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Effects of humic acids derived from cattle, food and paper-waste vermicomposts on growth of greenhouse plants

Norman Q. Arancon*, Stephen Lee, Clive A. Edwards and Rola Atiyeh

The Soil Ecology Laboratory, The Ohio State University, 1735 Neil Avenue, Columbus, OH 43210, USA

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Summary

Humic acids were extracted from cattle, food and paper-waste vermicomposts using an alkali/acid fractionation procedure which produced 1 g dry wt humates from 400 g vermicompost. They were applied to a soilless growth medium, Metro-Mix 360 (MM360), at rates of 0, 250 or 500 mg humates kg^{-1} dry wt of container medium, to young marigold, pepper, and strawberry plants grown in pots in the greenhouse. A range of 0, 20, 100, 150, 200, 250, 500, 1000, 2000, 4000 mg of humates kg^{-1} of container medium was used for tomatoes. Effects of the humic acids on the plant heights, leaf areas, shoot dry weights, root dry weights of peppers, tomatoes and marigolds and numbers of fruits of strawberries were assessed. Substitution of humates ranging from 250–1000 mg kg^{-1} MM360 increased root growth of marigolds and peppers, and increased root growth and numbers of fruits of strawberries significantly ($P \leq 0.05$). Leaf areas, plant heights and above-ground dry matter weights increased considerably in plants grown in pots containing humic acids but they were not significantly different from those grown in MM360 only ($P \leq 0.05$).

Key words: Vermicomposts, humic acids, plant growth, peppers, tomatoes, marigolds, strawberries

Introduction

It is well established that earthworms have beneficial physical, biological and chemical effects on soils and can increase plant growth and crop yields in both natural and managed ecosystems (Edwards & Bohlen 1996). These beneficial effects have been attributed to improvements in soil properties and structure, to greater availability of mineral nutrients to plants (Edwards 1998), and to biologically active metabolites acting as plant growth regulators (Tomati & Galli 1995). In recent years, the use of earthworms to break-down organic residues, including sewage sludge, animal manures, crop residues, and industrial refuse, to produce vermicomposts has increased tremendously (Edwards 1998). Earthworms fragment organic waste substrates, stimulate microbial activity greatly and increase rates of mineralization, rapidly converting the wastes into humus-like substances with a finer structure than composts but possessing a greater and more diverse microbial activity (Atiyeh et al. 2000b). The effects of such vermicomposts on the rates of growth

*E-mail corresponding author: Arancon.1@osu.edu

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of a variety of crops including, vegetables and ornamentals have been assessed in the greenhouse and some field crops (Atiyeh et al. 1999, 2000a,b). These investigations have demonstrated consistently that vermicomposted organic wastes can have beneficial effects on plant growth independent of nutrient transformations and availability. Whether they are substituted into greenhouse horticultural soilless container media or used as field amendments, vermicomposts have consistently improved seed germination, enhanced seedling growth and development, and increased plant flowering, fruiting and productivity much more than could be possible from the mere conversion of mineral nutrients into more plant-available forms (Atiyeh et al. 1999, 2000a,b,c, 2001, 2002). The greatest plant growth responses and yields have occurred usually when vermicomposts constituted a relatively small proportion (10–40 %) of the total volume of the plant growth medium into which they are substituted. Usually, greater proportions of vermicomposts substituted into growth media, have not increased plant growth as much as smaller amounts possibly because of high salt contents in the higher proportion of vermicompost. There have been suggestions that the dramatic increases in microbial activity in organic matter by earthworms (Edwards & Fletcher 1998) could result in production of significant quantities of plant growth regulators such as IAA, gibberellins and cytokinins by microorganisms (Krishnamoorthy & Vajranabhiah 1986; Edwards 1998). Large amounts of humic substances are produced during vermicomposting and these have been reported to have positive effects on plant growth independent of nutrition (Chen and Aviad 1990; Atiyeh et al. 2002). The focus of this paper is to investigate the effects of a range of concentrations of humic acids extracted from vermicompost on greenhouse plant growth.

Materials and Methods

Humic acids were extracted from cattle manure, food waste and paper waste vermicomposts using an alkali/acid fractionation procedure (Valdrighi et al. 1996). In the first experiment, marigolds (*Tagates patula* v. Antigua Gold F1), peppers (*Capsicum anuum grossum* v. King Arthur) and strawberries (*Fragaria ananasa* v. Tribute) were used as test plants. Seeds of marigolds and peppers and bare root seedlings of strawberries were sown into 30 cm pots containing soilles container medium, Metro-Mix 360 to which 0, 250 or 500 mg humate kg^{-1} dry weight were added. In the second experiment, seeds of tomatoes (*Lycopersicon esculentum* v. Rutgers) were sown in 10 cm plastic pots filled with Metro-Mix 360 to which humates, that were extracted from pig manure vermicompost, were applied to provide a range of 0, 20, 100, 150, 200, 250, 500, 1000, 2000, 4000 mg of humates kg^{-1} of container medium. After sowing, all pots were placed in a mist house for seven days. After germination, marigold, pepper and tomato seedlings were thinned to one plant per pot and the pots were moved into an environmentally-controlled glasshouse. All plants were watered daily with 100 ppm of Peters Professional plant nutrient solution to ensure that nutrient availability was not the factor responsible for changes in plant growth. Peters Professional is a water-soluble fertilizer that is recommended for continuous liquid feed programs of plants, and contains 7.77 % NH_4–N, 12.23 % NO_3–N, 10 % P_2O_5, 20 % K_2O, 0.15 % Mg, 0.02 % B, 0.01 % Cu, 0.1 % Fe, 0.056 % Mn, 0.01 % Mo, and 0.0162 % Zn. Twenty-one days after sowing, plant heights and total leaf areas of each of the marigold, pepper and tomato seedlings were measured. Plants were then harvested, separated into shoot and root portions, and oven-dried at 60 °C for three days to determine their shoot and root dry weights. Forty-two days after planting, the same measurements were taken of the strawberry plants, as well as the number of fruits and fruit fresh weight. The experiments were laid out in completely randomized design with 8 replications. Data were analyzed statistically by one-way ANOVA in a general linear model using SAS (SAS Institute 1990). Important factors such as mean plant height, leaf area, shoot and root biomass were separated statistically, with humic acid concentrations as the main factor. Least Significant Difference (LSD) at $P \leq 0.05$ was used to separate significant differences between treatment means.

Results and Discussion

Humic acids extracted from vermicomposts, substituted into to a commercial soilless, ranging from 250–1000 mg kg^{-1} planting medium (Metro-Mix 360) increased the root dry wt of marigolds, peppers, tomatoes and strawberries (Fig. 1) significantly and increased fruit weights of strawberries significantly ($P \leq 0.05$) (Fig. 2). Other vegetative parts such as shoot dry wts and leaf areas (data not shown) increased considerably on plants grown in humic acid-amended MM360 but these increases were not significantly different ($P \leq 0.05$) from those of plants grown in MM360 only. These experiments provide clear evidence for some biological mechanism by which vermicomposts can produce significant increases in overall plant productivity, independent of nutrient availability. The results from mixing the container media (MM360) with

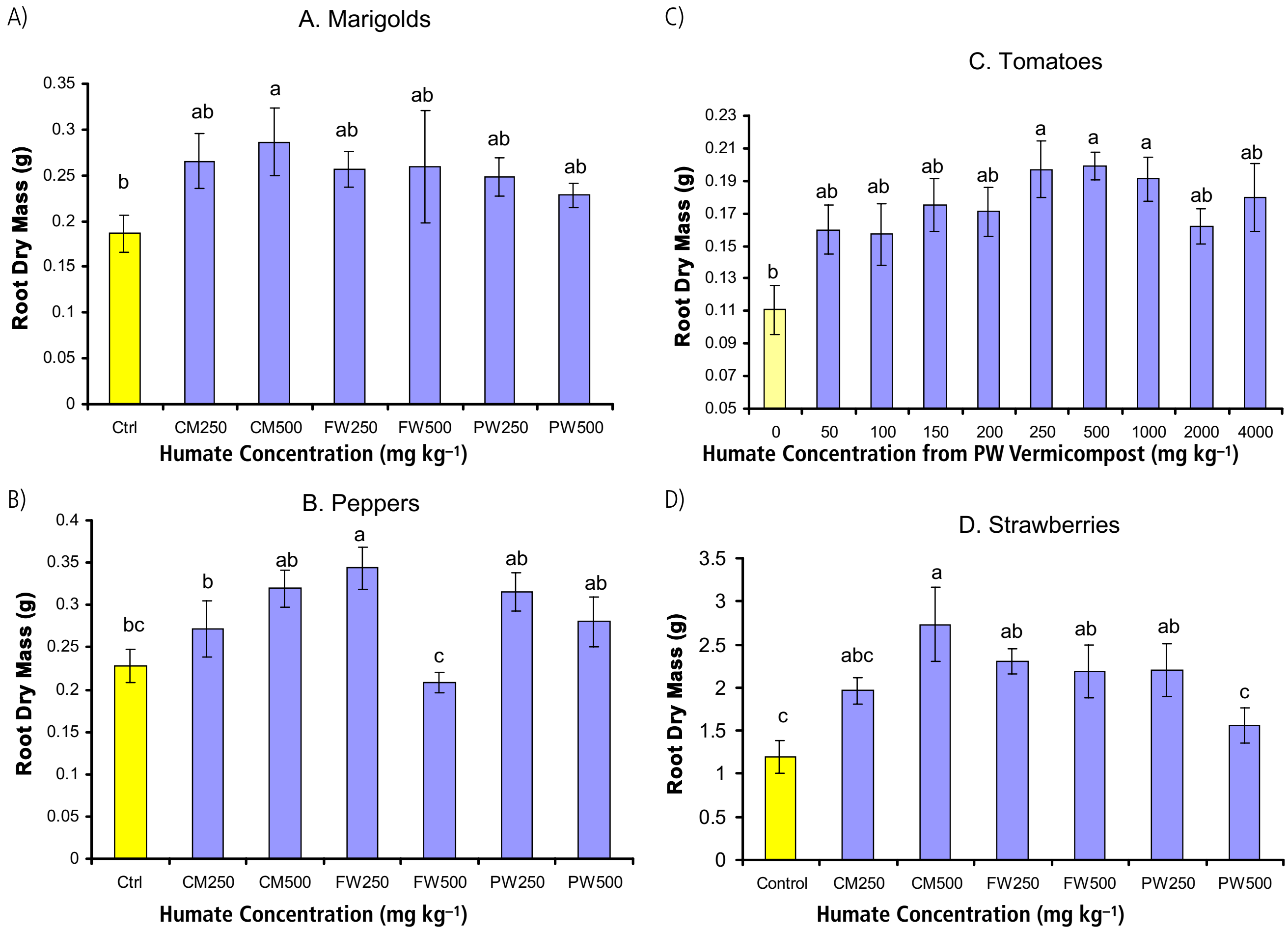

Fig. 1. Effects of humates derived from cattle manure, food waste and paper waste vermicomposts on A) root dry mass of marigolds; B) root dry mass of peppers C) root dry mass of tomatoes D) root dry mass of strawberries. Columns (Means ± SE) followed by the same letter(s) are not significantly different ($P < 0.05$). CM: Cow Manure; FW: Food Waste; PW: Paper Waste

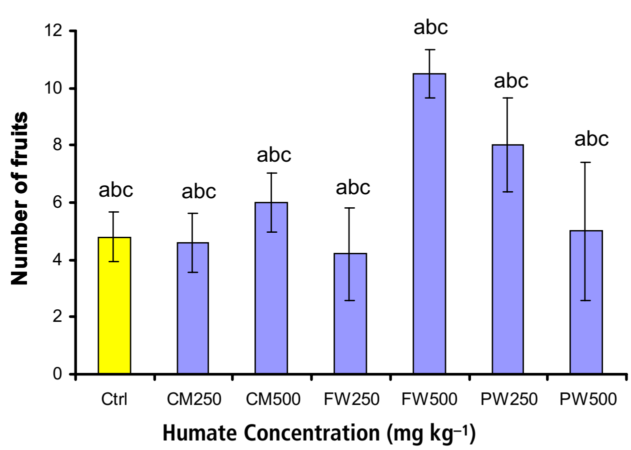

Fig. 2. Effects of humates derived from cattle manure, food waste and paper waste vermicomposts on number of fruits of strawberries. Columns (Means± SE) followed by the same letter(s) are not significantly different ($P < 0.05$). CM: Cow Manure; FW: Food Waste; PW: Paper Waste

a range of concentrations of vermicomposts-derived humic acids increased plant growth, in a pattern that was very similar to the growth responses of marigolds and other crops i.e. relatively large responses at low application rates (Atiyeh et al. 2002). As a general pattern, plant growth increased in response to treatments of the plants with 50–500 mg kg^{-1} humic acids, but decreased significantly ($P \leq 0.05$) when the concentrations of humic acids in the container medium exceeded 500–1000 mg kg^{-1} (Atiyeh et al. 2002). Mechanisms suggested to account for this stimulatory effect of humic substances at the low concentrations reported are numerous, 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 uptake of soil nutrients, and soil physical conditions. There is a further hypothetical explanation for the hormone-like mode of action of humic acid acids in these experiments. In our laboratory, we have extracted plant growth hormones such as indole acetic acid, gibberellins and cytokinins from vermicomposts in aqueous solution and demonstrated that these can also have significant effects on plant growth (Chen and Aviad 1990). However, such substances may be relatively transient in soils and it is possible that plant growth regulators such as IAA, which are water-soluble and light sensitive, may become adsorbed on to humates and thereby became much more persistent and act in conjunction with them to influence plant growth. This hypothesis 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 increased lateral root emergence, root elongation and plasma membrane H+ -ATPase activity of maize roots. This research provides clues as to how vermicomposts influence plant germination, growth flowering and yields so dramatically over and above their content of readily-available nutrients.

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