

Rizwan Ali Ansari · Irshad Mahmood
Editors

Plant Health Under Biotic Stress

Volume 1: Organic Strategies

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Rizwan Ali Ansari
Section of Plant Pathology
and Nematology, Department of Botany
Aligarh Muslim University
Aligarh, Uttar Pradesh, India

Irshad Mahmood
Section of Plant Pathology
and Nematology, Department of Botany
Aligarh Muslim University
Aligarh, Uttar Pradesh, India

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Preface

In order to understand the plant fitness entirely, it is high time for researchers to relinquish the obsolete theories and must unravel unexplored aspects pertaining to plant health. The book “Plant Health Under Biotic Stress” is being published in two volumes to provide the articulated, justified, and updated information which are either directly or indirectly related to soil and plant health. Plant Health Under Biotic Stress – Volume 1 (Organic Strategies) flashes light on the key literature related to application of organic matters including phytoextracts, chopped leaves, composted organic manures, and liquid manures in eco-friendly agriculture. The mechanisms underlying the effectiveness of these organic amendments in promoting plant health has also been presented and discussed in understandable ways. Although most of the chapters of volume 1 are limited to organic and their applications in the management of biotic/pathogens stress, however, some chapters related to actinobacteria have also been included just to widen the horizon of our understandings. We hope this book will be useful to advisers, extension officers, educators, and advanced researchers who are concerned about the protection of environment and plant health.

A sincere acknowledgment is extended to Prof. Tariq Mansoor, Hon’ble Vice Chancellor, Aligarh Muslim University, Aligarh, India, for being a constant source of inspiration for the researchers.

Prof. Akhtar Haseeb, Ex-Vice Chancellor, Narendra Deva University of Agriculture & Technology, Kumarganj, Faizabad, India; Prof. Saghir A. Ansari, Dean, Faculty of Agricultural Sciences; Prof. M. Yunus Khalil Ansari, former Chairperson, Department of Botany; Prof. Nafees A. Khan, Chairperson, Department of Botany; Prof. Mujeebur Rahman Khan, Chairperson, Department of Plant Protection; Prof. Zaki A. Siddiqui; Prof. Iqbal Ahmad; Prof. A. Malik; Prof. M. S. Ansari; Prof. M. Haseeb; Prof. S. Asharf; and Dr. R.U. Khan of Aligarh Muslim University, Aligarh, India, deserve special thanks for providing us critical suggestion during the write-up of this book.

This book would have remained just a dream if Dr. Rose Rizvi has not come and taken up each hurdle translating it into an enjoyable moment. She assisted us from onset of this journey and therefore indeed deserves to be acknowledged with great

appreciation. In addition, Dr. Sartaj A. Tiyagi, Dr. Safiuddin, Dr. Aisha Sumbul, Mr. Hari Raghu Kumar, and Ms. Aiman Zafar were constantly surrounded with us whenever we felt like giving up – sincere thanks to all of them.

Editors would have not completed this task without endless support, prayers, and encouragements of their elders during light and dark situations.

We can never forget our “little doctor,” Mr. Ayan Mahmood, who used to practically look up and smile at us with two lovely and twinkling eyeballs, each time muttering words of comfort and encouragement.

We hope that our efforts to forward the readers toward the better state of plant science shall be fruitful.

Aligarh, India

Rizwan Ali Ansari
Irshad Mahmood

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About the Editors



Dr. Rizwan Ali Ansari is a young and active member of the Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India. He obtained his PhD from the same university and has been involved in the research and development strategies of plant pathology/nematology. He has been engaged in the formulation of management modules involving various microorganisms, antagonists and organic additives active against a wide range of soil-borne plant pathogens infesting several agricultural crops. He has also attended several national and international conferences so far and received prestigious awards by various scientific societies like the Society of Plant Protection Sciences (SPSS) and Nematological Society of India (NSI) for his outstanding contribution in the field of plant pathology/nematology. He has published several book chapters, research and review articles pertaining to the utility of organic additives, mycorrhizal fungi as well as plant growth-promoting bacteria in the sustainable management of plant pathogens in various journals/books of great repute. Judicious application of organic additives and biological agents in the management of plant diseases, amelioration of soil and crop health and survey on disease prevalence caused by soil-borne pathogens on various economically important crops are the current research domain of Dr. Ansari.



Dr. Irshad Mahmood is working as a Professor of plant pathology and nematology in the Department of Botany, Aligarh Muslim University, Aligarh. He obtained his PhD from Aligarh Muslim University in the field of plant pathology and nematology. Promotion of organic farming across the world by utilizing organic additives and potent microorganisms for the sustainable management of phytoparasitic nematodes and plant pathogenic fungi resulting to augment soil and plant health is the domain of his research. He has been engaged with teaching programme of undergraduate and postgraduate-level students for the last 30 years and has many overseas visits including the United States, France and the United Kingdom. He has attended a significant number of national and international conferences pertaining to wide area of agricultural sciences and published around 150 original research papers, review articles and book chapters in various refereed national and international publication media, most of them in very high impact factors. He has successfully completed many training courses in various ICAR-sponsored research institutes in India and also in North Carolina State University, Raleigh, USA. He is also an active member of national and international scientific organizations; an expert for selection committee; a reviewer of journals, doctoral theses and funding agencies; and a recipient of Scientist of the Year award in the field of plant pathology and nematology. He has guided ten PhDs, several MPhil and a large number of MSc dissertations. He has also been engaged in the establishment of a joint government project with Aligarh Muslim University for improvement of infrastructural facilities in botanical garden to facilitate ex situ conservation and propagation of rare, endangered and threatened plants and the plants endemic to the region.

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

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 phyto-

pathogenic 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 CO₂ and wide spectrum of organic compounds, while anaerobic decompositions begin in the stored manures. In the absence of free oxygen, the organic inputs are converted to C compound having low molecular weight chiefly volatile organic substances and eventually CH₄ is released (Lazarovits 2001). In addition to these organic C and volatile substances, breaking down of the proteins may lead to the generation of H₂S. 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](https://www.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; Razaq 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; Alsanusi 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 $\text{NH}_4^+\text{-N}$ 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 CO₂ 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 (Buraue 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