HARNESSING VERMICOMPOST FOR EFFECTIVE PLANT DISEASE MANAGEMENT

Kartikay Bisen, Vinay J Silas, Aneeta Yadav

Faculty of Agricultural Sciences and Allied Industries, Rama University, Kanpur-209217

Corresponding Author Email: kartikaybisen.fas@ramauniversity.ac.in

Abstract

Vermicompost, the product of the decomposition of organic matter by earthworms, has emerged as a promising solution for plant disease management. This organic amendment not only enhances soil fertility and structure but also contributes to the suppression of plant pathogens through various mechanisms. Vermicompost is rich in beneficial microorganisms, including bacteria, fungi, and actinomycetes, which compete with and inhibit the growth of plant pathogens. It also contains bioactive compounds such as enzymes, antibiotics, and hormones that bolster plant immune responses and directly antagonize pathogens. Furthermore, vermicompost improves soil physical properties, promoting healthy root growth and reducing the susceptibility of plants to diseases. Research has demonstrated significant reductions in disease incidence and severity in crops treated with vermicompost, highlighting its potential as an eco-friendly, sustainable alternative to chemical pesticides. This paper reviews the current knowledge on the role of vermicompost in plant disease management, elucidating its mechanisms of action, benefits, and potential applications in integrated pest management strategies.

Introduction

Vermicomposting, the process of using earthworms to decompose organic waste, produces a nutrient-rich organic amendment known as vermicompost. This method not only offers an environmentally friendly way to manage organic waste but also generates a valuable product that enhances soil health and fertility. Vermicompost is distinguished by its high microbial activity and a diverse array of beneficial microorganisms, which are key contributors to its effectiveness as a soil amendment. The benefits of vermicompost are multifaceted. Firstly, it significantly improves soil structure, aeration, and water retention capacity, creating an optimal environment for plant roots. The rich nutrient profile of vermicompost, which includes essential macro and micronutrients, enhances plant growth and yields. Furthermore, vermicompost is known to promote seed germination, root development, and overall plant vigor.

In addition to its agronomic benefits, vermicompost plays a crucial role in plant disease management. The beneficial microorganisms in vermicompost, such as bacteria, fungi, and actinomycetes, help suppress plant pathogens through competitive exclusion, antibiosis, and induced systemic resistance. These microorganisms also produce bioactive compounds, including enzymes, antibiotics, and hormones, that bolster plant defenses and directly antagonize harmful pathogens. Research has shown that incorporating vermicompost into soil or as a part of potting mixes can reduce the incidence and severity of various plant diseases. This makes vermicompost a valuable component of integrated pest management strategies, offering a sustainable and eco-friendly alternative to chemical pesticides. In summary, vermicompost is not only an effective organic fertilizer but also a powerful tool for enhancing plant health and disease resistance. This introduction sets the stage for exploring the mechanisms through which vermicompost contributes to plant disease management and its broader implications for sustainable agriculture.

Application of Solid Vermicomposts in Plant Disease Management

Over the past two decades, considerable increase in experiments has occurred that proved the efficacy of vermicompost products in suppression of various phytopathogens (Edwards 1998). Solid vermicomposts has been regularly used in laboratory, greenhouse, and field against various pathogens such as *Fusarium*, *Pythium*, *Rhizoctonia*, *Phytophthora* and *Verticillium*. Vermicomposts produced from various waste including animal manures, dairy solids, cattle manure, sewage sludge showed potential to suppress phytopathogens in field condition including Phytophthora nicotianae, *Fusarium oxysporium* f. sp. *lycopersici* and *Rhizoctonia solani*. Edwards and Arancon (2004) successfully control the attack of *Pythium* in cucumber, *Rhizoctonia* in radish, *Phomopsis* in grape and *Verticillium* in strawberries in green house and field conditions.

Earlier solid vermicompost was only tested for the root disease of plants caused by the fungal species where plant growth media was replaced by which solid vermicomposts in order to evaluate their ability to suppress soil-borne fungal pathogens (Szczech et al., 2002; Szczech and Smolinska, 2001). Vermicompost produced from cattle manure have shown highest ability to suppress soil borne pathogenic fungi in comparison to vermicompost produced from various animal manures (Szczech et al., 2002). Reduction in *Fusarium oxysporum* and *P. nicotianae* infection in tomato was recorded when vermicompost was added to container media. The vermicomposts produced from cattle manure protected about 52% more plants in comparison to the control peat medium (Szczech et al., 2002).

Szczech and Smolinska (2001) reported the reduction in *Phytophthora infestans* infection in potato plants when grown in soil and vermicompost mixture while plants grown in inorganic fertilizers showed high susceptibility to disease. In addition to reduction in disease incidence in field, potato tuber harvested from vermicompost treated plant showed less loss in storage condition due to dry and wet putridity that controls. Inhibition of *P. nicotianae*, *P. brassicae* and *Fusarium lycopersici* in tomato crop was recorded with vermicompost applications (Edwards et al., 2004; Nakamura, 1996). Furthermore, vermicomposts produced from industrial and household waste were evaluated for their disease suppression ability. Szczech and Smolinska (2001) conducted a comparative experiment to verify the disease suppression potential of vermicomposts produced from sewage sludge and animal manures against tomato root rot caused by *P. nicotianae*. Vermicompost produced from sewage sludge decreased the population density of tested pathogen but they were not suppressive against P. nicotianae. Concentration of zinc in the vermicompost was suggested as a reason for decrease in the population density of *P. nicotianae*. However, vermicompost from animal manures failed to decrease the *P. nicotianae* population in pot but they successfully suppress the disease suggesting their effect against the pathogen as fungistatic rather than fungitoxic. The fungistatic effect of vermicomposts produced from urban wastes against *P. nicotianae* was reported by Widmer et al. (1998). Soil amended with vermicompost has successfully reduced the *P. nicotianae* infection in citrus seedlings there was no effect on the population of pathogen in the soil.

Vermicompost when incorporated in growth media suppressed the growth of *Phytophthora drechsleri*, *R. solani* and *F. oxysporium* (Rodrı´guez-Navarro et al., 2000). Incorporation of 10-30 % vermicompost in seed bed soil resulted in significant reduction in disease incidence by *Pythium* and *Rhizoctonia* in radhish in green house (Chaoui et al., 2002). Incorporation of vermicompost at small quantity (10 % by volume) in seed bed provided disease suppression on *Pythium*; however, the largest substitution rate (40 % by volume) also sustained suppression of *Rhizoctonia*. They reported the presence of *Trichoderma* spp. in vermicompost. Chaoui et al. (2002) also reported the disease suppression potential of vermicompost against *Verticillium*, *Phomopsis* in strawberries and grapes in field condition respectively. They stated that the sterilized vermicompost did not show any disease suppression ability, supporting the microbial antagonism as biological mechanism of disease suppression. Edwards (1998) stated that earthworms promote diversity and activity of micro flora in organic wastes and proved to have more potential for disease suppression than aerobic composts. This quality may be attributed to the stimulatory effects of earthworms on soil microbial activity. Disease suppression ability of three composts including green house waste, vermicompost dairy solid and windrow solid was evaluated against *P. aphanidermatum* and *F. oxysporum* f.sp. *radicis-cucumerinum*. Vermicompost prepared from dairy solid showed maximum disease suppression (Punja et al., 2002).

Rose et al., (2003) conducted a experiment to evaluate the potential of composted media including windrow-composted dairy solids, greenhouse compost and vermicomposted dairy solids; Crab/shrimp shell chitin; BCAs *Trichoderma harzianum*, BCA *Pseudomonas* chlororaphis strain 63-28, *Streptomyces griseoviridis*, *Gliocladium catenulatum* and *T. virens* against cucumber root and stem rot caused by *Fusarium oxysporum* f. sp. *radicis-cucumerinum*. Results showed that the incorporation of vermicomposted dairy solids and windrow-composted dairy solid reduced plant mortality. 68% reduction in pathogen population was recorded in compost amended plants. Sterilized compost did not show any pathogen suppression, suggesting the role of competing microorganism in suppression of pathogen.

Simultaneous evaluation of vermicompost as biocontrol agent of tomato damping off (*R. solani*) and plant growth promoter was carried out. Plant growth media was incorporated with vermicompost at rates of 0, 25, 50, 75 and 100 % (by volume). Reduction in disease incidence was recorded when vermicompost was amended at 20 % rate. When added at 25-100 % rate vermicompost promote plant growth and prevented the disease. Furthermore, total 36 microbes were isolated from vermicompost, 13 of which showed antagonistic activity against *R. solani* in vitro (Rivera et al., 2004). Plant growth promotion and disease suppression activity of vermicompost against *R. solani* was evaluated in patience plants (Impatiens walleriana). Vermicompost was mixed in soil at 25, 50 and 75 % by volume. Increased leaf area, plant height, and fresh and dry biomass was recorded with 100-75 % of vermicompost incorporation in comparison to control. Reduction in disease incidence of damping off caused by *R. solani* was recorded only with 75 % vermicompost amendment (Asciutto et al., 2006).

Comparative study of suppression effectiveness of two non conventional chemicals including oxalic acid and ZnSO4; biocontrol agent *Pseudomonas syringae* as foliar spray and seed coating combined with vermicompost amended in pot soil against *Sclerotium rolfsii* was conducted. Vermicompost incorporation in pot soil resulted in significant reduction in mortality of chickpea plants in comparison to control. However, more significant suppression was recorded in treatment in which plants were pre inoculated with chemicals as foliar spray (*Sahni* et al., 2008). Synergistic activity of non conventional chemicals and vermicompost induced the plant defense response similar to systemic acquired resistance (SAR) and enhanced plant vigor by modifying host plant nutrition.

Simsek-Ersahin et al. (2009) conducted a comparative study with *T. harzianum* and vermicompost to evaluate the disease suppression potential against damping-off of cucumber caused by *R. solani*. Vermicompost was produced from potato, tree bark and apple scabs. The vermicompost not fortified with *T. harzianum* showed the same pathogen suppression activity when fortified with *T. harzianum*. During in vitro study with vermicompost extract, an antagonistic bacterium was responsible for specific suppression of *R. solani*.

Table 1 Plant diseases managed by vermicompost

Pathogen	Host
R. solani	*Triticum aestivum*
Phytophthora nicotianae	*Solanum lycopersicum*
Fusarium spp.	*Solanum lycopersicum*
Plasmodiophora brassicae	*Brassica oleracea*
Pythium	*Cucumis sativus*
Rhizoctonia	*Raphanus sativus*
Botrytis cinerea and	*Fragaria ananassa*

Verticillium	
Sphaerotheca fulginae	*Vitis vinifera*
Erysiphe cichoracearum/ Powdery Mildew	*Abelmoschus esculentus*
Color rot disease	*Abelmoschus esculentus*
P. brassicae	*Brassica oleracea*
P.infestans	*Solanum tuberosum*
P. nicotinae	Orange
M. persicae	*Piper nigrum*
Aproaerema spp.	*Arachis hypogaea*
Phomopsis	*Vitis vinifera*
R. solani/ damping disease	*Solanum lycopersicum*
L. orbonalis	*Solanum melongena*
Rhizoctonia spp.	*Gerbera (African daisy)*
R. solani	*Impatiens wallerana*
M. sexta	*Nicotiana tabacum*

Application of Vermicompost extracts

In ornamental plants the growth effect of vermicompost is as same as traditional hormones used like cytokine, gibberellins and auxins in the soil. There are limited literatures are available that have studied the quality of vermiliquids and their potential to control plant pathogens and pests. Singh (1993) concluded that the application of pesticides in agricultural field has decreased significantly with the emergence of vermicompost and its extracts. There are many species of fungus on which vermicompost extract acts as inhibiting biocontrol agent such as *Botrytis cinerea*, *Corticium rolfsii* and *R. solani* (Edwards et al., 2004). It is also proved that vermicompost extracts are also able to terminate the activity of both soils borne and foliar plant pathogens (Rodrı ́guez-Navarro et al., 2000; Zaller, 2006). The effect of vermicompost extracts on pea plant against the powdery mildews of balsam and pea caused by *Erysiphe cichoracearum* and *Erysiphe pisi* respectively was examined. Results showed that vermicompost extract successfully inhibited the growth of spores produced by several fungi species (*Helminthosporium speciferum*, *Helminthosporium penniseti*, *Alternaria solani*, *Alternaria alternata*, *Curvularia penniseti*, *Curvularia maculans* and *Culvularia palliscens*) in vitro. In field conditions post treatment of plants with extract showed positive results and able to provide high degree of resistance in pea plants and in case of balsam aqueous extract of vermicompost showed significant action in both pre and post inoculation. All these results show the great potential of vermicompost extract a potential alternative method for disease management. Singh et al. 2003 advocated the foliar application of foliar aqueous extracts of vermicompost by the farmers as a cheap, feasible, easy and eco-friendly approach for crop protection.

Zaller (2006) investigated the effects of foliar sprays on plant with vermicompost aqueous extract on plant growth, fruit yield, fruit quality and late blight incidence on three tomato cultivars. Results showed decreased susceptibility of tomato plants to *Phytopthora infestans* infection. Zaller (2006) stated the significant application of vermicompost products in organic farming not only as a solid pot medium but also as liquid extract for foliar application. Manandhar and Yami (2008) comparatively investigated the efficacy of aerobic composts and vermicompost extract on *Fusarium moniliforme* causing foot rot in rice. They included four treatments in this experiments; non-aerated vermicompost tea (NCTV), vermicompost tea (ACTV), non-aerated compost tea (NCTC) and aerated compost tea (ACTC). Maximum pathogen suppression was recorded in vermicompost tea followed by aerated compost tea. Minimum suppression was recorded in non-aerated vermicompost tea. Efficacy of seed treatment with all four compost during field trial was also recorded. Vermicompost tea showed maximum potential in reducing the number of affected seeds. They suggested that the efficacy of different compost extracts may be dependent to several factors including aeration, maturation time and type of compost used.

There has been a serious debate on disease suppression efficacy of compost teas, produced by different methods such as either aerobically or anaerobically. Zaller (2006) reported that the compost extract prepared anaerobically from mushroom substrate showed maximum inhibition of apple scab than aerobically prepared extract. Potentiality of anaerobic compost extract to suppress disease was claimed to be due to metabolites produced by anaerobic microorganisms during the extract preparation. However, various evidences support that the aerobically produced extracts are much more significant suppressor of plant disease and number of aerobic microbes are higher in compost extracts (Hoitink et al., 1997). Edwards et al. (2006) have clearly verified that the vermicompost teas produced aerobically are more stable in comparison to non-aerobically produced extract. They identified plant growth regulators, hormones, humic acid, microorganisms in vermicompost extract that contributed to the enhanced growth of tomato plant.

Yami and Shrestha (2005) reviewed the diversity of beneficial microorganisms in the vermicompost. These microorganisms compete with other harmful microbes. Abundance of nitrogenous and oxygen compound is present in vermicast secreted from the worms (Yami and Shrestha (2005). The possible mechanisms for disease management by vermicompost extracts are not clearly understood, but induced resistance is mostly considered as one prominent mechanism (Zaller, 2006).

Table 2 Diseases managed with liquid vermicompost extract

Pathogen	**Host**
Blumeria graminis	*Hordeum vulgare*
Erysiphe cichoracearum	*Abies balsamea*
E. pisi	*Pisum sativum*
Meloidogyne javanica	*Solanum lycopersicum*
Meloidogyne incognita	*Nicotiana tabacum*
F. oxysporum	*Solanum lycopersicum*
S. cepivorum	*Allium sativum*
Podosphaera leucotricha	*Malus domestica*
Botrytis cinerea	*Fragaria ananassa*
R. solani	*Phaseolus vulgaris*
R. solani	*Solanum tuberosum*
Streptomyces scabiei	*Solanum tuberosum*
F. moniliforme	*Oryza sativa*
Podosphaera pannosa	*Rosa*
Taphrina deformans	*Prunus persica*
Brown rot	*Prunus avium (Cherry)*
A. alternata	*Chrysanthemum morifolium*
Typhula ishikariensis	*Agrostis (Bentgrass)*
Microdochium nivale	*Turf grasses*
P. ultimum	*Triticum aestivum*
P. ultimum	*Cucumis sativus*
M. hapla	*Solanum lycopersicum*
Pratylenchus spp.	*Solanum lycopersicum*

Mechanism of Plant Pathogen Control by solid and extract

Various studies and experiments carried out to explore the application of vermicompost either in solid or liquid state in plant disease management has demonstrated that suppression potential of vermicompost product is largely due to its biological nature rather than chemical nature (Szczech 1999; Simsek-Ersahin et al. 2009). A great numbers of evidence from scientific literatures supported that the conventional aerobic compost stimulated the microbial communities in vermicompost and resulted in disease suppression.

Disease suppression mechanism via application of compost is categorizes in two i.e. general and specific mechanism, both include nutrient availability, microbial antagonism, competition and induction of resistance response in hosts (Edwards et al. 2004). In case of vermicompost which harbour great number of microorganisms, it has been anticipated that general suppression mechanism must be more predominant. Earthworms greatly influence the microbial diversity and activity during the composting and therefore, the disease suppression potential of vermicompost is mostly attributed to its microbial diversity (Edwards et al. 2004). This statement is supported by various studies where suppression potential almost disappeared after autoclaving the vermicompost (Szczech and Smolinska 2001; Simsek-Ersahin et al. 2009).

General suppression mechanism includes competition for nutrient, secretion of antibiotics by beneficial microorganisms that inhibit the pathogenic microorganisms, hyperparasitism and probably induction of systemic resistance in host plant (Hoitink and Grebus 1994). Disease suppression mechanism is based on vast diversity of microbial populations that act as biocontrol agents and creates fungistatis conditions (Serra-Whittling et al. 1996). Nutrient-depended phytopathogens such as *Phytopthora* and *Pythium* were explained to suppress by general suppression mechanism.

ISR in host plant by organic amendments is also described as one of the factors defined within "general disease suppression". Induced systemic resistance in plants triggered by compost applications is suggested to be possibly derived from the presence of some antibiotics and actinomycetes in vermicomposts which increases the "power of biological resistance" (Pharand et al. 2002). However, this explanation is the least mutually accepted claim among all those proposed for general disease suppression mechanisms.

The other mechanisms described in general suppression of plant disease include antibiosis and competition. Application of vermicompost on soil greatly influences the diversity of microorganisms that compete and inhibit the pathogenic organisms. Food source for beneficial microorganisms in vermicompost is more readily available than other compost (Edwards et al. 2004).

Competition is another process which is important for general disease suppression because vermicompost increases the nutrient availability in the soil and hence increases the microbial biomass in the soil and competition occurs for same nutrient source. This will conclude that any process which increases the soil microbial biomass will increase the general disease suppression process for controlling plant pathogen and pest. The symbiotic association between plants fungi is continue from ancient times. In the condition when there is less nutrient available fungi consume nutrients for plants and in return plant provides carbon to fungi. The association of mycorrhizal fungi with plants is beneficial because fungi create a physical barrier and enhance the nutrient uptake ability of plants and hence protect plants from root diseases. Physical barrier create a barrier along the root which inhibit the entry of plant pest and pathogens but some nematodes can easily penetrate these barriers and hence mycorrhizal fungi also secrete antibiotics to control the penetration by nematodes.

Another mechanism known as specific disease mechanism is a process in which one organism is able to suppress the activity of only one organism. Thus it is a narrow range phenomenon of suppression. This will usually done where a specific organism is introduced in plants for inhibiting the disease causing ability of other specific organism. This process is done in case of *R. solani* and *S. rolfsii* with the introduction of valuable organism such as *Trichoderma* and *Gliocladium*.

Conclusion

With the increasing impact of chemical fertilizers and pesticides, organic farming is major area of research for scientist from the past 30 or 40 years. This will led to shift from agrochemical farming to organic farming using earthworms and vermicompost. As now a days earthworms are no more feasible in the soil and it is difficult to use by farmers practically. Thus, vermicompost is another way of organic farming which attracts both farmers and researchers. Vermicompost has many advantages like cost effective, easy to use, and in farm production is feasible. Vermicompost and its extracts have potential to use various types of waste products like agricultural waste, food waste, household waste, and industrial waste. From the last one or two decades all industrial and less industrial countries show huge interest in the production of vermicompost from small scale production to large scale production. All the countries like US, Canada, New Zealand, India, Cuba, Japan, and France already start the manufacturing plants for production of vermicompost. Basically, vermicomposting is a technique emerges from biotechnology which is a biological process for conversion of low value products into high value products. Vermicompost is of two type's i.e. solid vermicompost and aqueous vermicompost both are capable of high yield of plants and induces resistance in plants. Still now more research work is required to optimize the production of vermicompost. New techniques or methods have to be develop to understand the use of vermicompost and its extract to upsurge crop yield without distressing food security. It is well established fact that advantages of vermicompost and its products dominant its disadvantages but still more research work is required to use vermicompost as plant pathogen and pest control. It is now difficult task to estimate the impact of vermicompost on specific plant disease both in case of solid and aqueous vermicompost. The major factor which make vermicompost a potential in controlling plant pathogen and pest include microbial biomass, waste maturity period, type of pathogen, and production technique. It is necessary for the human race to continue the studies on mechanism of plant pathogen suppression because the time is not far when only organic farming is a way to sustain the world from harmful chemical fertilizers and pesticides.

References

Edwards, C. A. (1998). The use of earthworms in the breakdown and management of organic wastes.

Edwards, C. A. and Fletcher, K. E. (1988). Interactions between earthworms and microorganisms in organic-matter breakdown. *Agriculture, Ecosystems and Environment*, **24(1-3):** 235-247.

Edwards, C. A., and Arancon, N. Q. (2004). The use of earthworms in the breakdown of organic wastes to produce vermicomposts and animal feed protein. *Earthworm ecology*, **2:** 345-380.
tomato. *Journal of Phytopathology*, *147*(3), 155-161.

Szczech, M., and Smolinska, 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.

Szczech, M., Kowalska, B., and Smolinska, U. (2002). Induction of systemic resistance in radish by Pseudomonads developing in vermicompost-amended substrate. *Phytopathologia Polonica*, *24*.

Nakamura, Y. (1996). Interactions between earthworms and microorganisms in biological control of plant root pathogens. *Farming Journal*, **30(6):** 37-43.

Edwards, C. A., Dominguez, J., and Arancon, N. Q. (2004). The influence of vermicompost on plant growth and pest incidence. *Soil Zoology for Sustainable Development in the 21st century. Cairo*, **18:** 397-420.

Widmer, T. L., Graham, J. H., and Mitchell, D. J. (1998). Composted municipal waste reduces infection of citrus seedlings by *Phytophthora nicotianae*. *Plant disease*, *82*(6), 683-688.

Rodríguez-Navarro, J. A., Zavaleta-Mejía, E., Sanchez-Garcia, P., and González-Rosas, H. (2000). The effect of vermicompost on plant nutrition, yield and incidence of root and crown rot of gerbera (*Gerbera jamesonii* H. Bolus). *Fitopatologia*, *35*(1), 66-79.

Chaoui, H., Edwards, C. A., Brickner, A., Lee, S. S., and Arancon, N. Q. (2002). Suppression of the plant diseases, *Pythium* (damping-off), *Rhizoctonia* (root rot) and *Verticillium* (wilt) by vermicomposts. In: Brighton crop protection conference pests and diseases .Vol. 2, pp. 711-716.

Punja, Z. K., Rose, S., and Yip, R. (2002, October). Biological control agents and composts suppress Fusarium and Pythium root rots on greenhouse cucumbers. In *Canadian Greenhouse Conference (Vegetable Session)*.

Rose, S., Parker, M., and Punja, Z. K. (2003). Efficacy of biological and chemical treatments for control of Fusarium root and stem rot on greenhouse cucumber. *Plant disease*, *87*(12), 1462-1470.

Rivera, M. C., Wright, E. R., López, M. V., Garda, D., and Barragué, M. Y. (2004). Promotion of growth and control of damping-off (*Rhizoctonia solani*) of greenhouse tomatoes amended with vermicompost. *Phyton (Buenos Aires)*, *73*, 229-235.

Asciutto, K., Rivera, M. C., Wright, E. R., Morisigue, D., and López, M. V. (2006). Effect of vermicompost on the growth and health of *Impatiens wallerana*. *Phyton (Buenos Aires)*, **25(12)**:115.

Simsek-Ersahin, Y., Haktanir, K., Yanar, Y. (2009). Vermicompost from agricultural wastes suppress *Rhizoctonia solani* Kuhn in cucumber seedlings. *Journal of Plant Disease Protection*, *116*, 182–188.

Zaller, J. G. (2006). Foliar spraying of vermicornpost extracts: effects on fruit quality and indications of late-blight suppression of field-grown tomatoes. *Biological agriculture and horticulture*, *24*(2), 165-180.

Singh, U. P., Maurya, S., and Singh, D. P. (2003). Antifungal activity and induced resistance in pea by aqueous extract of vermicompost and for control of powdery mildew of pea and balsam/Antifungaie Aktivität und induzierte Resistenz in Erbsen durch wässrigen Extrakt aus Wurmkompost und Bekämpfung des Echten Mehltaus an Erbsen und Gartenbalsamine. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz/Journal of Plant Diseases and Protection*, 544-553.

Manandhar, T., and Yami, K. D. (2008). Biological control of foot rot disease of rice using fermented products of compost and vermicompost. *Scientific World*, **6(6):** 52-54.

Hoitink, H. A. J., Stone, A. G., and Han, D. Y. (1997). Suppression of plant diseases by composts. *Horticultural Science*, **32(2):** 184-187.

Edwards, C. A., Arancon, N. Q., and Greytak, S. (2006). Effects of vermicompost teas on plant growth and disease. *Biocycle*, **47(5):** 28.

Yami, K. D., and Shrestha, A. (2005). Selective utilization of organic substrates during vermicomposting and the study of microflora. *J Nepal Biotechnol Assoc*, *2*, 23-26.
Szczech, M. M. (1999). Suppressiveness of vermicompost against Fusarium wilt of tomato. *Journal of Phytopathology*, *147*(3), 155-161.

Simsek-Ersahin, Y., Haktanir, K., Yanar, Y. (2009). Vermicompost from agricultural wastes suppress *Rhizoctonia solani* Kuhn in cucumber seedlings. *Journal of Plant Disease Protection*, *116*, 182–188.

Hoitink, H. A., and Grebus, M. E. (1994). Status of biological control of plant diseases with composts. *Compost Science and Utilization*, **2(2):** 6-12.

Serra-Wittling, C., Houot, S., and Alabouvette, C. (1996). Increased soil suppressiveness to Fusarium wilt of flax after addition of municipal solid waste compost. *Soil Biology and Biochemistry*, **28(9):** 1207-1214.

Pharand, B., Carisse, O., and Benhamou, N. (2002). Cytological aspects of compost-mediated induced resistance against Fusarium crown and root rot in tomato. *Phytopathology*, *92*(4), 424-438.