., Roy, R. N., & Hiraoka, H. (2016). *On-farm composting methods*. Rome: UN-FAO.

Montemurro, F., Maiorana, M., Convertini, G., & Ferri, D. (2007). Alternative sugar beet production using shallow tillage and municipal solid waste fertilizer. *Agronomy for Sustainable Development, 27*, 129–137.

Morra, L., Pagano, L., Iovieno, P., Baldantoni, D., & Alfani, A. (2010). Soil and vegetable crop response to addition of different levels of municipal waste compost under Mediterranean greenhouse conditions. *Agronomy for Sustainable Development, 30*, 701–709.

Muchovej, R. M., & Obreza, T. A. (2001). *Biosolids: Are these residuals all the same?* Fact Sheet, SS-AGR-167.

Muchovej, R. M. C., & Pacovsky, R. S. (1997). Future directions of by-products and wastes in agriculture. In J. E. Rechcigl, & H. C. MacKinnon (Eds.), *Agricultural uses of by-products and wastes* (ACS symposium series, pp. 1–19). Washington, DC:American Chemical Society.

Mukhopadhyay, A. N. (2016). *Trichoderma* for plant disease management: A reality or myth? *The International Journal of Tea Science, 8*(4), 47–54.

Müller-Lindenlauf, M. (2009). *Organic agriculture and carbon sequestration. Possibilities and constrains for the consideration of organic agriculture within carbon accounting systems*. Natural Resources Management and Environment Department, Food and Agriculture Organization of the United Nations, Rome.

N'Dayegamiye, A., & Tran, T. S. (2001). Effects of green manures on soil organic matter and wheat yields and N nutrition. *Canadian Journal of Soil Science, 81*(4), 371–382.

Nannipieri, P., Ceccanti, B., & Grego, S. (1990). Ecological significance of biological activity in soil. *Soil Biochemistry, 6*, 293–355, Marcel Dekker, New York, USA.

Niggli, U., Fließbach, A., Hepperly, P., & Scialabba, N. (2009). Low greenhouse gas agriculture: Mitigation and adaptation potential of sustainable farming systems. *Ökologie & Landbau, 141*, 32–33.

Noble, R. (2011). Risks and benefits of soil amendment with composts in relation to plant pathogens. *Australasian Plant Pathology, 40*, 157–167.

Noble, R., & Coventry, E. (2005). Suppression of soil-borne plant diseases with composts: A review. *Biocontrol Science and Technology, 15*, 3–20.

Obreza, T. A., & O'Connor, G. A. (2003). *The basics of biosolids application to land in Florida*. One of a series of the Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

Oliveira, B. R., van Laarhoven, K., Smit, M. P., Rijnaarts, H. H., & Grotenhuis, T. (2017). Impact of compost and manure on the ripening of dredged sediments. *Journal of Soils and Sediments, 17*(2), 567–577.

Ouni, Y., Lakhdar, A., Scelza, R., Scotti, R., Abdelly, C., Barhoumi, Z., & Rao, M. A. (2013). Effects of two composts and two grasses on microbial biomass and biological activity in a salt-affected soil. *Ecological Engineering, 60*, 363–369.

Pane, C., Spaccini, R., Piccolo, A., Scala, F., & Bonanomi, G. (2011). Compost amendments enhance peat suppressiveness to *Pythium ultimum*, *Rhizoctonia solani* and *Sclerotinia minor*. *Biological Control, 56*, 115–124.

Pane, C., Palese, A. M., Spaccini, R., Piccolo, A., Celano, G., & Zaccardelli, M. (2016). Enhancing sustainability of a processing tomato cultivation system by using bioactive compost teas. *Scientia Horticulturae, 202*, 117–124.

Paplomatas, E. J., Tjamos, S. E., Malandrakis, A. A., Kafka, A. L., & Zouvelou, S. V. (2005). Evaluation of compost amendments for suppressiveness against Verticillium wilt of eggplant and study of mode of action using a novel Arabidopsis pathosystem. *European Journal of Plant Pathology, 112*, 183–189.

Park, J. H., Lamb, D., Paneerselvam, P., Choppala, G., Bolan, N., & Chung, J. W. (2011). Role of organic amendments on enhanced bioremediation of heavy metal(loid) contaminated soils. *Journal of Hazardous Materials, 185*, 549–574.

Pascaud, G., Soubrand, M., Lemee, L., Laduranty, J., El-Mufleh, A., Rabiet, M., & Joussein, E. (2017). Molecular fingerprint of soil organic matter as an indicator of pedogenesis processes in Technosols. *Journal of Soils and Sediments, 17*(2), 340–351.

Patni, N. K., & Jui, P. Y. (1987). Changes in solids and carbon content of dairy-cattle slurry in farm tanks. *Biological Wastes, 20*, 11–34.

Paz-Ferreiro, J., Trasar-Cepeda, C., Leirós, M. C., Seoane, S., & Gil-Sotres, F. (2009). Biochemical properties in managed grassland soils in a temperate humid zone: Modifications of soil quality as a consequence of intensive grassland use. *Biology and Fertility of Soils, 45*, 711–722.

Peacock, A. D., Mullen, M. D., Ringelberg, D. B., Tyler, D. D., Hedrick, D. B., Gale, P. M., & White, D. C. (2001). Soil microbial community responses to dairy manure or ammonium nitrate applications. *Soil Biology and Biochemistry, 33*, 1011–1019.

Penton, C. R., Gupta, V. V. S. R., Tiedje, J. M., Neate, S. M., Ophel-Keller, K., Gillings, M., Harvey, P., Pham, A., & Roget, D. K. (2014). Fungal community structure in disease suppressive soils assessed by 28S LSU gene sequencing. *PLoS One, 9*(4), 1–12.

Pérez-Piqueres, A., Edel-Hermann, V., Alabouvette, C., & Steinberg, C. (2006). Response of soil microbial communities to compost amendments. *Soil Biology and Biochemistry, 38*, 460–470.

Pharand, B., Carisse, O., & Benhamou, N. (2002). Cytological aspects of compost-mediated induced resistance against Fusarium crown and root rot in tomato. *Phytopathology, 92*, 424–438.

Piccolo, A. (1996). *Humus and soil conservation. Humic substances in terrestrial ecosystems* (pp. 225–264). Amsterdam: Elsevier.

Raaijmakers, J. M., & Weller, D. M. (1998). Natural plant protection by 2,4-diacetylphloroglucino lproducing Pseudomonas spp. in take-all decline soils. *Molecular Plant-Microbe Interactions, 11*, 144–152.

Raaijmakers, J. M., Paulitz, T. C., Steinberg, C., Alabouvette, C., & Moënne-Loccoz, Y. (2009). The rhizosphere: A playground and battlefield for soilborne pathogens and beneficial microorganisms. *Plant and Soil, 321*(1–2), 341–361.

Raaijmakers, J. M., Weller, D. M., & Thomashow, L. S. (1997). Frequency of antibiotic-producing Pseudomonas spp. in natural environments. *Applied and Environmental Microbiology, 63*(3), 881–887.

Raimbault, B. A., & Vyn, T. J. (1991). Crop rotation and tillage effects on corn growth and soil structural stability. *Agronomy Journal, 83*(6), 979–985.

Ramaswamy, J., Prasher, S. O., Patel, R. M., Hussain, S. A., & Barrington, S. F. (2010). The effect of composting on the degradation of a veterinary pharmaceutical. *Bioresource Technology, 101*, 2294–2299.

Razzaq, A. (2001). Assessing sugarcane filtercake as crop nutrients and soil health ameliorant. *Pakistan Sugar Journal, 21*(3), 15–18.

Reddy, G. S. (2008). *Green leaf manuring and organic farming in: Organic farming in rainfed agriculture: Opportunities and constraints* (pp. 74–77). Hyderabad: Central research Institute for Dryland Agriculture.

Rietz, D. N., & Haynes, R. J. (2003). Effects of irrigation-induced salinity and sodicity on soil microbial activity. *Soil Biology and Biochemistry, 35*, 845–854.

Rizvi, R., Ansari, R. A., Zehra, G., & Mahmood, I. (2015). A farmer friendly and economic IPM strategy to combat root-knot nematodes infesting lentil. *Cogent Food & Agriculture, 1*(1), 1053214.

Rocha, G. J. M., Martin, C., Soares, I. B., Souto-Maior, A. M., Baudel, H. M., & Moraes, C. A. (2011). Dilute mixed-acid pretreatment of sugarcane bagasse for the ethanol production. *Biomass & Bioenergy, 35*, 663–670.

Rodríguez-Kábana, R. (1986). Organic and inorganic nitrogen amendments to soil as nematode suppressants. *Journal of Nematology, 18*, 129–135.

Ros, M., Hernandez, M. T., & Garcìa, C. (2003). Soil microbial activity after restoration of a semi-arid soil by organic amendments. *Soil Biology and Biochemistry, 35*, 463–469.

Saison, C., Degrange, V., Oliver, R., Millard, P., Commeaux, C., Montange, D., & Le Roux, X. (2006). Alteration and resilience of the soil microbial community following compost amendment: Effects of compost level and compost- borne microbial community. *Environmental Microbiology, 8*, 247–257. https://doi.org/10.1111/j.1462-2920.2005.00892.x.

Sanmanee, N., Panishkan, K., Obsuwan, K., & Dharmvanij, S. (2011). Study of compost maturity during humification process using UV-spectroscopy. *World Academy of Science, Engineering and Technology, 80*, 403–405.

Sardar, S., Ilyas, S. U., Malik, S. R., & Javaid, K. (2013). Compost fertilizer production from sugar press mud (SPM). *International Journal of Microbiology Research, 1*(2), 20–27.

Sarrantonio, M., & Gallandt, E. (2003). The role of cover crops in North American cropping systems. *Journal of Crop Production, 8*(1–2), 53–74.

Sarwar, M. A., Ibrahim, M., Tahir, M., Ahmad, K., Khan, Z. I., & Valeem, E. E. (2010). Appraisal of press mud and inorganic fertilizers on soil properties, yield and sugarcane quality. *Pakistan Journal of Botany, 42*(2), 1361–1367.

Scheuerell, S. J., Sullivan, D. M., & Mahaffee, W. F. (2005). Suppression of seedling damping-off caused by *Pythium ultimum*, *P. irregulare,* and *Rhizoctonia solani* in container media amended with a diverse range of Pacific Northwest compost sources. *Phytopathology, 95*, 306–315.

Schuerell, S. J., & Mahaffee, W. F. (2002). Compost tea: Principles and prospects for disease control. *Compost Science & Utilization, 10*, 313–338.

Scotti, R., Bonanomi, G., Scelza, R., Zoina, A., & Rao, M. A. (2015). Organic amendments as sustainable tool to recovery fertility in intensive agricultural systems. *Journal of Soil Science and Plant Nutrition, 15*(2), 333–352.

Scotti, R., Conte, P., Berns, A. E., Alonzo, G., & Rao, M. A. (2013). Effect of organic amendments on the evolution of soil organic matter in soils stressed by intensive agricultural practices. *Current Organic Chemistry, 17*, 2998–3005.

Serra-Wittling, C., Houot, S., & Alabouvette, C. (1996). Increased soil suppressiveness to Fusarium wilt of flax after addition of municipal solid waste compost. *Soil Biology and Biochemistry, 28*, 1207–1214.

Shahbaz, M., Kuzyakov, Y., Sanaullah, M., Heitkamp, F., Zelenev, V., Kumar, A., & Blagodatskaya, E. (2017). Microbial decomposition of soil organic matter is mediated by quality and quantity of crop residues: Mechanisms and thresholds. *Biology and Fertility of Soils, 53*, 1–15.

Simon, A., & Sivasithamparam, K. (1989). Pathogen-suppression: A case study in biological suppression of Gaeumannomyces graminis var. tritici in soil. *Soil Biology and Biochemistry, 21*, 331–337.

Singh, M., Singh, A., Singh, S., Tripathi, R. S., Singh, A. K., & Patra, D. D. (2010). Cowpea (Vigna unguiculata L. Walp.) as a green manure to improve the productivity of a menthol mint (Mentha arvensis L.) intercropping system. *Industrial Crops and Products, 31*(2), 289–293.

Smith, M. M., Aber, J. D., & Rynk, R. (2016). Heat recovery from composting: A comprehensive review of system design, recovery rate, and utilization. *Compost Science & Utilization, 1*, 12.

Smolinska, U. (2000). Survival of *Sclerotium cepivorum* Sclerotia and *Fusarium oxysporum* Chlamydospores in Soil Amended with Cruciferous Residues. *Journal of Phytopathology, 148*(6), 343–349.

St.Martin, C. C. G., & Brathwaite, R. A. I. (2012). Compost and compost teas: Principles and prospects as substrates and soil-borne disease management strategies in soil-less vegetable production. *Biological Agriculture and Horticulture, 28*, 1–33.

Stark, C. H., Condron, L. M., O'Callaghan, M., Stewart, A., & Di, H. J. (2008). Differences in soil enzyme activities, microbial community structure and short-term nitrogen mineralisation resulting from farm management history and organic matter amendments. *Soil Biology and Biochemistry, 40*, 1352–1363. https://doi.org/10.1016/j.soilbio.2007.09.025.

Steinberg, C., Edel-Hermann, V., Alabouvette, C., & Lemanceau, P. (2007). Soil suppressiveness to plant diseases. In J. D. van Elsas, J. C. Jansson, & J. T. Trevors (Eds.), *Modern soil microbiology* (2nd ed., pp. 455–478). Boca Raton: CRC Press.

Steiner, C., Teixeira, W. G., Lehmann, J., Nehls, T., de Macêdo, J. L. V., Blum, W. E., & Zech, W. (2007). Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil. *Plant and Soil, 291*(1–2), 275–290.

Sugumaran, M. P., Shanmugam, P. M., Ramasamy, S., & Siddeswaran, K. (2016). Effect of different organic manures on the performance of improved White Ponni in Tamil Nadu. *Advanced Life Sciences, 5*(8), 3394–3397.

Sumbul, A., Rizvi, R., Mahmood, I., & Ansari, R. A. (2015). Oil-cake amendments: Useful tools for the management of phytonematodes. *Asian Journal of Plant Pathology, 9*(3), 91–111.

Szczech, M., & Smolińska, U. (2001). Comparison of suppressiveness of vermicomposts produced from animal manures and sewage sludge against *Phytophthora nicotianae* Breda de Haan var. *nicotianae*. *Journal of Phytopathology, 149*, 77–82.

Tamm, L., Thürig, B., Bruns, C., Fuchs, J. G., Köpke, U., Laustela, M., & Weber, F. (2010). Soil type, management history, and soil amendments influence the development of soil-borne (Rhizoctonia solani, Pythium ultimum) and air-borne (Phytophthora infestans, Hyaloperonospora parasitica) diseases. *European Journal of Plant Pathology, 127*(4), 465–481.

Tejada, M., Dobao, M. M., Benitez, C., & Gonzales, J. L. (2001). Study of composting of cotton residues. *Bioresource Technology, 79*, 199–202.

Tejada, M., Garcia, C., Gonzalez, J. L., & Hernandez, M. T. (2006). Use of organic amendment as a strategy for saline soil remediation: Influence on the physical, chemical and biological properties of soil. *Soil Biology and Biochemistry, 38*, 1413–1421.

Tenuta, M., & Lazarovits, G. (2002). Ammonia and nitrous acid from nitrogenous amendments kill the microsclerotia of Verticillium dahliae. *Phytopathology, 58*, 41–45.

Termorshuizen, A. J., Van Rijn, E., Van Der Gaag, D. J., Alabouvette, C., Chen, Y., Lagerlöf, J., Malandrakis, A. A., Paplomatas, E. J., Rämert, B., & Ryckeboer J Steinberg, C. (2006). Suppressiveness of 18 composts against 7 pathosystems: Variability in pathogen response. *Soil Biology and Biochemistry, 38*(8), 2461–2477.

Termorshuizen, A. J., van Rijn, E., van der Gaag, D. J., Alabouvette, C., Chen, Y., Lagerlöf, J., Malandrakis, A. A., Paplomatas, E. J., Rämert, B., Ryckeboer, J., Steinberg, C., & Zmora-Nahum, S. (2007). Suppressiveness of 18 composts against 7 pathosystems: Variability in pathogen response. *Soil Biology and Biochemistry, 38*, 2461–2477.

Thacker, B. (2007). *Management of byproduct solids generated in the pulp and paper industry*. In Presentation to EPA OSW Staff, Washington, DC, January 23, 2007. USAEPA, Washington DC, USA. pp. 18. Available at: http://www.epa.gov/wastes/conserve/imr/irc-meet/03-paper.pdf (Cited 12th Feb. 2010; verified 1st August, 2012).

Thangarajan, R., Bolan, N. S., Tian, G., Naidu, R., & Kunhikrishnan, A. (2013). Role of organic amendment application on greenhouse gas emission from soil. *Science of the Total Environment, 465*, 72–96.

Thomashow, L. S., Weller, D. M., Bonsall, R. F., & Pierson, L. S. (1990). Production of the antibiotic phenazine-1-carboxylic acid by fluorescent Pseudomonas species in the rhizosphere of wheat. *Applied and Environmental Microbiology, 56*, 908–912.

Tian, G., Kang, B. T., & Brussaard, L. (1992). Biological effects of plant residues with contrasting chemical compositions under humid tropical conditions decomposition and nutrient release. *Soil Biology and Biochemistry, 24*, 1051–1060.

Tilston, E. L., Pitt, D., & Groenhof, A. C. (2002). Composted recycled organic matter suppresses soil-borne diseases of field crops. *New Phytologist, 154*, 731–740.

Tiquia, S. M., Lloyd, J., Herms, D. A., Hoitink, H. A. J., & Michel, F. C., Jr. (2002). Effects of mulching and fertilization on soil nutrients, microbial activity and rhizosphere bacterial community structure determined by analysis of TRFLPs of PCR-amplified 16S rRNA genes. *Applied Soil Ecology, 21*, 31–48.

Tiyagi, S. A., Rizvi, R., Mahmood, I., & Khan, Z. (2015). Evaluation of organic matter, bio-inoculants and inorganic fertilizers on growth and yield attributes of tomato with respect to the management of plant-parasitic nematodes. *Emirates Journal of Food and Agriculture, 27*(8), 602.

Trankner, A. (1992). Use of agricultural and municipal organic wastes to develop suppressiveness to plant pathogens. In E. S. Tjamos, G. C. Papavizas, & R. J. Cook (Eds.), *Biological control of plant diseases* (pp. 35–42). New York: Plenum Press.

Tuitert, G., Szczech, M., & Bollen, G. J. (1998). Suppression of *Rhizoctonia solani* in potting mixtures amended with compost made from organic household waste. *Phytopathology, 88*, 764–773.

Twarog, S. (2008). East African Organic Product Standard and more. *The World of Organic Agriculture–Statistics and Emerging Trends*.

Vallini, G., Bianchin, M. L., Pera, A., & De Bertoldi, M. (1983). Composting agro-industrial byproducts. *Byocycle, 24*, 43–47.

Van Bruggen, A. H. C., & Finckh, M. R. (2016). Plant diseases and management approaches in organic farming systems. *Annual Review of Phytopathology, 54*, 25–54.

van Diepeningen, A. D., de Vos, O. J., Korthals, G. W., & van Bruggen, A. H. (2006). Effects of organic versus conventional management on chemical and biological parameters in agricultural soils. *Applied Soil Ecology, 31*(1), 120–135.

Van Elsas, J. D., & Costa, R. (2007). Molecular assessment of soil microbial communities with potential for plant disease suppression. In Z. K. Punja, S. H. Boer, & H. Sanfaçon (Eds.), *Biotechnology and plant disease management* (p. 498). King's Lynn: CAB International.

Van Elsas, J. D., & Postma, J. (2007). Suppression of soil-borne phytopathogens by compost. In L. F. Diaz, M. de Bertoldi, W. Bidlingmaier, & E. Stentiford (Eds.), *Compost science and technology* (pp. 201–204). Amsterdam: Elsevier.

Venkatakrishnan, D., & Ravichandran, M. (2013). Integrated nutrient management on sugarcane yield and yield attributes. *Plant Archives, 13*(1), 239–242.

Wang, R., Zhang, Y., Cerdà, A., Cao, M., Zhang, Y., Yin, J., Jiang, Y., & Chen, L. (2017). Changes in soil chemical properties as affected by pyrogenic organic matter amendment with different intensity and frequency. *Geoderma, 289*, 161–168.

Warren, K. S. (1962). Ammonia toxicity and pH. *Nature, 195*(4836), 47–49.

Weber, J., Karczewska, A., Drozd, J., Licznar, M., Licznar, S., Jamroz, E., & Kocowicz, A. (2007). Agricultural and ecological aspects of a sandy soil as affected by the application of municipal solid waste composts. *Soil Biology and Biochemistry, 39*, 1294–1302.

Weller, D. M., & Cook, R. J. (1983). Suppression of take-all of wheat by seed treatments with fluorescent pseudomonads. *Phytopathology, 73*, 463–469.

Weller, D. M., Raaijmakers, J. M., McSpadden, B. B., & Thomashow, L. S. (2002). Microbial populations responsible for specific soil suppressiveness to plant pathogens. *Annual Review of Phytopathology, 40*, 309–348.

Whitbread, A. M., Jiri, O., & Maasdorp, B. (2004). The effect of managing improved fallows of Mucuna pruriens on maize production and soil carbon and nitrogen dynamics in sub-humid Zimbabwe. *Nutrient Cycling in Agroecosystems, 69*(1), 59–71.

Whitman, T., Pepe-Ranney, C., Enders, A., Koechli, C., Campbell, A., Buckley, D. H., & Lehmann, J. (2016). Dynamics of microbial community composition and soil organic carbon mineralization in soil following addition of pyrogenic and fresh organic matter. *ISME, 10*(12), 2918–2930.

Willer, H., Yussefi, M., & Sorensen, N. (2010). *The world of organic agriculture: Statistics and emerging trends 2008*. London: Earthscan.

Williams, D. M., Blanco-Canqui, H., Francis, C. A., & Galusha, T. D. (2017). Organic farming and soil physical properties: An assessment after 40 years. *Agronomy Journal, 109*(2), 600–609.

Wortmann, C. S., Isabirye, M., & Musa, S. (2009). Crotalaria ochroleuca as a green manure crop in Uganda. *Field Crops Research, 61*(2), 97–107.

Xie, Z., Tu, S., Shah, F., Xu, C., Chen, J., Han, D., Liu, G., Li, H., Muhammad, I., & Cao, W. (2016). Substitution of fertilizer-N by green manure improves the sustainability of yield in double-rice cropping system in South China. *Field Crops Research, 188*, 142–149.

Yang, Y. J., Dungan, R. S., Ibekwe, A. M., Valenzuela-Solano, C., Crohn, D. M., & Crowley, D. E. (2003). Effect of organic mulches on soil bacterial communities one year after application. *Biology and Fertility of Soils, 38*, 273–281.

Yogev, A., Raviv, M., Hadar, Y., Cohen, R., & Katan, J. (2006). Plant waste–based composts suppressive to diseases caused by pathogenic *Fusarium oxysporum*. *European Journal of Plant Pathology, 116*, 267–278.

Yogev, A., Raviv, M., Hadar, Y., Cohen, R., Wolf, S., Gil, L., & Katan, J. (2010). Induced resistance as a putative component of compost suppressiveness. *Biological Control, 54*, 46–51.

Zaccardelli, M., De Nicola, F., Villecco, D., & Scotti, R. (2013a). The development and suppressive activity of soil microbial communities under compost amendment. *Journal of Soil Science and Plant Nutrition, 13*, 730–742.

Zaccardelli, M., Villecco, D., Celano, G., & Scotti, R. (2013b). Soil amendment with seed meals: Short term effects on soil respiration and biochemical properties. *Applied Soil Ecology, 72*, 225–231.

Zelenev, V. V., Van Bruggen, A. H. C., & Semenov, A. M. (2005). Short-term wavelike dynamics of bacterial populations in response to nutrient input from fresh plant residues. *Microbial Ecology, 49*(1), 83–93.

Zhang, W., Dick, W. A., & Hoitink, H. A. J. (1996). Compost-induced systemic acquired resistance in cucumber to Pythium root rot and anthracnose. *Phytopathology, 86*, 1066–1070.

Zhang, H., Ding, W., Yu, H., & He, X. (2015a). Linking organic carbon accumulation to microbial community dynamics in a sandy loam soil: Result of 20 years compost and inorganic fertilizers repeated application experiment. *Biology and Fertility of Soils, 51*, 137–150.

Zhang, Z., Zhao, J., Yu, C., Dong, S., Zhang, D., Yu, R., Wang, C., & Liu, Y. (2015b). Evaluation of aerobic co-composting of penicillin fermentation fungi residue with pig manure on penicillin degradation, microbial population dynamics and composting maturity. *Bioresource Technology, 198*, 403–409.

Zheng, J., Chen, J., Pan, G., Wang, G., Liu, X., Zhang, X., Li, L., Bian, R., Cheng, K., & Zheng, J. (2017). A long-term hybrid poplar plantation on cropland reduces soil organic carbon mineralization and shifts microbial community abundance and composition. *Applied Soil Ecology, 111*, 94–104.

Zhao, Y., Wang, P., Li, J., Chen, Y., Ying, X., & Liu, S. (2009). The effects of two organic manures on soil properties and crop yields on a temperate calcareous soil under a wheat–maize cropping system. *European Journal of Agronomy, 31*(1), 36–42.