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Improving physico-chemical and microbiological quality of compost tea using different treatments during extraction

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Compost tea is gaining much interest due to its nutritional, biostimulation and disease suppression benefits to the plants. Four experiments were carried out to determine the effect of incubation temperature, incubation periods, dilution rate and nutritional sources on the microbial populations, physico-chemical properties and indole acetic acid (IAA) levels. Incubation at 28°C showed the highest number of bacteria and aerobic N_2-fixing bacteria (ANFB), along with the highest levels of total nitrogen and IAA. All the microbial populations increased in proportion with increase in the incubation period; however, increasing the incubation more than 48 h did not show any significant improvement ($P \leq 0.05$) in the physico-chemical properties or IAA levels. All microbial numbers and chemical properties decreased by increasing the dilution rate. Adding a mixture of the three used nutrients (molasses "0.5% v/v", ammonium nitrate "0.5 g/L" and di-potassium phosphate "0.5 g/L") resulted in the highest microbial populations (except for ANFB) as compared to the molasses, or double the amount of each other chemical alone. This study show the optimum conditions for preparing compost tea with high microbiological and physico-chemical properties. The study includes ANFB, important for soil application, and IAA, important for foliar application, which have not been studied before in compost tea.

Key words: Compost tea extraction, factors, microbiology, physico-chemical, indole acetic acid (IAA), aerobic N_2-fixing bacteria (ANFB).

INTRODUCTION

The use of liquid organic fertilizers and biofertilizers containing beneficial microorganisms for supporting organic farming has gained much global interest (Naidu et al., 2010). Compost tea is a compost extract that is brewed, either aerobically or anaerobically, with microbial food sources of carbohydrate and protein. Such trend is

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commercially increasing, and is resulting in microbiologically enriched compost extract, commonly called "compost tea". Compost tea is used in agriculture either as soil amendment or as foliar application, and is a safe replacement for the potential hazards of costly chemical fertilizers and pesticides (Ingham, 1999; Pant et al., 2009; Radovich and Arancon, 2011).

The benefits of using compost teas in agriculture are: biostimulation and improvement of crop yield and quality, suppression of plant pathogenic microorganisms and, supplying the plant with water-soluble nutrients (Anonymous, 2007; Hegazy et al., 2013; Pane et al., 2014). In addition, compost extract enriches soil with microorganisms and "brings the soil back to life" (Martens, 2001). Such enrichment has a positive effect on the microbial selection, where the typical application rate of 150-200 L/ha changes the microbial composition towards more beneficial groups for the soil and plant (Hoitink and Boehm, 1999). Some of the benefits of these microbial groups are the production of plant growth promoters and chemicals such as siderophores, which reduce availability of iron for phytopathogens in the rhizosphere, tannins and phenols which inhibit most plant pathogens (Antonio et al., 2008). Other microbes are capable of nitrogen fixation and/or phosphate solubilization, making it available to plants (Glick et al., 1999). It is also reported that compost extract increases the carbon level and organic matter in soil, which help in building soil aggregates, and thus, improve soil structure and water holding capacity (Ha et al., 2008).

The production of compost extract with high quality depends on several factors, such as: adding nutritional sources, dilution rate and water quality, level of aeration, compost quality and age, and incubation time. Compost quality is also an important factor, which depends on the consistency of the used materials and the methods used for compost preparation. Some researchers consider the definition of compost "quality" is open-ended, because of the wide variety of benefits that compost provides (Shrestha et al., 2011). Generally, the extraction process should continue until most of the compost contents of soluble nutrients and microorganisms are extracted into the solution, where some authors adopt times of extraction and fermentation of one or two weeks (Pane et al., 2012).

Many compost tea producers include additives in order to increase the populations and diversity of microorganisms and to increase the level of plant disease suppression (Pane et al., 2012). Molasses, kelp extract, fish emulsion and rock dust have been used as cheap and commonly available nutritional sources (Ingham, 2005; Naidu et al., 2010). The additives would affect the C : N ratio and the forms of carbohydrates or nitrogen source in the extraction medium, which should change the composition of the microbial group such as bacteria, actinomycetes and fungi; however, not enough research has been done in this area (Pant et al., 2009; Naidu et al., 2010). Even though many studies have focused on the disease suppression aspect as affected by compost-to-water ratio, this ratio obviously affects the nutritional and microbial composition of the produced extract (Radovich and Arancon, 2011; Weltzien, 1990). A wide range of dilution rate was used in the extraction process, ranging from 1:1 to 1:50 (Weltzien, 1990; Zhang et al., 1998) with the most commonly used ration of 1:3 to 1:10 (Scheuerell and Mahaffee, 2004). It is also expected that the highly diluted extract could pose the risk of microbial contamination.

IAA is one of the most active auxins in plants, controlling many important physiological processes including cell development and division, playing a role in plant resistance to different pathogens, and microorganism-plant signaling. It is a product of several microorganisms, some of which are natural components of compost tea, and is proposed to contribute to plant growth and defense against pathogens (Lynch, 1985; Gravel et al., 2007; Hardoim et al., 2008).

In this study, we aimed to optimize the four major production variables, namely, incubation temperatures, incubation periods, compost dilution rate and additives of microbial food sources during compost extraction. In addition, we investigated the effect of these variables on compost extract aspects that has not been addressed before, which is the numbers of ANFB and the levels of IAA.

MATERIALS AND METHODS

Source of compost and preparation of compost teas

Garbage compost was obtained from the Cairo Organic Fertilizers Company, Cairo, Egypt, and was composed mainly of a household biodegradable wastes, after sorting out plastics, glass and metals at the site of composting. Based on the company's analyses, it has a 30% organic carbon, 1.0% total nitrogen, 35% moisture and pH 7.5±0.2. Compost teas were prepared according to the method of Ingham (2005) with some modifications. Compost extractions were done in four different experiments to measure the effects of: incubation temperatures, incubation periods, compost-to-water ratio and addition of microbial food sources. Each experiment consisted of four treatments, in a 50 L plastic bucket, and a working volume of 20 L for brewing. Garbage compost was sealed in a cotton bag and submerged into tap water in plastic bucket, and each was amended with microbial food source. The water used was pump aerated for 30 min to remove chlorine before addition to the compost. Compost soaking was done in the laboratory, while being aerated continuously (10 L/min air delivery per bucket through air stones). Samples were taken in three replicates for the microbiological and chemical analyses.

Experimental design and treatments

Four experiments were carried out indoors in the Agricultural Microbiology Department Laboratory, Faculty of Agriculture, Zagazig University, Egypt. Each experiment consisted of four treatments with three replications and the experimental design was a complete randomized. In all experiments, unless otherwise is mentioned, molasses was used at 0.5% (v/v), compost-to-water ratio was 1:20, incubation temperature was 28°C, and the incubation period was 48 h.

The first experiment involved aerated incubation of compost extracts at four different temperatures, namely 20, 28, 37 and 45°C for 48 h. The second experiment consisted of compost extracts incubated at different periods (12, 24, 48 and 72 h). The third experiment consisted of compost extracts incubated in different dilution ratios (1:10, 1:20, 1:30 and 1:40, compost: water on a weight/volume basis). The forth experiment involved aerated incubation of compost extracts with four different microbial food sources. In addition to molasses, ammonium nitrate and potassium phosphate were tested as cheap and available sources for the major nutritional elements required for plants (NPK), and sources for nitrogen and phosphorus required for microorganisms; also potassium phosphate contains a soluble form of phosphate, unlike other commercial chemical fertilizers. The tested treatments contained: 1) molasses (0.5% v/v), 2) ammonium nitrate (1 g/L), 2) di-potassium phosphate (1 g/L) and 4) molasses (0.5% v/v) plus ammonium nitrate (0.5 g/L) and di-potassium phosphate (0.5 g/L), which were added to each treatment in a bulk amount for the three replicates, followed by distributing them, and submerging the compost bags.

Physico-chemical analyses of compost teas

Physico-chemical analyses of compost teas (CT) were determined at the end of incubation in accordance with AOAC (2002). A pH meter (ORION 720A, Boston, USA) was used for determining the pH values, and a conductivity meter (HORIBA - HE-960CW) for the EC. Total nitrogen was measured using micro-Kjeldahle, and total phosphorus was measured colorimetrically using JENWAY 6305 UV-vis Diode Array Spectrophotometer, by the hydroquinone method. Total potassium was determined using a Carl Zeiss flame-photometer with acetylene burn.

Determination of indole acetic acid (IAA) in compost teas

IAA in the compost teas was assayed by modified procedure of Glickmann and Dessauxa (1995). CT were centrifuged at 5000 rpm for 15 min, then 1 ml of CT supernatant was added to 1 ml of Salkowski´s reagent, well mixed in a 3 l spectrophotometer cuvette, and the mixture was left in the dark for 30 min at room temperature. Rosy color developed means the presence of IAA and color density was measured using JENWAY 6305 UV-vis Diode Array Spectrophotometer at 530 nm. The level of IAA was estimated by standard IAA graph, and the results were expressed as μg IAA /ml.

Microbial analyses

Microbial populations in the garbage compost and compost tea, that is, bacteria, aerobic N_2-fixing bacteria, actinomycetes and fungal populations, were determined using plate count or most probable number (MPN) technique. Bacteria were enumerated on nutrient agar (Difco, 1985) and incubated at 30°C for 2 days. Enumeration of potential N_2-fixing bacteria as strict aerobes was done using the most probable number (MPN) technique of Abd-El-Malek (1971) on Ashby modified medium and incubated at 30°C for 7 days. It was enumerated as surface pellicle formation. Actinomycetes were enumerated on starch casein agar (Conn and Leci, 1998) and incubated at 28°C for 7 to 14 days, while fungi were enumerated on Martin's Rose bengal agar (Martin, 1950), and incubated at 25°C for 3–5 days, with three replicates of all microbial counts.

Statistical analysis

Data recorded in three replicates for the parameters in various treatments were subjected to the analysis of variance (ANOVA) according to Snedecor and Cochran (1980), using SPSS statistical package version 16.0 (SPSS Inc., Chicago, IL, USA) to quantify and evaluate the sources of variation. Duncan's multiple range test (DMRT) was applied to compare the mean performances of different treatments for the specific parameters under study and the rankings were denoted by superscripts in the relevant tables. Differences in means were compared at $P \leq 0.05$.

RESULTS AND DISCUSSION

In this study, four major microbial groups were determined, namely, bacteria, aerobic N_2-fixing bacteria, actinomycetes and fungi, as a measure for the biological activity and quality of the produced compost tea. Previous reports have shown that increasing the population and activity of microorganisms improve quality of compost tea, since it increases its effectiveness, support its binding to the foliage of the plant and contribute to plant health and systematic resistance to diseases (Kavroulakis et al., 2005; Scheuerell and Mahaffee, 2002; Naidu et al., 2010). In addition, certain bacterial groups, like the nitrogen fixing bacteria are important for soil fertility and as a safe alternative for the potential hazards of chemical nitrogen fertilizers (El-Aidy et al., 2012).

The effect of incubation temperatures during the preparation of compost tea on the microbial populations of bacteria, aerobic N_2-fixing bacteria, actinomycetes and fungi, is shown in Table 1. At an incubation temperature of 28°C, the numbers of bacteria was at the highest level, and numbers of aerobic N_2-fixing bacteria was signify-cantly higher ($P \leq 0.05$) than the numbers at 37 and 45°C. In contrast, the number of actinomycetes and fungi were at the highest level at incubation temperature of 45°C, being significantly higher ($P \leq 0.05$) than all other temperatures. Such higher number of actinomycetes and fungi is probably due to the survival of their thermophilic spores during the cooling stage of the compost. Also, increasing the temperature causes water evaporation, which results in more concentration of the nutrients, and therefore, promotes the growth of some microbial species (Pant, 2011). On the other hand, the low temperature may slow down the growth rate of the actinomycetes and fungi. Apparently, the best incubation temperature was 28°C, since it has the highest number of nitrogen fixing bacteria that are important for soil fertility.

Table 2 shows the effect of incubation periods during the preparation of compost tea on the previously mentioned microbial groups. All microbial groups showed the same trend by increasing their numbers in proportion

Table 1. Microbial populations of bacteria, aerobic N_2-fixing bacteria, actinomycetes and fungi, in compost teas under different incubation temperatures.

Incubation temperature	Total bacteria (log10 CFU/g)	ANFB (log10 CFU/g)	Actinomycetes (log10 CFU/g)	Fungi (log10 CFU/g)
20 °C	6.77 ± 0.57[b]	3.31 ± 0.09[c]	2.12 ± 0.06[a]	2.52 ± 0.09[a]
28 °C	7.07 ± 0.61[c]	3.42 ± 0.11[c]	2.29 ± 0.09[ab]	2.54 ± 0.09[a]
37 °C	6.72 ± 0.58[b]	3.2 ± 0.09[b]	2.38 ± 0.09[b]	3.11 ± 0.09[b]
45 °C	6.24 ± 0.54[a]	2.5 ± 0.08[a]	2.58 ± 0.05[c]	3.5 ± 0.09[c]

Different letters ([a] through [c]) represent significant differences ($P \le 0.05$) among numbers in the same column.

Table 2. Microbial populations of bacteria, aerobic N_2-fixing bacteria, actinomycetes and fungi, in compost teas under different incubation periods.

Incubation period (h)	Total bacteria (log10 CFU/g)	ANFB (log10 CFU/g)	Actinomycetes (log10 CFU/g)	Fungi (log10 CFU/g)
12	6.40±0.47[a]	2.24±0.10[a]	1.86±0.05[a]	2.11±0.12[a]
24	6.69±0.50[b]	2.58±0.13[b]	2.08±0.08[b]	2.32±0.13[b]
48	7.09±0.55[c]	3.35±0.21[c]	2.32±0.08[c]	2.58±0.11[c]
72	7.32±0.55[d]	3.9±0.25[d]	2.66±0.09[d]	3.21±0.14[d]

Different letters ([a] through [d]) represent significant differences ($P \le 0.05$) among numbers in the same column.

Table 3. Microbial populations of bacteria, aerobic N_2-fixing bacteria, actinomycetes and fungi, in compost teas under different compost dilution ratios.

Dilution ratios	Total bacteria (log10 CFU/g)	ANFB (log10 CFU/g)	Actinomycetes (log10 CFU/g)	Fungi (log10 CFU/g)
1:10 w/v	8.41±0.71[d]	5.23±0.31[c]	3.04±0.13[c]	3.41±0.15[c]
1:20 w/v	7.07±0.63[c]	3.34±0.30[b]	2.48±0.11[b]	2.5±0.08[b]
1:30 w/v	6.39±0.68[b]	2.88±0.45[a]	2.12±0.10[a]	2.34±0.07[ab]
1:40 w/v	6.16±0.67[a]	2.70±0.35[a]	2.04±0.08[a]	2.22±0.09[a]

Different letters ([a] through [d]) represent significant differences ($P \le 0.05$) among numbers in the same column.

with the incubation period, with incubation period of 72 h being significantly higher ($P \le 0.05$) than all other periods for all microbial groups. This is most likely due to the increasing extraction of the soluble material and microorganisms from the compost into the liquid, which is generally beneficial for agricultural application. Extraction of a larger amount of soluble material from the compost, allows more nutritional sources for the beneficial microorganisms, and also, more nutrients available to the plants (Anonymous, 2007). On the other hand, long incubation period is not always preferred, as it may allow the oxygen to be consumed by the aerobic micro-organisms, especially if pump aeration is not performed, hence, the anaerobic microorganisms will grow. In addition, it would not be economical to increase the incubation period more than 72 h.

The populations of the different microbial groups as affected by the dilution rate during the compost tea incubation, were determined and presented in Table 3. Generally, the numbers of all microbial groups have decreased as the dilution rate increased. The decreasing rate between the first two dilutions (1:10 and 1:20) was much higher, being always significantly different ($P \le 0.05$) in all microbial groups, than the decreasing rate between the other dilutions (e.g., the difference between 1:30 and 1:40 is not significant ($P \le 0.05$) in the three microbial groups ANFB, actinomycetes and fugi). Even though dilution 1:10 has the highest microbial

Table 4. Microbial populations of bacteria, aerobic N_2-fixing bacteria, actinomycetes and fungi in compost teas under different nutritional sources.

Nutritional sources	Total bacteria (log10 CFU/g)	ANFB (log10 CFU/g)	Actinomycetes (log10 CFU/g)	Fungi (log10 CFU/g)
Molasses	7.06±0.61[c]	3.44±0.21[c]	2.32±0.15[b]	2.55±0.18[b]
NH_4NO_3	6.48±0.45[a]	1.53±0.13[a]	2.24±0.15[b]	2.40±0.19[b]
K_2HPO_4	6.21±0.44[b]	4.50±0.23[d]	2.08±0.11[a]	1.89±0.15[a]
Molasses + NH_4NO_3+ K_2HPO_4	7.54±0.44[d]	2.42±0.20[b]	2.56±0.14[c]	3.34±0.19[c]

Different letters ([a] through [d]) represent significant differences ($P \leq 0.05$) among numbers in the same column.

populations, it would not be recommended since it may be so concentrated that not all the nutrients and microorganisms are extracted. Dilution rate of 1:20 could be the best, as it should allow a full pull-out of the compost extractable components, and at the same time, keep the produced tea with enough level of nutrients and microorganisms (Anonymous, 2007; Ingham, 1999). In addition, it was reported that tea dilution rate of 1:50 has less efficiency in disease suppression as compared to the rates of 1:3 and 1:10 (Weltzien, 1990). It is also expected that higher levels of dilution would render the produced tea with so little nutrients, that it would not allow a normal growth or survival of the microorganisms.

As microorganisms are fundamental component of the compost extract, and are influenced by the nutritional additives during the extraction process (Bess, 2000), determining the effect of some nutritional sources was carried out in the study. Table 4 shows the effect of adding different nutritional sources on the four microbial groups. Molass (0.5% v/v) as a commonly added component during the extraction, was used as a control. Adding ammonium nitrate alone resulted in a considerable decrease in the numbers of ANFB, which is reasonable since this group of bacteria is known to be negatively affected by the presence of any nitrogen source in the media. The presence of potassium phosphate alone, however, increase the numbers of ANFB to its maximum level as compared to all other treatments, and signify-cantly decreased ($P \leq 0.05$) the numbers of all other groups to their lowest levels. Obviously, the reason for the decreasing numbers of the other groups is that they require an external source of nitrogen to grow and proliferate, which is absent in this treatment. The mixture of the three nutrients (molass, ammonium nitrate and potassium phosphate) resulted in a significant increase ($P \leq 0.05$) in the population of all microorganisms (except for the ANFB) for the reasons mentioned before. These results coincide with previous reports (Naidu et al., 2010) stating that adding the microbial nutrients is helping beneficial microorganisms to be active, and more likely to survive and be transferred to the soil or plant surfaces. Additionally, introducing nutrients and the consequent increase of microbial population can boost the biological control efficiency, but the selection of the additives must be done with extreme caution (Scheuerell, 2003). For instance, the addition of molasses alone was found to support the growth of human bacterial pathogens if they already exist in the compost to begin with (Duffy et al., 2004), and thereby abolishing the ability for disease suppressive characteristics of compost tea (Scheuerell, 2003). Molass was significantly better ($P \leq 0.05$) nutrient for bacteria as compared to either ammonium nitrate or potassium phosphate alone. It was also better than potassium phosphate alone for fungi and actinomycetes. That might be due to the chemical composition of the molass, which is a complex carbohydrate containing a variety of minerals (Castle and Watson, 1985).

In all these experiments, the numbers of total aerobic bacteria were the highest among other microbial groups, represented in the average of $\log_{10}$ 6.84 cfu/ml. Such number is well appropriate for offering the treated plants with enough microbial coverage for foliar pathogen suppression. On the other hand, actinomycetes were the lowest group in its population (average of $\log_{10}$ 2.31 cfu/ml) which is in accordance with previous reports stating that compost teas are not appropriate media for extraction and growth of actinomycetes (Anonymous, 2014).

Physico-chemical properties are very important factor in determining the value of the produced compost tea. Most important are the major nutritional elements that are necessary for all plant in large amounts. Determining the changes in IAA as a result of the different treatment is also important, especially for the foliar plant treatment, even though it has not been studied before.

Table 5 shows the effect of different incubation temperatures on physico-chemical analyses (pH, E.C., total N, P and K) and IAA content in compost teas after48 h. Total nitrogen was significantly higher ($P \leq 0.05$) under the incubation temperature of 28°C as compared to the other incubation temperatures. Similar behavior was shown in the IAA, with significantly higher level detected at the same temperature as compared to the others. These results correlates very well with those of the

Table 5. Effect of different incubation temperatures on physico-chemical analyses and IAA content in compost teas after 48 h.

Treatments (°C)	pH	E.C. (ds/m)	Total N (mg/L)	Total P (mg/L)	Total K (mg/L)	IAA (µg/L)
Incubation at 20	7.4[a]	1.51[a]	1.70[a]	16.73[a]	450.0[a]	2.51[a]
Incubation at 28	7.4[a]	1.43[a]	1.86[b]	16.73[a]	452.0[a]	3.17[b]
Incubation at 37	7.3[a]	1.47[a]	1.76[a]	16.66[a]	455.5[a]	2.73[a]
Incubation at 45	7.2[a]	1.51[a]	1.74[a]	16.73[a]	451.0[a]	2.65[a]

Different letters ([a] and [b]) represent significant differences ($P \leq 0.05$) among numbers in the same column.

Table 6. Effect of different incubation periods on physico-chemical analyses and IAA content in compost teas incubated at 28°C.

Treatments (h)	pH	E.C. (ds/m)	Total N (mg/L)	Total P (mg/L)	Total K (mg/L)	IAA (µg/L)
Incubation for 12	7.7[b]	1.54[a]	1.72[a]	16.59[a]	450.0[a]	1.51[a]
Incubation for 2	7.5[ab]	1.50[a]	1.88[b]	16.73[a]	455.0[a]	2.87[b]
Incubation for 48	7.4[ab]	1.57[a]	1.94[b]	16.66[a]	460.5[a]	3.34[c]
Incubation for 72	7.2[a]	1.57[a]	1.96[b]	16.73[a]	467.0[a]	3.65[c]

Different letters ([a] through [c]) represent significant differences ($P \leq 0.05$) among numbers in the same column.

Table 7. Effect of compost dilution ratios on physico-chemical analyses and IAA content in compost teas incubated at 28°C for 48 h.

Treatments (w/v)	pH	E.C. (ds/m)	Total N (mg/L)	Total P (mg/L)	Total K (mg/L)	IAA (µg/L)
Compost dilution ratios 1:10	7.6[b]	1.62[b]	3.14[c]	25.83[d]	634.0[d]	3.41[b]
Compost dilution ratios 1:20	7.4[a]	1.50[b]	1.86[b]	16.73[c]	451.0[c]	3.17[b]
Compost dilution ratios 1:30	7.3[a]	1.34[ab]	1.31[a]	11.48[b]	366.5[b]	2.83[a]
Compost dilution ratios 1:40	7.3[a]	1.16[a]	0.97[a]	7.56[a]	280.0[a]	2.77[a]

Different letters ([a] through [d]) represent significant differences ($P \leq 0.05$) among numbers in the same column.

microbial growth, where the high population of ANFB were shown at 28°C, explaining the increase of total nitrogen. Also, the higher levels of IAA at 28°C may be due to the highest numbers of bacteria shown at this incubation temperature. The ability of several bacterial species to synthesize IAA has been reported before (Ali et al., 2009). All other parameters did not show any significant difference due to the temperature variations.

Table 6 shows the effect of different incubation periods of extraction on physico-chemical analyses and IAA content in compost teas. The factors that were affected clearly were the total nitrogen and IAA, where both of them increased significantly ($P \leq 0.05$) in response to increasing the incubation period. Forty eight hours, however, seem to be the most suitable, since further increase in the incubation period did not result in significant increase in both of them, making such increase not economically valuable. The pH values were also affected, as they slightly decreased with increase in the incubation period, however, all other parameters were not affected. Also, the results for the pH were close to those obtained by Pant et al. (2012), who recorded a pH value of 7.4 for the compost tea produced from food waste vermicompost in a 1:10 dilution ratio. Conversely, the E.C. level in their work (1 ds/m) was clearly lower than ours (1.6 ds/m for the same dilution rate), which is likely due to their use of deionized water in their experiment, while we used tap water.

The effect of the compost dilution ratios on physico-chemical analyses and IAA content was studied in compost teas incubated at 28°C for 48 h (Table 7). All values of the studied parameters were decreased with increase in the dilution rate. It is not practical, however, to produce a highly concentrated compost extract, as it would not be able to extract all the nutrients and microorganisms from the compost, so, a dilution of 1:20 is probably the most suitable to use. Previous studies (Pant, 2011) have shown that the application of

Table 8. Effect of different microbial nutritional sources on physico-chemical analyses and IAA content in compost teas after 48 h.

Treatments	pH	E.C. (ds/m)	Total N (mg/L)	Total P (mg/L)	Total K (mg/L)	IAA (µg/L)
Molasses	7.4[a]	1.67[a]	1.73[a]	16.80[a]	453.0[a]	3.60[a]
NH_4NO_3	7.3[a]	2.65[b]	35.22[c]	16.73[a]	451.0[a]	3.64[a]
K_2HPO_4	7.5[a]	2.68[b]	1.76[a]	156.94[c]	875.5[c]	3.71[a]
Molasses + NH_4NO_3 + K_2HPO_4	7.4[a]	3.36[c]	19.56[b]	79.73[b]	641.0[b]	5.65[b]

Different letters ([a] through [c]) represent significant differences ($P \leq 0.05$) among numbers in the same column.

vermicompost tea increased plant yield and root growth, and that the result of the extract dilution (1:10 to 1:100) was generally linear in decrease in plant growth. Almost the same trend was shown for the levels of tissue nitrogen, phytonutrient and microbial activities in soil. The decreasing rate of the different parameters was obviously faster in N, P and K, than the three other studied parameters. Edwards et al. (2006) found that there was no significant difference on tomato seedlings growth response with the applications of vermicompost teas with 1:25 and 1:10 ratios. Other researchers (Touart, 2000; Scheuerell and Mahaffee, 2002), however, reported effective results on disease suppression and yield improvement when limiting compost to water ratio to 1:10.

The effect of microbial nutritional sources on the physico-chemical characteristics and IAA content in compost teas were also studied (Table 8). As expected, total nitrogen was at its highest level (316.7) when ammonium nitrate was added to the extraction solution, and with lesser extent when a mixture of the three chemicals was added. The same trend was observed with total phosphorus and total potassium where their levels reached their peaks (224.2 and 875.5, respect-tively) when potassium phosphate was added to the extraction solution. IAA and E.C. levels increased with the presence of the mineral nutrients and reached their peaks with the mixture of all components. IAA was also increased in all treatments containing nutritional sources as compared to the molasses alone, with the collective nutritional mixture reaching the maximum level. Such higher IAA levels are likely due to its synthesis by the extracted microbial population and the supporting nutrients. It is already reported that several strains of bacteria such as *Bacillus, Pseudomonas, Escherichia, Micrococcus* and *Staphylococcus* genera are able to synthesize IAA (Ali et al., 2009). At a temperature of 28°C, the highest population of bacteria (Table 1) was accompanied by the highest level of IAA concentration (Table 5). In the experiments of incubation periods and dilution rate, the correlation is even more obvious. In the experiment of the nutritional sources, the number of bacteria decreased by using NH_4NO_3 and K_2HPO_4 when compared with the molasses alone (Table 4), while the IAA levels did not change significantly (Table 8). Such deviation from the previous trend might be explained by a positive selection for the two mineral compounds toward promoting the growth of IAA-producing bacterial species, while molass increase the bacterial population in a general manner. When molass and the two mineral compounds were combined together, both the general bacterial population and the IAA-producing species (reflected by the much higher level of IAA) were increased significantly.

Conclusion

This study demonstrated the optimum conditions for compost extraction which enhances the microbial activity, physico-chemical characters and IAA content. Incubation temperature of 28°C was most suitable for growing important microbial groups such as bacteria (producing IAA and biological activity) and aerobic nitrogen-fixing bacteria. Also, at this temperature, the highest levels of IAA and nitrogen content were shown. The number of all microbial groups increased due to increasing incubation periods up to 72 h, and similar trend was established in the levels of IAA and nitrogen content; however, in our study, there was no significant increase in both of them after 48 h. Among the tested dilution rates, the dilution of 1:20 (w/v) seems to be most appropriate in terms of microbial and nutritional contents. Enriching the extraction solution with molasses, NH_4NO_3 and K_2HPO_4 resulted in the highest number of all microorganisms, except for the ANFB. The same result was true with the IAA, where it reached its maximum level with the mixture of the three additives.

Conflict of interests

The authors did not declare any conflict of interest.

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