# 18. The influence of vermicomposts on plant growth and pest incidence

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## SUMMARY

During the last twenty years, considerable progress has been made in developing methods of breaking down organic wastes, including animal wastes, crop residues, urban and industrial organic refuse and sewage biosolids; which has been termed vermicomposting. Vermicomposts have a fine particulate structure, low C:N ratio, with the organic matter oxidized and stabilized and converted into humic materials. They contain nutrients transformed into plant-available forms and are extremely microbially-active. Additions of low rates of substitution of vermicomposts into greenhouse soil-less plant growth media or low application rates to field crops have consistently increased plant germination, growth, flowering, and fruiting, independent of nutrient availability. This can be at least partially, attributed to the production, by the greatly increased microbial populations, of plant growth regulators, including plant hormones, such as indole-acetic acid, gibberellins and cytokinins and also humic acids, which simulate the effects of hormones.

Vermicomposts can suppress the incidence of plant pathogens such as *Pythium*, *Rhizoctonia* and *Verticillium* significantly, by general or specific suppression mechanisms. Vermicomposts applied to soils have considerable influence on the trophic structure of nematode populations, significantly suppressing plant parasitic species populations. Greenhouse experiments have shown that low substitutions of vermicomposts into soil-less plant growth media can decrease the amounts of feeding and

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damage by sucking pests such as aphids and mealy bugs and chewing pests such as caterpillars.

All of these various inputs of vermicomposts into plant growth produce significant and economic increases in yields of ornamental, vegetable, and fruit crops. Vermicomposting has considerable potential for the large-scale conversion of environmentally undesirable organic wastes into value-added materials with great potential in horticulture and agriculture.

**Keywords**: vermicompots, plant growth, pest incidence, microbial activity, organic wastes

## INTRODUCTION

It is well-established that earthworms have beneficial effects on soils and soil fertility (Edwards 1985). These effects include: biological and chemical effects on soil organic matter degradation (Edwards and Bohlen 1996, and Edwards 1998), release of nutrients (Gilot 1997), and on soil structure (Kahsnetz 1992), soil turnover (Edwards 1998), water holding capacity and drainage, and aggregate formation and turnover (Edwards and Bohlen 1996). All of these activities contribute to soil fertility and increase plant growth and crop yields. There is an extremely large body of scientific evidence, that has been accumulated over the last fifty years, showing that the addition of earthworms to soils with low natural populations can have very significant effects on the growth of plants. Most of the relevant literature has been summarized by Lee (1985), Edwards and Bohlen (1996), Edwards (1998) and Edwards *et al.* (1995). Many experiments have conclusively shown that addition of earthworms can increase the growth of cereals in temperate countries (*e.g.*, van Rhee 1965, Atlavinyté 1974, Edwards and Lofty 1976, 1980, Atlavinyté and Vanagas 1982, Stephens and Davoren 1997). More recently, it has been shown through a range of field experiments, that inoculation of earthworms into soils in tropical farming systems can also have dramatic effects on plant growth and yields (Lavelle 1992, Spain *et al.* 1992, Lavelle and Spain 2001). In grasslands, especially those with no native earthworms, the effects of earthworm inoculations has been even more dramatic, so that yields of grasslands in New Zealand have greatly increased, consistently, and even sometimes doubled as a result of adding earthworms (Stockdill and Cossens 1966, Stockdill 1982, Syers and Springett 1983).

Although it has been shown that earthworms utilize microorganisms as their main source of nutrition (Edwards and Fletcher 1988), there are usually greatly increased numbers of bacteria, actinomycetes and fungi in freshly-deposited earthworm casts than in the surrounding soil (Edwards and Bohlen 1996). Such increases may be due to enhancement of microbial populations, occurring during passage through the earthworm's intestine; either because the food selected by the earthworm forms a richer substrate for microbial activity or because fragmentation of organic matter in the earthworm's gizzard increases the available surface area for microbial activity (Dkhar and Mishra 1986, and Tiwari and Mishra 1993). There is also evidence of earthworms increasing the overall metabolic activity of the microbial biomass in soils (Wolters and Jorgensen 1992, and Schindler-Wessels *et al.* 1996). There is considerable research evidence that earthworms can stimulate the microbial decomposition of organic matter significantly, both during the passage through the earthworm gut and in their casts, for some time after the casts are deposited (Scheu 1987, and Daniel and Anderson 1992). The microbial activity in the casts eventually falls and rates of organic matter breakdown decrease as the cast material becomes increasingly humified and protected.

## EFFECTS OF VERMICOMPOSTS ON PLANT GROWTH

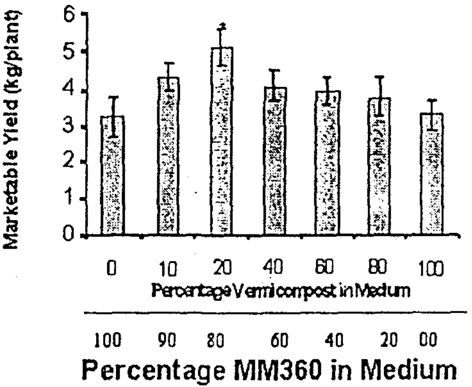
In recent years, there has been considerable progress in the utilization of earthworms to breakdown organic wastes including: animal wastes, crop residues, urban and industrial organic refuse and sewage biosolids (Edwards and Neuhauser 1988, and Edwards 1998). The earthworms fragment the organic waste substrate, greatly stimulate microbial activity and increase rates of mineralization, rapidly converting the organic wastes into humus-like substances, with a much finer particulate structure than traditional thermophilically-produced composts. These processes have been summarized in detail by Edwards and Neuhauser (1988), Edwards (1998) and Dominguez and Edwards (2004 - see previous Chapter). The effects of nutrient transformations produced by earthworms in soils and in vermicomposts are well-documented and contribute significantly to plant growth and crop yields (Edwards and Bohlen 1996, Edwards 1998,. Lavelle and Spain 2001).

It is clear that rapid breakdown of organic wastes by earthworms, interacting with microorganisms, produces vermicomposts with a much greater microbial activity and biodiversity, than the parent organic wastes; with increases in microbial activity sometimes by several orders of magnitude. It seems likely that this greatly enhanced microbial activity may not only increase the rate of nutrient transformations into forms readily available for plants, but also have effects on plant growth through increased enzymatic activity and disease suppression (Edwards 1998).

There is an increasing evidence from work in the Soil Ecology Laboratory at The Ohio State University that the addition of vermicomposts into soil-less bedding plant media can increase the germination, growth, flowering and fruiting, of a wide range of greenhouse vegetables and ornamentals, such as: tomatoes (Figure 1) (Atiyeh *et al* 1999, and Atiyeh *et al*, 2000 a), vegetable seedlings (Atiyeh *et al.* 2000 b), marigolds (Figure 2) (Atiyeh *et al.* 2000 e, and 2001), and other vegetables and ornamentals (Atiyeh *et al.* 2000 c, d, and e) and that amendments of field crops with low application rates of vermicomposts can increase the growth of vegetables such as peppers (Figure 3)

(Arancon *et al.* 2003 f), fruits such as strawberries (Figure 4) (Arancon *et al.* 2003 a), and grapes and ornamentals such as petunias. All of these increases in both greenhouse and field were independent of nutrient supplies which were equalized between treatments. In all the greenhouse and field experiments at The Ohio State University, increases in growth in response to vermicomposts were in response to small application rates, were significant and consistent, and were mostly independent of nutrient supply.

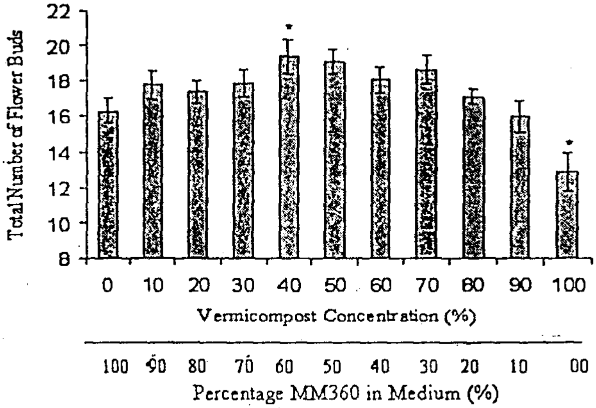
**Figure 1. Marketable yields of tomatoes grown in the greenhouse in a range of mixtures of vermicompost and a commercial medium Metro-Mix 360 (with all necessary nutrients supplied).**



In recent years, a very substantial body of evidence has accumulated demonstrating that microorganisms, including bacteria, fungi, yeasts, actinomycetes and algae, are capable of producing plant hormones and plant-growth regulating substances (PGRs) such as auxins, gibberellins, cytokinins, ethylene and abscisic acid, in appreciable quantities (Arshad and Frankenberger 1993, and Frankenberger and Arshad 1995). Many of the microorganisms that are common in the rhizospheres of plants can produce such plant growth-regulating substances, for instance Barea *et al.* (1976) reported that, of 50 bacterial isolates obtained from the rhizosphere of various plants, 86 % could produce auxins, 58 % gibberellins and 90 % kinetin-like substances. There have been many studies on the production of plant growth-regulating substances by mixed microbial populations in soil, but there are relatively few investigations into their availability to plants, and persistence, fate in soils, or documentation on their effects on plant growth (Arshad and Frankenberger 1993, and Frankenberger and Arshad 1995). Some workers have shown that PGRs can be taken up by plants from soil in sufficient amounts to influence plant growth. For instance, it was shown that auxins produced by *Azospirillum brasilense* could affect the growth of graminaceous plants (Barbieri *et al.* 1988, and Kucey 1993). There is increasing evidence that microbially-produced gibberellins can influence plant growth and development (Mahmoud *et al.* 1984, and Arshad and

Frankenberger 1993). Increased vigour of seedlings has been attributed to microbial production of cytokinins by *Arthrobacter* and *Bacillus* spp. in soils (Inbal and Feldman 1982, and Jagnow 1987).

Figure 2. Total number of flower buds (mean±standard error) produced by marigold plants in a standard commercial potting medium (Metro-Mix 360) substituted with different concentrations of pig manure vermicompost. Columns followed by * are significantly different from Metro-Mix 360 (0% vermicompost) at $P \leq 0.05$.



It has been suggested that earthworms may be important agents that influence the enhanced production of plant growth-regulating substances through promoting greatly increased microbial activity in organic matter and soils (Nielson 1965, Springett and Syers 1979, Grappelli *et al.* 1987, Tomati *et al.* 1983, 1987, 1988, and 1990, Tomati and Galli 1995, Nardi *et al.* 1988, Graff and Makeschin 1980, Dell'Agnola and Nardi 1987, Edwards and Burrows 1988, Edwards 1998, Krishnamoorthy and Vajranabiah 1986). Since earthworms increase microbial activity so dramatically, sometimes by orders of magnitude, it is not unreasonable to conclude that earthworm activity might increase the rates of production of PGRs by soil microorganisms significantly.

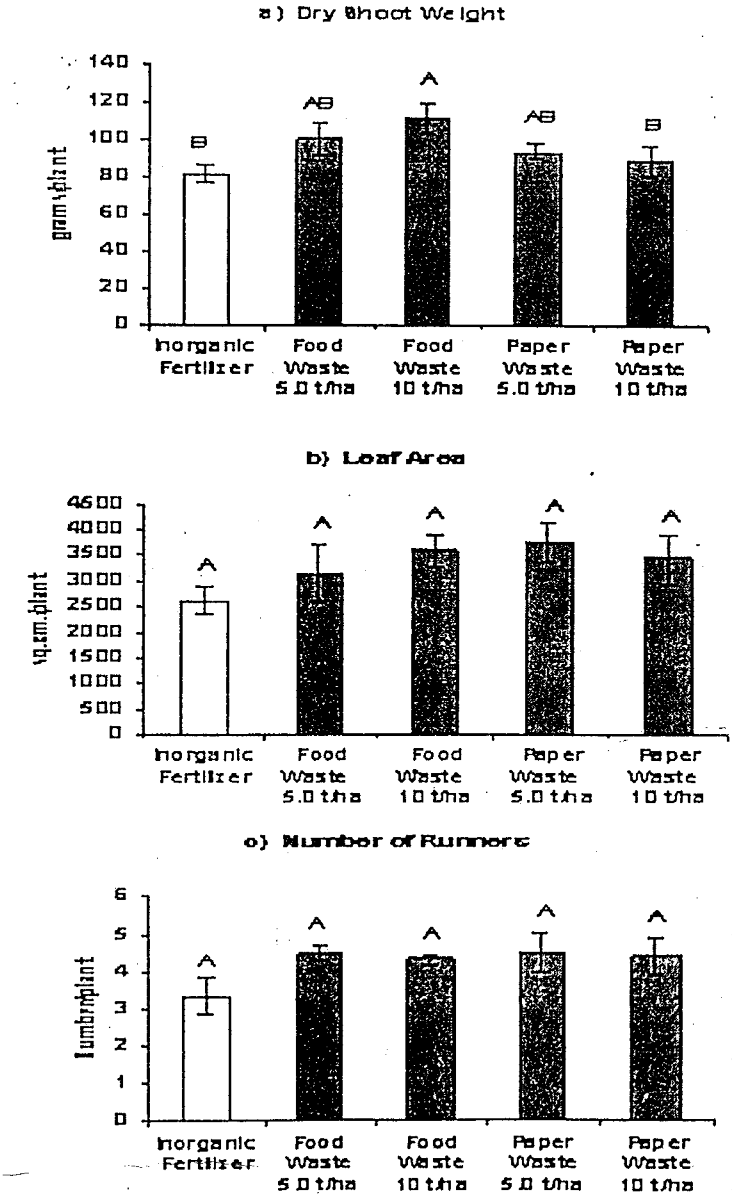


Figure 3. Shoot biomass, leaf areas and number of runners of strawberries grown in soils treated with food waste and paper waste vermicomposts and inorganic fertilizer control, 200 days after transplanting in Fremont, OH.

Columns followed by same letter(s) are not significantly different at $P \leq 0.05$.

The first suggestion that earthworms might produce plant growth regulators was by Gavrilov (1963). This was supported by the first report of the presence of plant growth-regulating substances in the tissues of *Aporrectodea caliginosa*, *Lumbricus rubellus* and *Eisenia fetida* by Nielson (1965), who isolated indole substances from earthworms and reported increases in the growth of peas due to extracts from the earthworms. He also extracted a substance that stimulated plant growth from *Aporrectodea longa, Lumbricus terrestris,* and *Dendrobaena rubidus,* but his experiments did not exclude the possibility of PGRs that he found came from microorganisms that were living in the earthworm guts and tissues.

Graff and Makeschin (1980) tested the effects of substances that had been produced by *Lumbricus terrestris*, *Allolobophora caliginosa* and *Eisenia fetida* on the dry matter production of ryegrass. They added liquid eluates from pots containing earthworms to pots containing no earthworms, and concluded that plant growth-influencing substances were released into the soil by all three species, but did not speculate further on the nature of these substances.

Tomati *et al.* (1983, 1987, 1988, and 1990), Grappelli *et al.* (1987) and Tomati and Galli (1995), tested vermicomposts produced from organic wastes, by the action of earthworms, as media for growing ornamental plants and mushrooms. They concluded that plant growth increases that occurred in all of their experiments were much too large to be explained purely on the basis of the nutrient content of the vermicomposts. Moreover, plant growth changes included: stimulation of rooting, dwarfing, time of flowering, and lengthening of internodes. They compared the growth of *Petunia, Begonia*, and *Coleus* after adding aqueous extracts from vermicompost, with adding auxins, gibberellins, and cytokinins, to soil, and concluded that they found excellent evidence of hormonal effects, produced by earthworm activity, which was supported by the high levels of cytokinins and auxins they found in the vermicomposts.

Edwards and Burrows (1988) reported that the growth of 28 ornamentals and vegetables, in plant growth media produced by the processing of organic wastes by the earthworm *E. fetida,* was much greater than that in commercially-available plant growth media, and was too great to be explained solely through influence of earthworm activity on plant nutrient quality and availability. They reported that the *growth of ornamentals was influenced significantly* even when the earthworm-processed organic wastes were diluted 20:1 with other suitable materials and the *nutrient content was balanced to that of inorganic fertilizers.* Moreover, the growth patterns of the plants, which included changed leaf development, stem and root elongation, and flowering by biennial ornamental plants in the first season of growth, indicated the likelihood of some biological factor, other than nutrients, such as the production of plant growth-influencing substances (PGIs), *e.g.*, humic acids or free enzymes, being responsible. Scott (1988), reported that the growth of the hardy ornamentals, *Chamaecyparis lawsonian, Elaeagnus pungens Cupressocyparis leylandi, Pyracantha* spp. *Cotoneaster conspicus* and

*Viburnum bodnantense*, increased significantly after addition of low levels of earthworm-worked organic wastes to the growth media even when the nutrients in the two media were balanced.

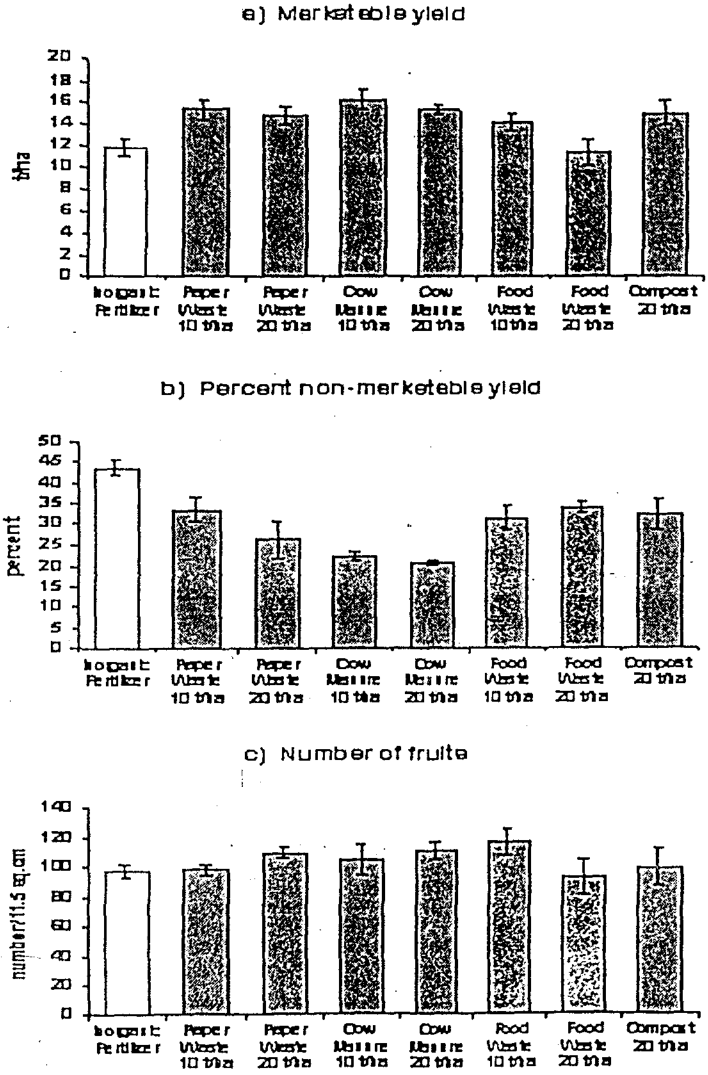


Figure 4. Yield and yield attributes of peppers grown in soils treated with food waste, paper waste cattle manure vermicomposts, traditional composts, and inorganic fertilizer in Piketon, Ohio. Columns followed by same letter(s) are not significantly different at $P \leq 0.05$.

Krishnamoorthy and Vajranabhaiah (1986) showed, in laboratory experiments involving large earthworm populations, that seven species of earthworms could very dramatically promote the production of cytokinins and auxins in organic wastes. They also demonstrated a significant positive correlations (r = 0.97) between earthworm populations and the amounts of cytokinins and auxins present in ten different field soils, and concluded that earthworm activity was linked strongly with PGR production. They reported that auxins and cytokinins produced through earthworm activity could persist in soils for up to 10 weeks although they degraded in a few days if exposed to sunlight.

During the last decade, the biological activities of humic substances have been extensively investigated (McCarthy *et al.* 1990, and Hayes and Wilson 1997). Studies of the effects of humic substances on plant growth, under conditions of adequate mineral nutrition, have consistently resulted in positive plant growth effects (Chen and Aviad 1990, and Hayes and Wilson 1997). For instance, humic substances increased the dry matter yields of corn and oat seedlings (Lee and Bartlett 1976, and Albuzio *et al.* 1994); numbers and lengths of tobacco roots (Mylonas and Mccants 1980); dry weights of shoots, roots, and nodules of soybean, peanut, and clover plants (Tan and Tantiwiramanond 1983), vegetative growth of chicory plants (Valdrighi *et al.* 1996); and induced shoot and root formation in tropical crops grown in tissue culture (Goenadi and Sudharama 1995).

Vermicomposts originating from animal manure, food wastes, sewage sludges or paper-mill sludges have been reported to contain high levels of *humic substances* (Atiyeh *et al.* 2002, Canellas *et al.* 2000, Arancon *et al.* 2003 c). Recently, the biological activities of humic substances derived from earthworm faeces have been investigated (Dell'Agnola and Nardi 1987, Nardi *et al.* 1988, Muscolo *et al.* 1993). For instance, Dell'Agnola and Nardi (1987) reported hormone-like effects of depolycondensed humic fractions obtained from the faeces of the earthworms, *Allolobophora rosea* and *Allolobophora caliginosa*. Treating carrot cells with humic substances obtained from the faeces of the earthworm *A. rosea* increased cell growth and induced morphological changes similar to those induced by auxins (Muscolo *et al.* 1996). From work at The Ohio State University it seems that vermicomposts, which consist of an amalgamate of humified earthworm faeces and organic matter, can stimulate plant growth beyond that produced by mineral nutrients, because of the direct or indirect effects of the humic substances present in the vermicomposts, acting as PGRs, and this has been confirmed (Atiyeh *et al.* 2000 a, b, c, d, and e, Arancon *et al.* 2003 c).

In work at The Ohio State University, treating plants with humic substances, increased growth was correlated with increasing concentrations of humic substances, but usually with a decrease in growth at higher concentrations of the humic materials (Figure 5). This stimulatory effect of humic substances at low concentrations has been explained by various theories, the most convincing of which hypothesizes a "direct" action on the plants which is hormonal in nature, together with an "indirect action" on the metabolism of soil microorganisms, the dynamics of soil nutrients, and soil physical conditions (Cacco and Dell Angola 1984, Nardi *et al.* 1988, Albuzio *et al.* 1989, Casenave de Sanfilippo *et al.* 1990, Chen and Aviad 1990, Muscolo *et al.* 1993, 1996, and 1999).

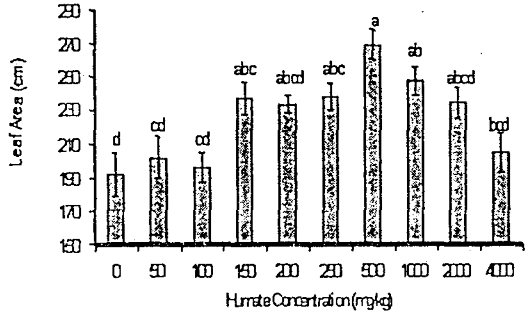
Laboratory and greenhouse research at OSU, has provided new evidence that, earthworm activity on organic matter to produce vermicomposts, can lead to the production of water-extractable and base-extractable plant growth influencing substances (PGIs) in vermicomposts, in quantities that could significantly influence plant germination, growth, flowering and yields of greenhouse crops. These data suggest that there are biological and biochemical changes during the production of vermicomposts, including production of PGRs, such as plant hormones and humic acids. For instance, in bioassays, leaf development of radish seedlings grown in a full Hoagland nutrient solution, was compared with that in complete nutrient solutions amended with 2 % or 5% aqueous extracts of vermicomposts. The extracts increased leaf area significantly, suggesting a *non-nutrient mediated plant growth response.* In aqueous extracts of vermicomposted cattle waste, separated fractions by High Performance Liquid Chromatography (HPLC) and analyzed then by Gas Chromatography-Mass Spectrometry (GC-MS). Indole-3-acetic acid (IAA) was conclusively and smaller amounts of giberellins and cytokinins.

In laboratory/greenhouse bioassays at The Ohio State University it was demonstrated that auxins were present in vermicomposts in significant amounts using a *Coleus* bioassay. It was also shown that gibberellins were present in relatively small quantities, using a dwarf 5 maize bioassay (Sembdner *et al.* 1976), and that cytokinins were present in small amounts, using a cucumber bioassay (Hahn and Bopp 1968).

Chemical analyses for indole acetic acid (IAA) in vermicomposts using HPLC and GC-MS confirmed these findings. Tomato seedlings responded positively to IAA and gibberellic acid 3 ($GA_3$), and negatively to a single application of kinetin, but positively to a second application of this PGR. These experiments demonstrated clearly that tomato plants could take up PGRs, including those produced in vermicomposts, from soil through their roots in quantities sufficient to influence their growth.

Humic acids were extracted from vermicomposts and a range of doses added to tomato seedlings that were provided with all needed nutrients. Greenhouse experiments with some humate doses produced very significant increases in plant growth in greenhouse experiment (Figure 5). The humic acids were extracted from pig manure-based vermicomposts, using the classic alkali/acid fractionation procedure (Valdrighi *et al.* 1996). The dry yield of humates was 4 gm $kg^{-1}$ of vermicomposts. The incorporation of 150, 200, 250 and 500 mg/kg of humates from pig manure vermicompost into Metro-Mix 360 increased the heights and the leaf areas of tomato seedlings grown in these mixtures significantly, compared to those grown in the Metro-Mix 360 controls with no humates added. The greatest plant heights occurred in potting mixtures containing 200 mg/kg humates, whereas greatest leaf areas occurred in potting mixtures containing 500 mg/kg humates. The dry weights of shoots of tomato seedlings grown in mixtures containing 200, 250, and 500 kg/mg humates were 47.0, 37.4, and 43.4 %, respectively, greater than those of seedlings grown in Metro-Mix 360 controls. The dry weights of roots of tomato seedlings, grown in mixtures containing 250, 500, and 1000 mg/kg of humates from pig manure-vermicompost, were 77.5, 79.3, and 72.1 %, respectively, more than those of seedlings grown in the controls with no humates. These effects of humates on growth all occurred when the plants were supplied with all their required nutrients (Atiyeh *et al.* 2002). In later experiments, humates extracted from cattle, food and paper waste vermicomposts produced similar growth increases on peppers and strawberries (Arancon *et al.* 2003 f).

Figure 5. Effects of humic acid extracts from pig manure vermicompost, applied to a soil-less potting medium at different concentrations, on tomato leaf area (with all needed nutrients supplied).



We hypothesized (Atiyeh *et al.*, 2002, and Arancon *et al.* 2003 c) that plant growth hormones may be very transient in soils since they are highy water-soluble and rapidly degrade in sunlight. However, if they become adsorbed on to humic acids, which are extremely stable, they would persist much longer in soils and continue to influence plant growth. This theory was confirmed by Canellas *et al.* (2000), who demonstrated that there were exchangeable auxin groups in the macrostructure of humic acids extracted from vermicomposts. These workers also showed that these complexes influence lateral root development of maize. This research provides clues as to why vermicomposts influence plant germination, growth, flowering, and yields so dramatically over and above their content of readily-available nutrients, and make positive contributions to soil structure and fertility.

Thus there is increasing evidence of the various ways in which components of ermicomposts can increase the germination, growth, flowering, and fruiting of a wide ange of crops as discussed in this Chapter. This also has implications for organic farming ecause if earthworms can promote the activity and effects of PGRs in organic wastes, it nay also be true that in soils to which organic matter is added, the production of PGRs by nicroorganisms may be increased by soil-inhabiting earthworm activity.

## FFECTS OF VERMICOMPOSTS ON PLANT PATHOGENS, PLANT ARASITIC NEMATODES AND ARTHROPOD PESTS

The suppression of plant pathogens by organic matter and thermophilic omposts (Hoitink and Grebus 1997) and plant parasitic nematodes by various forms of rganic matter is well-documented (Akhtar and Malik 2000). There are many nsubstantiated reports in the popular organic literature of the control of pests by organic atter. However, it is only recently that the potential of vermicomposts in the uppression of pests has begun to be explored. It seems very probable that based on creased research, that vermicomposts will be commonly used for pest management.

### ) Suppression of plant diseases by vermicomposts

There is an extremely extensive literature on the suppression of plant diseases by rganic amendments (Lazarovits *et al.* 2000, Fikre *et al.* 2001, Ramamoorthy *et al.* 2000, ettiol *et al.* 1997, and 2000, Somasekhara *et al.* 2000, Rajan and Sarma 2000, Blok *et al.* 00, Shiau *et al.* 1999, Arafa and Mohamed 1999, Goudar *et al.* 1998, Narayanaswamy *al.* 1998, Raguchander *et al.* 1998, Hooda and Srivastava 1998, Velandia *et al.* 1998, ixon *et al.* 1998, Ehteshamul *et al.* 1998, Lima *et al.* 1997, Panneerselvam and aravanamuthu 1996, Ara *et al.* 1996, Karthikeyan and Karunanithi 1996, Sanudo and olina 1995, Dutta and Hegde 1995, Diyora and Khandar 1995, Kulkarni *et al.* 1995, am *et al.* 1988, Kannaiyan 1987), and traditional thermophilic composts (Huelsman and dwards 1998, Goldstein 1998, Jaworska *et al.* 1998, Hoitink *et al.* 1986, and 1997). arious mechanisms have been suggested for this suppression, but most of these are sed on some form of microbial antagonism. Specific diseases that have been controlled traditional thermophilic composts include among others: *Fusarium* (Liping *et al.* 2001, annangara *et al.* 2000, Cotxarrera *et al.* 2001, Harender *et al.* 1997), *Gaeumannomyces aminis*, and *Plasmidiophora brassicae* (Pitt *et al.* 1998) *Phytophthora* (Hoitink and uter 1986, and Pitt *et al.* 1998), and *Rhizoctonia* (Kuter *et al.* 1983).

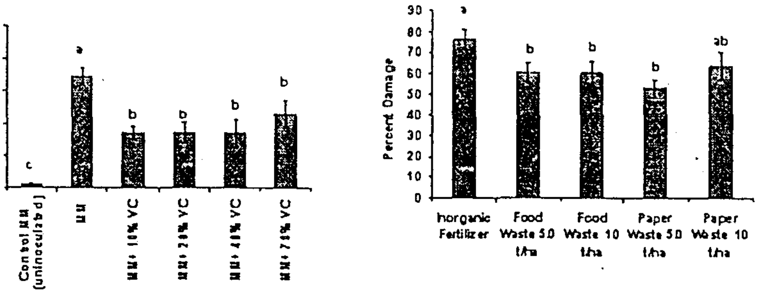
Traditional composting is a thermophilic process that selectively promotes icrobial activity, whereas vermicomposting is a non-thermophilic method that greatly omotes increased activity by a wide range and diversity of microorganisms. We have nsiderable evidence from our research at The Ohio State University of much greater icrobial activity and biodiversity in vermicomposts than in traditional composts. Our aboratory and field research work provides evidence that vermicomposts may have an even greater potential for disease suppression than traditional thermophilic composts. For instance, general observational evidence of decreases in plant disease incidence and of pathogen suppression were recorded in earlier studies involving 28 species of crop plants grown in vermicomposts (Edwards and Burrows 1988, and Scott 1988).

Nakamura (1996) reported suppression of *Plasmodiophora brassicae, Phytophthora nicotianae* (tomato late blight), and *Fusarium lycopersici* (tomato fusarium wilt) by vermicomposts. Szczech (1999, and 2002) reported suppression of *Fusarium lycopersici,* as well as *Phytophthora nicotianae* on tomatoes, by vermicomposts. Rodriguez *et al.* (2000) demonstrated general suppression of fungal diseases of gerbera plants such as *Rhizoctonia solani*, *Phytophthora drechsleri* and *Fusarium oxysporum* by the incorporation of vermicompost into the growth media. Orlikowski (1999) described sporulation reduction of the pathogen *Phytophthora cryptogea* after treatment with vermicomposts. Studies by Nakasone *et al.* (1999) showed that aqueous extracts of vermicomposts inhibited the mycelial growth of *Botrytis cinerea*, *Sclerotinia. sclerotiorum*, *Corticium rolfsii*, *Rhizoctonia solani* and *Fusarium oxysporum.*

In recent research in the Soil Ecology Laboratory in greenhouse experiments at The Ohio State University there was significant suppression of *Pythium* and *Rhizoctonia* (Figure 6 a), resulting from substituting low rates (10-30 %) of vermicompost into horticultural bedding mixtures in the greenhouse (Chaoui *et al.* 2002). Suppression of diseases of field crops was achieved with low application rates of vermicomposts. The diseases suppressed in the field were *Verticillium* wilt on strawberries (Figure 6 b) and *Phomopsis* and powdery mildew (*Sphaerotheca fulginae*) on grapes.

Two mechanisms of pathogen suppression have been described, one of which is based on microbial competition, antibiosis, hyperparasitism, and possibly systemic plant resistance (Hoitink and Grebus 1997). In this mechanism, propagules of pathogens such as *Pythium* and *Phytophthora* are suppressed by a mechanism that has been termed 'general suppression' (Chen *et al.* 1987) with many microorganisms acting as biocontrol agents. This mechanism has also been suggested as effectively suppressing human pathogens, such as coliform bacteria and other faecal pathogens (Hoitink and Grebus 1997). The second method of suppression of diseases such as *Rhizoctonia,* with only a narrow range of microorganisms facilitating the suppression, is termed 'specific suppression' (Hoitink *et al.* 1997). It seems likely that these two mechanisms of suppression also apply to vermicomposts, but probably 'general suppression' is much more common for vermicomposts since vermicomposting greatly increases the biodiversity of microorganisms, whether pathogenic or beneficial.

6. a) *Rhizoctonia* symptom suppression in radish. Seedlings planted in a soil-less n (MM360) substituted with vermicompost, inoculated with 1:4000 dilution *Pythium*. is sterilized MM360. The disease scale is rated 1(symptomless) to 5 (severe). b) *lium* wilt symptom suppression in strawberry field crops amended with topical tions of vermicompost (5 and 10 t/ha)



(a)

(b)

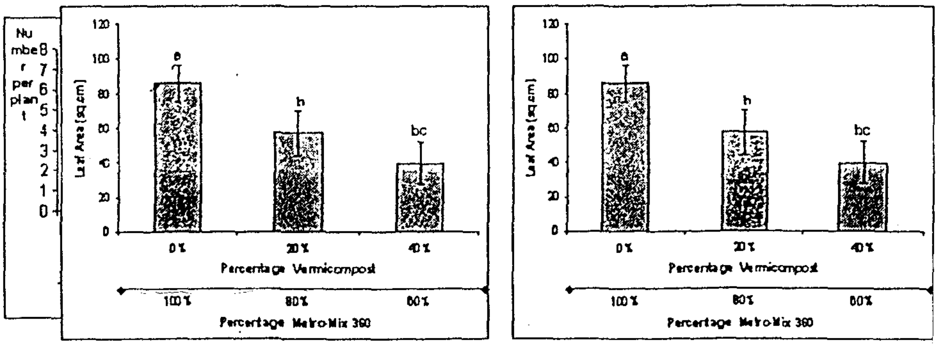
## Suppression of insect and mite attacks by vermicomposts

There are reports in the literature demonstrating that field applications of various f organic matter and traditional thermophilic composts can suppress attacks by ests, such as aphids and scale insects (Cullinan and Pimentel 1986, Costello and 1995, Yardim and Edwards 1998, Huelsman *et al.* 2000, Eigenbrode and Pimentel ⁻or instance, organic fertilizers suppressed corn insect pests (Biradar *et al.* 1998), aphids (Morales *et al.* 2001) and European corn borer (Phelan *et al.* 1996), insect pests (Rao 2002), brinjal shoot and fruit borer (Sudhakar *et al.* 1998), and ects (Morales *et al.* 2001). Surekha (2000) reported that the treatment of soils micomposts or farm yard manure reduced the incidence of aphids, jassids and ers, as pests.

More recently, there have been scattered reports of the suppression of insect pest n plants by vermicompost amendments. Biradar *et al.* (1998) reported a clear n between the amounts of vermicomposts in the medium in which *Leucaena hala* was grown and the degree of infestation by the psyllid *Heteropsylla* Rao *et al.* (2000) reported decreased incidence of the leaf miner *Aproaerema a* on groundnuts, in response to field treatments of soils with vermicomposts. *l.* (2001) reported lower overall pest densities of the ground nut leaf miner *ema modicella*) in plots treated with vermicomposts. Ramesh (2000) described l attacks by sucking pests in response to vermicomposts. Rao (2002) reported e decreases in attacks by the jassid (*Empoasca verri*) and the aphid (*Aphis a*), and changed predator populations, in response to field applications of vermicomposts. George Hahn (California Vermiculture), in an article in the Los Angeles Times in 2000, claimed that vermicomposts repelled a number of insect pests. Such reports, although not numerous, provide an adequate basis to justify further research into this subject, since it would be very attractive financially, if it can be proved that vermicomposts can significantly and consistently suppress arthropod pest populations. Recent greenhouse research in the Soil Ecology Laboratory at OSU has demonstrated significant suppression of populations of aphids (*Myzus persicae*), mealy bugs (*Pseudococcus*) and caterpillars (*Pieris brassicae*) by substituting low rates of vermicomposts into a soil-less plant growth medium (Metro-Mix 360) for tomatoes, peppers, and cabbages (Figure 7).

The possible mechanisms of arthropod pest suppression by organic matter, composts and vermicomposts is still speculative, but changes in the nutrient characteristics and balances of plants in response to vermicomposts compared with inorganic fertilizers and possibly the phenol contents of plant leaves, have been suggested mechanisms, since organic nitrogen is released more slowly from organic amendments such as vermicomposts than from inorganic fertilizers. This would make plants less acceptable to arthropod attacks. (Patriquin *et al.* 1995)

Figure 7. a) Mealy bug infestations on tomatoes substituted with different amounts of vermicomposts into a soilless medium (MM 360) b) Attacks by cabbage white caterpillars on cabbages grown in MM 360 and MM 360 substituted by 20% and 40% vermicompost



(a) (b)

### (c) Suppression of plant parasitic nematode attacks by vermicomposts

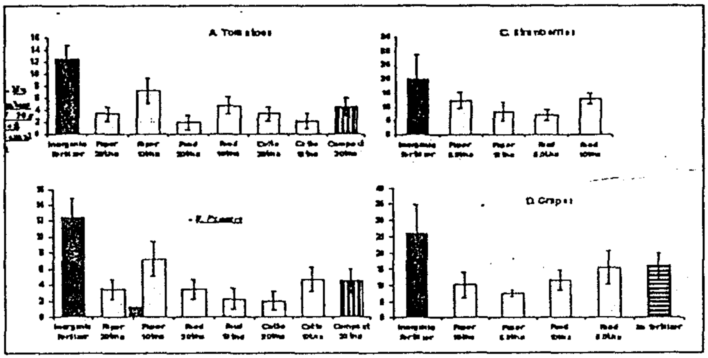
There is a very extensive scientific literature, demonstrating that additions of organic matter to soils, may sometimes decrease populations of plant parasitic nematodes appreciably (Addabdo 1995, Akhtar and Malik 2000, Akhtar 2000). Akhtar (2000) reviewed 212 scientific papers which discussed effects of various organic amendments on plant-parasitic nematode populations. There are also a number of reports that traditional thermophilic composts can suppress plant parasitic nematode populations (McSorley and Gallaher 1995, Gutpa and Kumar 1997, Sipes *et al.* 1999, Miller 2001). Studies carried out by Zambolim *et al.* (1996) demonstrated the effectiveness of coffee compost in the control of the nematode *Meloidogyne javanica* on tomatoes. Chen *et al.* (2000) demonstrated decreases in egg production of the nematode *M. hapla* when brewery compost was added to soil. However, such results have usually resulted from large field application rates of composts which may not be economical for commercial nematode management.

There have been a few reports in the scientific literature of vermicomposts suppressing populations of plant parasitic nematodes. Swathi *et al.* (1998) demonstrated that 1.0 kg $m^{-2}$ of vermicompost suppressed attacks of *Meloidogyne incognita* in tobacco plants. Morra *et al.* (1998) reported partial control of *Meloidogyne incognita* by vermicompost amendments to soils in a tomato-zucchini courgette rotation. Ribeiro *et al.* (1998) reported that vermicomposts decreased the numbers of galls and egg masses of *Meloidogyne javanica*. Arancon *et al.* (2002, and 2003 e) reported significant suppression of plant parasitic nematodes by field applications of vermicomposts, ranging from 2 to 8 kg/ha applied to tomatoes, peppers, strawberries and grapes crops (Figure 8). Suppression of plant parasitic nematodes by field applications of paper waste, food waste and cattle manure vermicomposts were also reported by the same group of workers at The Ohio State University (Arancon *et al.* 2002, and 2003 e).

There are a number of possible mechanisms for the decrease in populations of plant parasitic nematodes by vermicomposts. Predatory-prey interactions that decrease populations of plant parasitic nematodes may also provide one feasible explanation of the mechanism. For instance, according to Bilgrami (1996), a mite *Hypoaspis calcuttaensis* oraciously preys on plant parasitic nematodes, predaceous nematodes and saprophagous ematodes. Studies by Nakasone *et al.* (1999) showed that aqueous extracts of ermicomposts inhibited the mycelial growth of *B. cinerea, Sclerotinia. sclerotiorum, C. olfsii, R. solani* and *F. oxysporum*. Vermicomposts perhaps increase numbers of mnivorous nematodes or arthropods that selectively prey on plant parasitic nematodes. ermicomposts might also promote the growth of nematode-trapping fungi as well as ecies of fungi that attack and destroy nematode cysts and affect, either directly or directly, populations of plant parasitic nematodes (Kerry 1998). Alternatively, izobacteria can colonize roots and kill plant parasitic nematodes by producing enzymes nd toxins that are toxic to them (Siddiqui and Mahmood 1999). As well as such biotic interactions, abiotic factors provided by vermicomposts might also reduce populations of plant parasitic nematodes. For example, vermicomposts may contain compounds that might affect the survival of nematodes. For instance, nematodes can be killed due to the release of toxic substances such as hydrogen sulphide, ammonia, and nitrates, during vermicomposting (Rodriguez-Kabana 1986).

All of the recent experiments at The Ohio State University have consistently and significantly decreased populations of plant parasitic nematodes on a range of crops. This is useful evidence that vermicomposts have potential in plant parasitic nematode management programmes.

Figure 8. Numbers (Means ± SE) of plant parasitic nematodes in inorganic fertilizer-treated ( ▪ ), vermicompost-treated (▭), compost-treated(▥) and unfertilized (▤ ) soils planted with tomatoes (A), peppers (B), strawberries (C), and grapes (D).



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