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Original article

Effects of humic acids from vermicomposts on plant growth

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Abstract

The interactions between earthworms and microorganisms can produce significant quantities of plant growth hormones and humic acids which act as plant regulators. Experiments were designed to evaluate the effects of humic acids extracted from vermicompost and compare them with the action of commercial humic acid in combination with a commercial plant growth hormone, indole acetic acid (IAA) which is a commonly found in vermicomposts. In the first experiments, humic acids were extracted from cattle, food and paper waste vermicomposts. They were applied to a plant growth medium, Metro-Mix360 (MM360), at rates of 0, 250 or 500 mg humates kg^{-1} dry wt. of MM360, to marigold, pepper, and strawberry plants in the greenhouse. Substitution of humates ranging from 250 to 1000 mg kg^{-1} MM360 increased the growth of marigold and pepper roots, and increased the growth of roots and numbers of fruits of strawberries significantly. In other experiments, humic acids extracted from food waste vermicomposts were applied at a rate of 500 mg kg^{-1} dry wt. of MM360, singly or in combination with IAA at a rate of 10^{-5} μM, to pepper seedlings. This experiment was designed to compare the differences in effects between the most effective dosage rate of humic acid from food waste, a phytohormone (IAA), and a commercial source of humic acid. The numbers of pepper flowers and fruits increased significantly in response to treatment with humic acid, IAA and a combination of humic acid and IAA. Peppers treated with humic acids extracted from food waste vermicomposts produced significantly more fruits and flowers than those treated with commercially-produced humic acids.

Keywords: Humic acids; Vermicomposts; Plant growth regulators; Earthworms; Marigolds; Peppers; Strawberries

1. Introduction

There have been many studies of the production of plant growth-regulating substances by mixed microbial populations in soil, but relatively few investigations into their availability to plants, persistence and fate in soils or effects on plant growth [2]. It has been 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 in commercially-available plant growth media, and was too much to be explained solely through influence of earthworm activity on plant nutrient quality and availability [9]. These workers 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 their nutrient contents balanced to these of comparable growth media. Moreover, the growth patterns of the plants, including 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

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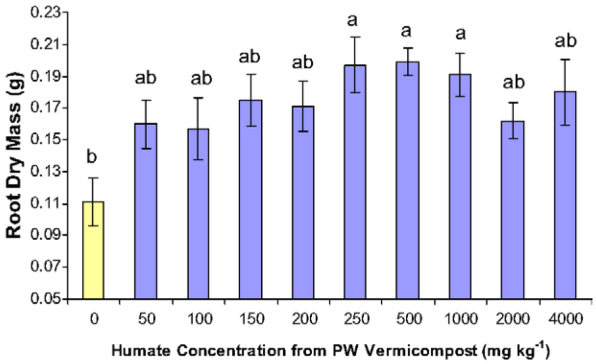

Fig. 1. Effects of humates derived from paper waste vermicomposts on root dry mass of tomatoes. Columns (mean ± S.E.) followed by the same letter(s) are not significantly different ($P < 0.05$). All received equal nutrients.

production of plant growth-influencing substances e.g. humic acids or free enzymes, being responsible. In recent years, humic substances have been shown to increase yields of corn and oats, tobacco roots, soybeans, peanuts, and clover; chicory plants, tropical crops and other crops [10]. More recently, workers have reported increases in the growth of crops grown in planting media amended with humic acids that were extracted from vermicompost [1,6]. These reports hypothesized that plant growth hormones may become adsorbed on to humic fractions so the plant growth response is a combined hormonal/humic one.

The experiments reported here summarize the results showing positive effects of additions of humic acids into soil-less planting media (MM360) in the greenhouse [1,6]. Other experiments were made to compare the effects of humic acids extracted from food waste vermicomposts to those from humic acids produced commercially and a synthetic plant growth hormone, indole acetic acid (IAA).

2. Materials and methods

Humic acids were extracted from cattle manure, food waste and paper waste vermicomposts using a standard alkali/acid fractionation procedure [12] which produced 2.5 g humate from 1 kg vermicompost. In the first experiment, marigolds (*Tagates patula* v. Antigua Gold F1), peppers (*Capsicum annuum 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 a soil-less container bedding plant medium Metro-Mix (MM360) to which 0, 250 or

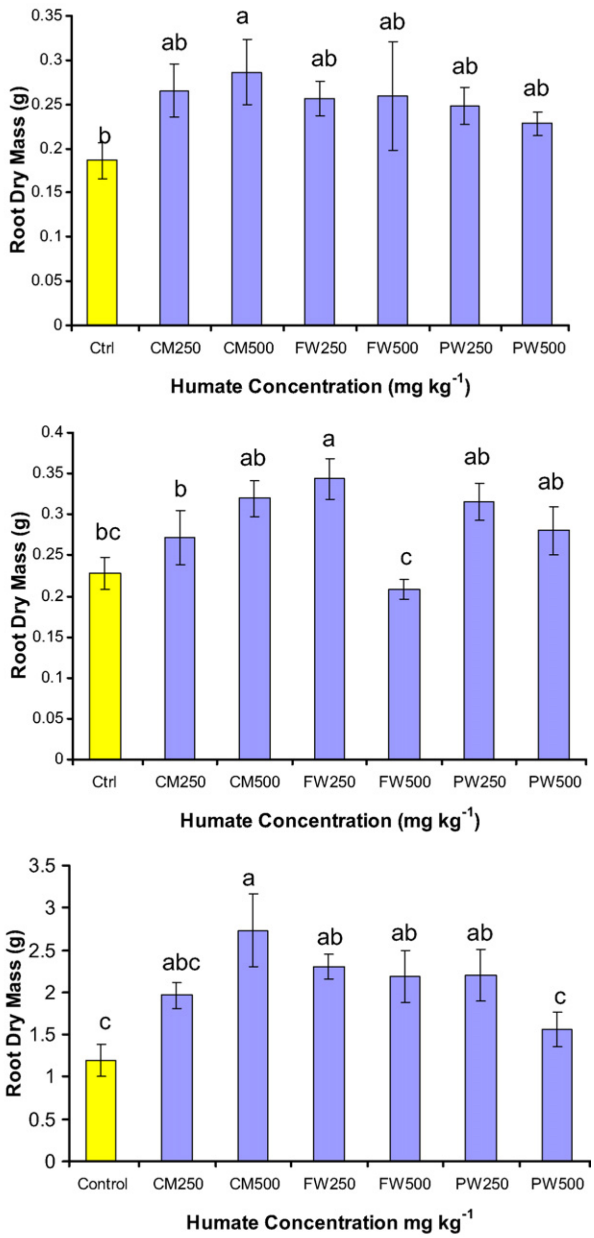

Fig. 2. Effects of humates derived from cattle manure, food waste and paper waste vermicomposts on A) root dry mass of marigolds; B) root dry mass of peppers C) root dry mass of strawberries. Columns (mean ± S.E.) followed by the same letter(s) are not significantly different ($P < 0.05$). CM: cow manure; FW: food waste; PW: paper waste. All received equal nutrients.

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 MM360 to which humates, that were extracted from pig manure vermicompost, were applied

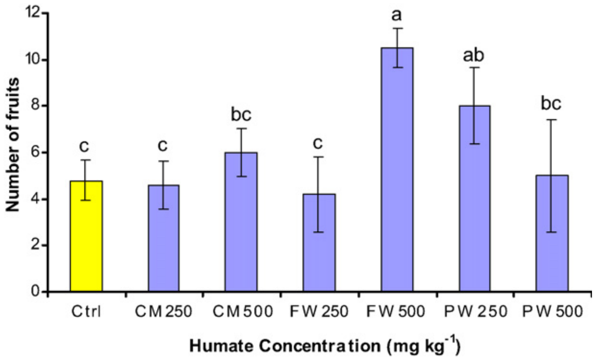

Fig. 3. Effects of humates derived from cattle manure, food waste and paper waste vermicomposts on number of fruits of strawberries. Columns (mean ± S.E.) followed by the same letter(s) are not significantly different ($P < 0.05$). CM: cow manure; FW: food waste; PW: paper waste. All received equal nutrients.

to provide a range of application rates: 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 7 days. After germination, marigold, pepper and tomato seedlings were thinned to one plant per pot and the pots were moved into an environmentally-controlled greenhouse. All plants were watered daily with 100 ppm of 20–10–20 ppm Peters Professional plant nutrient solution to ensure that nutrient availability was not the factor, responsible for changes in plant growth, by saturating the plants with as much as nutrients as they need. Peters Professional is a water-soluble fertilizer recommended for continuous liquid feed of bedding 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 marigold, pepper and tomato seedling was measured. Plants were harvested, separated into shoot and root portions, and oven-dried at 60 °C for 3 days to determine their shoot and root dry weights. Forty-two days after planting, the same measurements were taken on the strawberry plants, as well as counting the numbers and fresh weights.

In another series of experiments, three pepper seeds (*C. annuum* v. California wonder) were sown into 11.5 cm pots filled with MM360 and treated with either commercially-extracted humic acids, commercially-extracted humic acids together with IAA, humic acids extracted from food waste vermicompost, humic acids extracted from food waste vermicompost as well as IAA, or only IAA. Humic acids were applied at a rate of 500 mg kg^{-1} of MM360 and IAA at a concentration of 10^{-5} μM in solution into the planting media to achieve saturation. All pots were placed in a mist house for 10 days. Following germination, plants were thinned to one plant per pot. Each pot was fertilized by saturating the media with 100 ppm Peter's Solution daily. Plant heights, numbers of floral buds, flowers and fruits were assessed weekly for 13 weeks. On the 13th week, the plants were harvested to determine leaf areas, dry root weights, dry shoot weights, plant heights, numbers of fruits and total weights of fruits for each plant. Total C and N in the leaf tissues were determined by combustion using a Carlo Erba NA 1500 Series 2 apparatus (Milano, Italy). The experiments were laid out in the greenhouse in a completely randomized design with 10 replications. Data were analyzed statistically by one-way ANOVA in a general linear model using SAS (SAS Institute, 1990). Parameters such as mean plant heights, leaf areas, 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 identify significant differences between treatment means.

3. Results and discussion

Substitution of humic acids into soil-less MM360 at rates ranging from 250 to 1000 mg kg^{-1} planting medium (MM360) (Fig. 2A–C) increased root dry weights of marigolds, peppers and number of fruits of strawberries significantly ($P \leq 0.05$). The same range of humic acids (Fig. 3) substituted into MM360 (250–1000 mg kg^{-1}) increased the fruit weights of tomatoes significantly ($P \leq 0.05$) (Fig. 1). These experiments provide clear evidence for some biological mechanism by which vermicomposts can produce significant increases in overall plant growth and productivity, independent of nutrient availability. Mixing the container media (MM360) with a range of concentrations of vermicompost-derived humic acids increased plant growth, in a pattern very similar to the growth responses of marigolds and other crops to vermicomposts i.e. relatively large responses at low application rates [6]. 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} [6]. 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''

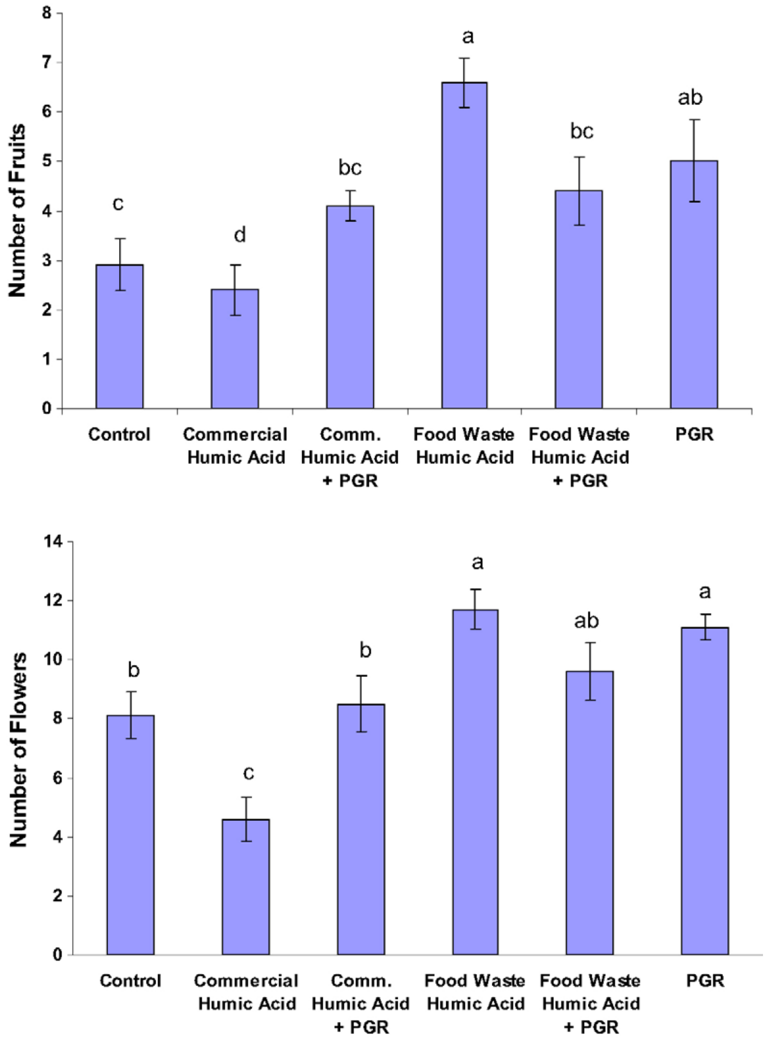

Fig. 4. Effects of humates derived food waste vermicomposts IAA and commercial humates on A) number of flowers and B) number of fruits of peppers. All received equal nutrients.

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 possible hypothetical explanation for the hormone-like mode of action of humic acids in these experiments. In our laboratory, we have extracted plant growth hormones such as IAA, gibberellins and cytokinins from vermicomposts in aqueous solution and demonstrated that these can also have significant effects on plant growth [8,9]. However, such substances may be relatively transient in soils and we hypothesize that of transient plant growth regulators such as IAA, which are water-soluble and degraded in light, may become adsorbed on to humates and thereby become much more persistent in soils and media and act over a much longer period to influence plant growth.

In the second series of experiments, humic acids extracted from food waste vermicomposts increased the numbers of flowers and fruits of peppers significantly ($P \leq 0.05$) compared with peppers planted in MM360 only (Fig. 4). However, the numbers of flowers and fruits did not differ significantly from those treated with IAA only (Fig. 4) demonstrating clearly that humic acid had an effect on pepper plants similar to the effects of a plant growth regulator such as IAA. The commercially-produced humic acids produced smaller increases in numbers of pepper fruits and flowers but numbers increased dramatically when IAA was added, demonstrating further that humic acids from food waste vermicomposts are superior to other humic acids since they influenced plant growth in a similar way to IAA and humates.

When plant growth hormones, such as auxins are applied at higher concentrations (beyond optimum), they could reduce the growth and development of plants [11]. Such a response could have occurred in peppers treated with a combination of humic acids from food waste vermicomposts and IAA, where the numbers of fruits were significantly fewer than those on peppers treated with humic acids from food waste vermicomposts plus IAA compared with the numbers on plants treated with IAA only. The combination of IAA and humic acid could have increased the concentration of plant growth hormones already present in the humic acids extracted from food wastes. In another report, exchangeable auxin groups were identified in the macrostructure of humic acids extracted from vermicomposts [7]. These workers also showed that these complexes increased lateral root emergence, root elongation and plasma membrane H+ -ATPase activity of maize roots. In our experiments, the total C and N in the plant tissues did not differ significantly between treatments showing clearly that the increases in some plant parameters we obtained were much greater than the effects of plant nutrients such as C and N. 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 [3,4,5].

Acknowledgements

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