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Bio-compost Application for Controlling Soil-borne Plant Pathogens – A Review

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Abstract*- Control of soil borne pathogens is difficult because these pathogens survive for many years as sclerotia in soil or as mycelim in organic matter under several environmental conditions. Control of plant diseases has commonly relied on culture practices and on the use of fungicidal treatments However, culture practices alone are not efficient and at the present time. Chemical control was massively applied, however, for the increasing public concern over the fungicides usage. Recently, alternative control methods are strongly desired for sustainable agriculture. Organic amendments play an important role as environmentally friendly and sustainable alternative approach to protect plants against soil borne pathogens. Soil amendments, using composted agricultural wastes fortified with bio control agents could be acceptable approaches in this regard. The use of organic agricultural wastes in this respect can be an advantageous both in soil fertility, recycling of agricultural residues and could provide a powerful tool for management of plant diseases.

***Index Terms*-bio compost, compost tea, plant health, plant diseases control, soil borne pathogens,**

I. INTRODUCTION

Plant pathogens are responsible for many acute and chronic diseases of crop plants that can result in severe losses for growers. Economic losses to soil borne pathogens are estimated at 50-75% of the attainable yield for many crops. Yield failures resulting from acute diseases such as vascular wilts, root rot and damping-off may be even more severe and have destroyed entire agriculture industries. About 90% of the 2000 major diseases of the principle crops in the US are caused by soil borne plant pathogens [1]. The vegetable crops losses due to diseases in Georgia, USA were estimated by [2] as about 42.8 $ million. Moreover, plant disease continue to cause severe damage to most agricultural crops during different stages of plant growth resulting in heavy losses of both yield and quality. Considering the regularity with which most serious diseases of crop plants appear in an area year after year, the rapid spread of most plant disease, and the difficulty of curing a disease after it has begun to develop, it is easy to understand why almost all control methods are aimed at protection plant from becoming diseased rather than at curing them after they have become diseased. As a matter of fact, few infectious plant diseases can be satisfactory controlled in the field by therapeutic means, although certain diseases can be cured under managed environmental conditions. Prevention plays a very important role in disease control. But even with the best of preventive programs, disease organisms will get a foothold in the greenhouse. Some disease organisms are transmitted in soil or groundwater and then are carried in on the bottom of a pot or the sole of a shoe. Numerous pathogens are readily transported on these plant materials. Knowing the inevitability of disease, the manager must be careful to check daily for its presence in the same manner that he or she watches for insects and checks the need for water. The value of IPM pertains equally well to disease control [3,4]. As control measures, some cultural practices, *i.e.* crop rotation, sowing date, fertilizers and irrigation were tried by many investigators but they failed to provide satisfactory control against plant pathogens [5]. Regarding chemical control, the phytopathogens are not sensitive to selective pesticides as most pesticides have its own mode of action [6,7]. While many soilborne diseases have been controlled, in part, by use of chemical pesticides, alternatives to the use of chemicals would be of value. Plant associated microbes used as biocontrol agents can play a role in reducing losses to such diseases, thus assuring a more sustainable agriculture and the long term ability of our land to produce food. Biological control should play a major role in reducing the population of plant pathogens with management systems [8]. Soilborne plant pathogens attacking host plant roots, later in the season, causing much damage to the plants. Such control is inadequate for agriculture. Antagonistic microorganisms have been suggested as one of several possible means for controlling plant pathogens without any damage to the host plant. Antagonists considered as a potential cost-effective means for reducing population of plant pathogens in soil [9]. Biological control of plant pathogens with antagonists has been the subject of numerous reviews and several books. Promising antagonists that may be useful for controlling soilborne plant pathogens were also reported [10]. Biocontrol involves harnessing disease-suppressive microorganisms to improve plant health. Disease suppression by biocontrol agents is the sustained manifestation of interactions among the plant, the pathogen, the biocontrol agent, the microbial community on and around the plant, and the physical environment. Even in model laboratory systems, the study of biocontrol involves interactions among a minimum of three organisms. Therefore, despite its potential in agricultural applications, biocontrol is one of the most poorly understood areas of plant-microbe interactions. So far, plant diseases control research in the last twenty years has contributed to better understanding of biology, host-parasite relationships and control of plant diseases by chemical pesticides, plant resistance inducers and biocontrol microorganisms. These research achievements should be exploited for the development of novel control methods. Maintaining equilibrium between the pathogen

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population and its hosts by constant supply of a biocontrol agent that will keep disease to a minimum. One of the main procedures used in the research of biologically active substances is using compost for controlling soilborne plant pathogens and increasing the soil fertility as well. The suppressive activity of different compost types toward several plant pathogens is well documented in the recent review by [11]. Further, the investigation on the biological activity of these materials on antagonistic soil-borne fungi is of great interest, in that their contribution to biological control should be safeguarded. Very few information is reported in the literature on the suppressive effects of soil native humic substances (HS) and HS-like fractions on phytopathogenic fungi and also no information is reported on antagonistic soil-borne fungi. Although some information is available on the mechanisms responsible for the suppressive action of compost and compost extracts on plant pathogenic fungi [11] very limited information exists on the relationship between chemical properties of HS and HS-like fractions and fungal suppressive capacity. The present review focused on the use of composts, against soilborne pathogens and plant disease incidence and severity in agricultural crops.

II. COMPOST PRODUCTION AND ITS USE IN SUSTAINABLE FARMING SYSTEMS

The growth of the organic industry over the last decade as well as widespread recognition of the need to use practices that regenerate agricultural resources have inspired farmers to seek out alternatives to conventional methods of soil fertility management. As a result, farmers and researchers alike have tweaked and improved composting on all scales from small piles for garden use to industrial windrows for municipal and agricultural waste management. Unlike traditional manure or farmyard waste stockpiling, composting is the active management of organic waste to optimize conditions in the pile, leading to rapid decomposition with as little loss of nutrients as possible. By ensuring that microorganisms have enough water and oxygen, and a balance of C to N, farmers and nursery-owners can turn organic waste into a valuable soil amendment.

III. COMPOST AND COMPOST TEA

Solid compost prepared from remain stocks high in C, such as yard waste, wood chips, straw, or dry stalks, mixed with materials high in N, such as manure, freshly cut grass, plant residues, or food wastes. There are many types of compost based on the raw materials used, e.g. ornamental, cotton, maize, rice, wheat sugarcane bagasse (industrial wastes of sugarcane) and other plants as well as domestic residues. Meanwhile, compost tea, in modern terminology, is a compost extract brewed with a microbial food source. molasses, kelp, rock dust, humic-fulvic acids. The compost-tea brewing technique, an aerobic process, extracts and grows populations of beneficial microorganisms. Compost teas and herbal teas are tools that can be made on the farm to enhance crop fertility and to inoculate the phyllosphere and rhizosphere with soluble nutrients, beneficial microbes, and the beneficial metabolites of microbes. There are many types of compost tea such as Manure Tea (Manure-based extracts); Herbal Tea (Plant-based extracts) and Liquid Manures (Mixtures of plant and animal byproducts seeped as an extract, stinging nettle, comfrey, seaweed, fish wastes, fish meal). The difference between the use of soil-applied composts and watery compost extracts can perhaps best be summarized in that the teas give immediate but very short-term control of surface spreading pathogens, while soil composts act more slowly over a longer period of time and require much larger amounts. For long term effects in solid media, it is not unusual that at very least 5% by volume and often as much as 40% compost in the seedling mix are required to bring about effective disease control [12].

IV. LABORATORY ASSESSMENT OF THE COMPOST POTENTIAL AND ITS HUMIC ACID FRACTION AGAINST SOILBORNE PATHOGENIC FUNGI

The partial and moderate replacement of traditional potting substrates with compost would achieve not only various economic and environmental benefits, such as a reduced use of chemical pesticides and a preservation of peat bogs, but also the added value of controlling pathogenic fungi and promoting the growth of ornamental plants. Both aspects are very important in sustainable agriculture. The organic fraction is the main component of commercial growing substrates, and is demonstrated to be the major factor responsible for their disease-suppressive properties. A limited number of studies report a significant action of humic fractions (HS) in the growth inhibition of different fungal species [13,14,15,16]. Recently, a significant effect of HS from soil and composts has been demonstrated on the mycelial growth and conidial germination of two formae speciales of *Fusarium oxysporum* [16], and on the growth and sclerotial formation of Sclerotinia sclerotiorum and two antagonistic Trichoderma species [16]. The mechanisms by which composts and their humic fractions inhibit plant pathogens are not fully understood, although recent studies showed a significant relationship between the chemical and functional properties of HS and their capacity to suppress soil pathogenic fungi [15,16]. Recently, study of [17] investigated the possible capacity of various plant growth substrates and, especially, their humic fraction to inhibit the growth of two common pathogenic fungi, with the aim of using them as an environmentally safe alternative to pesticides. A series of bioassays were designed in the laboratory and in phytotron chamber to test the effect of humic acids (HAs) isolated from different potting substrates, at two concentrations, on the growth *in vitro* of fungal mycelium of *Pythium ultimum* and *Fusarium oxysporum* f. sp. *callistephi*. They found that a general decrease of the radial growth of the mycelium of two fungi

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was observed throughout the experimental time with a maximum inhibitory effect after 24 h from inoculation. They conclude that The HA fractions isolated from a compost and its mixtures with peat or coconut fiber exhibited a general suppressive activity, especially at the higher dose, against two plant pathogens examined in *in vitro* experiments. In conclusion, the results of this study are in favour of the recent trend of using compost in peat-based potting mixtures confirming the related economical and environmental advantages. In another research [18] five commercial composts were evaluated to suppress the root-rot pathogens (*Fusarium solani* (Mart.) App. and Wr, *Pythium ultimum* Trow, *Rhizoctonia solani* Kuhn, and *Sclerotium rolfsii* Sacc.) of cucumber plants under *in vitro* conditions. They found that all tested un-autoclaved and un-filtrated composts water extracts had inhibitor effect against pathogenic fungi, compared to autoclaved and filtrated ones. Also, the inhibitor effects of 40 bacteria and 15 fungi isolated from composts were tested against the mycelial growth of cucumber root-rot pathogens. Twenty two bacteria and twelve fungal isolates had antagonistic effect against root-rot pathogens. The antagonistic fungal isolates were identified as 6 isolates belong to the genus *Aspergillus* spp., 5 isolates belong to the genus *Penicillium* spp. and one isolate belong to the genus *Chaetomium* spp.

V. FIELD APPLICATION OF COMPOST AGAINST SOILBORNE PATHOGENS

In recent decades, a number of investigations have demonstrated the effectiveness of composts of various origins in suppressing soil-borne plant pathogens [11,14, 19,20, 21,22], and their application to soil has been proposed to control many different diseases. However, not all composts have been shown to exert beneficial effects on plant growth and health. Moreover, organic amendments play an important role as environmentally friendly and sustainable alternative approach to protect plants against soil borne pathogens. Soil amendments, using composted agricultural wastes fortified with bio control agents could be acceptable approaches in this regard. The use of organic agricultural wastes in this respect can be an advantageous both in soil fertility, recycling of agricultural residues and could provide a powerful tool for management of plant diseases. It has been reported that several composts and/or composts fortified with bio control agent used as soil amendments reduced pathogens propagules density and protected plants from soil borne plant pathogens [23,24,25]. Using agricultural wastes, domestic food wastes or some grains as substrates for *T. harzianum* growth formulation and directly delivery in soil for controlling soil borne pathogens on some crops were recorded [26,27,28]. Amendment of compost with *Trichoderma harzianum* also was reported to accelerate agricultural wastes composting and improved its diseases suppressive effect [29,30,31,32,33,34]. In this regards, several researchers have been recorded that bio compost application as soil amendment could suppress diseases caused by *R. solani* and Fusarium spp. on many economic crops [26,27,32]. Using agricultural wastes, domestic food wastes or some grains as substrates for *T. harzianum* growth formulation and directly delivery in soil for controlling soil borne pathogens on some crops were also recorded [26,27,32]. Such means comprise elimination of pathogens density in the soil and maintaining soil condition, favorable for root development and enhancement the competitive ability of bio agents against pathogens. Therefore, these methods introduced efficient disease control and increasing yield of many crops [23,24,35,36,37]. Also, [34] found that amended soil around stems of diseased mandarin trees by bio compost (BCAW) and Topsin-M (1g/L) treatments as twice applications per season resulted in recovering great number of diseased trees and decreased the disease severity on others. Population density of *Fusarium* spp. was highly decreased, where population density of *Trichoderma* spp. was increased in rhizosphere soil of treated trees by bio compost (BCAW). Control of root rot pathogens through amended soil with organic materials formulated with bio-control agents may be attributed to : i) increasing the activity of indigenous micro flora resulting in suppression of pathogens population through competition or specific inhibition, ii) releasing degradation compounds such carbon dioxides, ammonia, nitrites, saponine or enzymes which are generally toxic to the pathogens, iii) inducing plant defense mechanisms, iv) cellulose and glucanese are prevalent to high concentration in soil as a result of biodegradation of cellulose and lignin [27,29,38]. Also, results of a s field study [39] indicate that both antagonistic bacteria *B. subtilis* and *P. fluorescens* alone or in combination with compost significantly reduced the peanut crown rot during two growing seasons. The most effective treatments were compost combined with *B. subtilis* or *P. fluorescens*. They conclude that this observation could be attributed to accumulation and survival of introduced bio-agents and compost to the cultivation soil at the first growing season. In this regard, several investigators studied survival and activity of introduced bio-agents to cultivation soil. Long term antagonistic ability against soil borne pathogens for over one cultivation season through mixing bio-agents with cultivation soil was recorded [40]. Also, it was reported that temporal population dynamics and survival of antagonists are relevant for the management of disease epidemic cycles arising from amplification of pathogen inoculum. Facultative parasites are capable of saprophytic multiplication, even in the absence of a crop, hence increasing the amount of primary inoculum, which may aggravate disease epidemics in future crops [41]. Furthermore, [42] studied the introduced *Trichoderma atroviride* SC1 was into soil in two consecutive years. They conclude that one year after soil inoculation, *T. atroviride* SC1 could still be recovered in the treated areas. Moreover, [43] studied the survival of two bacterial strains in two soils of different texture cropped with wheat. They

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found that *B. subtilis* populations declined rapidly in both soils and then stabilized at the levels of added spores. Meanwhile, *P. fluorescens* showed a slow, steady decline in both soils, survival was better in the finer-textured soil, a silt loam, than in the coarser loamy sand. For both bacteria, some translocation to deeper soil layers was observed. The best survival of *B. subtilis* MBI 600 occurred as spores in sterilized soil, and spore applications to pasteurized soil in an integrated control strategy may allow sufficient establishment of the bio-control agent to target pathogens causing damping-off [44]. On the other hand, the incidence of several soil-borne plant pathogens have also been reduced by using composts made of different raw materials [19,45,46,47]. Since [48] first suggested compost could be used as a peat substitute to control root pathogens, bio-control research has increasingly focused on developing the right combination of composts and antagonistic microbes. *Trichoderma* in combination with composts from agricultural waste was used to suppress *Rhizoctonia solani* in cucumber seedlings [49], and *Trichoderma* sp. and sewage sludge compost were used to suppress Fusarium wilt of tomato [50]. Currently it is believed that a combination of antagonistic microbes with mature compost may be more efficient in inhibiting disease than using single antagonistic microbial strains or compost alone [50, 51,52]. Furthermore, the effect of *T. harzianum* and some essential oils alone or in combination with compost on the peanut crown rot disease under field conditions was evaluated [53]. They reported that under field conditions, results indicated that all treatments significantly reduced the peanut crown rot disease. The highest reduction was obtained with combined treatments (compost + *T. harzianum* + thyme and compost + *T. harzianum* + lemongrass) which reduced the disease incidence at both pre- and post-emergence growth stages, respectively. They suggested that combined treatment between biocompost and essential oils might be used commercially for controlling peanut crown rot disease under field conditions. On the other hand, several investigators conducted with applying physical and biological control measures as fungicides alternatives against soilborne plant pathogens. Therefore the efficacy of soil mulching and/ or bio compost (compost fortified with bio control agents) for managing of the major fungal root pathogens of tomato plants under field conditions were also investigated. Currently, it is believed that a combination of antagonistic microbes with mature compost may be more efficient in inhibiting disease than using single antagonistic microbial strains or compost alone [45,49,51]. With the knowledge of the adverse effects of synthetic fungicides worldwide, attention is rapidly, being shifted to non-synthetic, safer alternatives. In this concern, [54] focuses their study to find compounds that are safe to humans and the environment. An alternative to pesticide application is that, it may be possible to utilize a scheme which may provide protection against a broad spectrum of disease-causing pathogenic microorganisms. They found that that all treatments (soil mulching and /or bio compost) significantly reduced tomato diseases incidence and severity of grown tomato plants comparing with untreated control. Moreover, soil mulching in combination with bio-compost and *T. harzianum* treatments significantly reduce the incidence of root rot, crown and root rot and wilt disease incidence and severity in treated soil comparing with untreated soil (control). The population density of *Fusarium* spp. was decreased in mulched soils at the end of experimental period. However, soil solarization was more effective in reducing the pathogen's population either alone or combined with bio compost treatment. Similar results have been reported by [55]. They stated preliminary findings on the application of *Trichoderma harzianum* and *Bacillus megaterium* evaluated as multiple applications for the control of Phytophthora root rot of avocado seedlings in the greenhouse. These antagonists were also applied in various combinations with composted citrus waste and soil solarization in young avocado orchards to evaluate their effect on trees. Multiple applications were made with the purpose of simulating continuous application of antagonists through the irrigation system, in contrast with single application of bio-control agents. Multiple applications of *T. harzianum* eliminated the effect of Phytophthora in the greenhouse, whereas *B. megaterium* was ineffective. In the field, the best effect on plant growth was obtained with *T. harzianum* in combination with solarization, followed by application of 4kg composted citrus waste per tree. Also, the long term efficacy of *T. harzianum* and *P. fluorescens* alone or in combination with compost for controlling bean root rot disease in solarized or un-solarized soil under field conditions were studied [56]. They found that the pronounced applied treatments throughout two successive growing seasons were compost A (animal waste) combined with *T. harzianum* or *P. fluorescens*, followed by compost P (agriculture waste) combined with the same bioagents in solarized soil which they reduced the root rot disease at pre-, and post-emergence growth stages, respectively. Referring to the obtained results in the present study, it could be suggested that combined treatment between compost and bioagents as safety method might be used commercially for controlling bean root rot disease under field conditions.

VI. COMPOST AND PLANT HEALTH

Composts are made of various types of feed stocks, so they vary in chemical and physical composition. A report of [57] stated that although composts are sources of important nutrients, a crop may not get all of the nutrients it needs from compost alone. On average, compost contains between 0.5 and 2 percent N. If the compost C:N is less than 15, only a fourth to a half of the N may be released from its organic form over the growing season. Rather than thinking of compost as a fertilizer, think of it as a soil conditioner that can improve the physical, chemical, and microbial properties of soil. Microbes transform organic nutrients into forms available for uptake by plants, and they can reduce soil borne plant diseases. Fungi and rhizobacteria are effective as bio-control agents in a number of ways. They can out-compete plant pathogens for resources and promote the growth of a plant or boost its resistance to attack from disease. Some microbes in compost have antibiotic properties that can actually destroy harmful microbes in the soil. Increases in organic matter also attract larger soil organisms, such as earthworms, that help degrade crop residues, release nutrients, and improve infiltration. Some investigators indicated that addition of organic manures as opposed chemical fertilizers increased vegetative growth characters, yield and fruit quality of vegetable crops [58,59,60,61,62]. On squash, [58] showed that plants had increased yields when planted in municipal solid waste compost amended soil in spite of application of NPK fertilizers at recommended rates. On pepper, [59] stated that early and total yields of all organic sources were significantly higher than that of chemical fertilizer. In the same line on cucumber, [62] found that organic treatment (compost) produced significantly greater early yield (1.85 kg/m2) and total yield (4.49 kg/m2) than chemical treatment which produced 1.38 kg/m^2 and 3.51 kg/m^2 for early and total yields, respectively. Organic fertilizers are claimed to produce higher nutritional quality of vegetables in forms of vitamin C, TSS, dry matter and acidity [60,63,64]. For nitrate content, [65] found that nitrate content in tomato fruits was lowest in the organic system and highest in the conventional system as the differences were highly significant. Similar trend corresponding to the combined treatments (compost + *T. harzianum* + thyme and compost + *T. harzianum* + lemongrass) significant increase in peanut yield calculated more than 75.0 and 80.0 during two growing seasons, respectively [53]. Also, some of plant morphogenesis, *e.g.* averages of plant height, number of branches/plant showed significant increase in tomato plants grown in mulched soil with biocompost and bioagent application [54]. They added that there was a significant effect of the soil mulching and bio compost treatments on the quantitative parameters, *i.e*. No. of fruits/ plant, fruit weight plant (kg), fruit weight (g) and total yield Fadden (t) of tomato fruit yield. On the light of obtained results in the present study, it could be suggested that combined treatment between biocompost and essential oils might be used commercially for controlling tomato crown rot disease under field conditions. As for bean yield the highest increase was obtained at combined treatments of compost A (animal waste) and *T. harzianum* or *P. fluorescens*, followed by combined treatments between compost P (agriculture waste) and *T. harzianum* or *P. fluorescens* in solarized soil [56]. The favorable effect of organic treatments on vegetative growth, especially at the early stage of plant growth may be due to that compost made from bio solids contains almost all of the macro- and micro-nutrients essential for plant growth, in addition to humic substances which increased soil fertility and cation exchange capacity, thus increased the availability of certain nutrients [66]. Also, applying compost improved physical conditions of soil, providing energy necessary for microorganisms activity and increasing the availability and uptake of nutrients, which positively reflected on vegetative growth [64,67, 68,69]. The stimulation of plant growth by using compost + compost tea or seaweed extracts may be attributed to the combined effect of compost, compost tea (which contains humic acids, vitamins, amino acids and both of macro and micro nutrients which enhanced cucumber growth) and seaweed extracts which contains some growth regulators such as cytokinins [70], auxin [71] and gibberellins [72].

VII. CONCLUSION

Despite apparent advances in physical and biological control as a reliable strategy for plant diseases management, little progress has been made in developing tactics for practical application in agro-ecosystems, especially those involving cropping systems. Efficacious strategies that target multiple various plant pathogens are needed. Best success in achieving this may well involve selection of several “core strains” of agents that are adapted to soils and climates in specific regions and are able to suppress growth of soil borne pathogens comprising the dominant species at that site. To gain acceptance of these strategies, integration of biological control into current management systems is imperative so that the potential effectiveness of the agents can be demonstrated. Biocompost targeted for niche markets and their use in sustainable agricultural systems will likely demonstrate the greatest effectiveness in plant diseases management in the short term. This will generate impetus for continued discovery and development of biocompost for more widespread use. From a plant diseases management standpoint, the integration of multiple tactics, including a diversity of potential compost and biologically-based approaches, favors the effectiveness and stability required for long-term plant diseases management. The integration of biological control into current systems also offers augmentative control options, as pesticides use becomes more restricted. It is well known that continued use of single pesticide control tactics favors resistance development in certain plant pathogens populations and conventional cropping systems. Biocompost technology used in appropriate integrated plant diseases management in diversified cropping systems may aid in restoring fertility and productivity to degraded ecosystems and avoid the buildup of pesticide resistant and invasive pathogens. Biocompost appropriately integrated in agricultural and environmental restoration systems can play a major role in reclaiming and restoring biodiversity to ecosystems degraded through continuous implementation of conventional cropping systems. Situations in which environment quality are restored in

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both ecologically sound farming systems and native habitats will benefit from the use of effective bio compost.

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