Available online at www.elixirpublishers.com (Elixir International Journal)

Agriculture

Elixir Agriculture 85 (2015) 34716-34721

ISSN: 2229-712X

Germination and early growth of eucalyptus plants in commercial potting substrate amended with different rates of vermicompost

Mohammad R* and Asghari Poor

Young Researchers Club, Shirvan Branch, Islamic Azad University, Shirvan, Iran.

ARTICLE INFO

Article history:

Received: 4 December 2012;

Received in revised form:

22 August 2015;

Accepted: 29 August 2015;

Keywords

Alternative media;

Organic amendment;

Productivity;

Vermicompost;

Eucalyptus

ABSTRACT

Vermicompost has been promoted as a viable alternative container media component for the horticulture industry. The purpose of this research was to investigate the use of vermicompost at different points in the production cycle of eucalyptus seedlings. The incorporation of vermicompost of city refuse origin into germination media up to 20% v/v enhanced shoot and root weight, leaf area, and shoot:root ratios of seedlings; however amendment with vermicompost had little influence on seed germination. Moreover there was no effect on the germination of seed of any species. When seedlings of eucalyptus were transplanted into 6-cell packs there was greater plant growth in media amended with vermicompost compared to the control media, and the greatest growth when vermicompost was amended into both the germination and transplant media. This effect was increased when seedlings in the transplant media were irrigated with water containing fertilizer.

Introduction

Eucalyptus seedlings are commonly produced in the greenhouse in mixtures of commercial soilless bedding plant growth media with fertilizers before transplanting outdoors. Over the last few years, however, due to rising costs and uncertain future availability of peat moss, there is a need in the transplanted seedling industry for alternative components in commercial potting substrates. In addition, because peat-based commercial potting substrates have low ion exchange capacities there is concern about the environmental impact of leachates containing high concentrations of chemical fertilizers (5).

Recently, increased importance is being given to the potential of vermicomposts, which are products of a mesophilic, aerobic biodegradation and stabilization of organic materials, produced through interactions between earthworms and microorganisms, as plant growth media and soil amendments (3).

They contain nutrients in forms that are readily taken up by the plants, such as nitrates, exchangeable phosphorus, and soluble potassium, calcium, and magnesium (Edwards and Burrows, 1988; Orozco et al., 1996). There are reports on the presence of plant growth regulators in vermicompost (Krishnamoorthy and Vajrabhiah, 1986). The increases in plant growth have mostly been related to improvements in physical and chemical structure of the growth media. However, the use of vermicompost appears to affect plant growth in ways that can not be directly linked to physical or chemical properties (Dash and Petra, 1979). It seems likely that some growth promotion is due to plant hormone-like activity related to microflora associated with vermicomposting and to metabolites produced as a consequence of secondary metabolism (Parle, 1963; Tomati et al., 1987; Atiyeh et al., 2002). Based on all these characteristics, vermicompost should have great commercial potential in the horticultural industry as container media for growing bedding.

There are only few research studies that have examined the growth of vegetable and bedding plants in potting media mixed with earthworm-processed organic wastes (Edwards and Burrows, 1988; Wilson and Carlile, 1989; Subler et al., 1998; Atiyeh et al., 1999). In all of these studies, it was confirmed that earthworm-processed organic wastes have beneficial effects on the growth and development of plant seedlings.

Substitutions of different proportions of vermicomposts, produced commercially from cattle manure, food waste or paper waste, into corresponding proportions of MM360 (a commercial soil-less greenhouse bedding plant medium), have been shown in a laboratory and greenhouses to increase the rates of germination, growth and flowering of a range of greenhouse ornamental and vegetable seedlings significantly including marigolds (Atiyeh et al., 2001), tomatoes (Atiyeh et al., 2000), and peppers (Arancon et al., 2004), even when all necessary mineral nutrients were supplied.

The length, weight, number of seeds, number of shoots in Vinca rosea and tillers in Oryza sativa increased when grown in 50:50 soil to vermicompost mixtures (Reddy, 1986). Root weights of wheat were greater in soil inoculated with earthworms (Edwards and Lofty, 1980). By contrast, soil containing vermicompost did not increase the number of blooms or have an effect on flower size of annual plants when compared to control soil (Bal and Curry, 1977). Growth of nursery stock is affected by the addition of vermicompost. Growth of Acacia mearnsii and Pinus patula was adversely affected by vermicompost in the media mix, however Eucalyptus grandis growth was enhanced in 1:1 pine bark:vermicompost mix provided additional nutrition was added (Donald and Visser, 1989). To date there has not been any research reported on the use of vermicompost in the cropping cycle of bedding plants.

It is necessary to know the nature and the magnitude of effects of any amendments to the soil before suggesting any practice which can only be achieved through several field trials.

Therefore, the objective of this experiment was to assess the germination, early plant growth, and nutrient concentration of eucalyptus (5) tree, grown for 158 days in different rates of

Tele:

E-mail addresses: moasgharipour@gmail.com

substitutions of vermicomposts, produced from different mixture of city refuse into a garden soil under greenhouse conditions.

Material and Methods

Site description and description of vermicompost used

The experiment was conducted in 2012 using the greenhouse and field facilities of the University of Zabol, in Southeast Iran (61°293N, 31°23E, 450 m above sea level), which has a warm and arid climate with a mean annual temperature of 23 °C and average annual precipitation of 63 mm. The sandy loam soil [19% clay (<2 μm), 21% silt (2-20 μm), 41% fine sand (20-200 μm) and 19% coarse sand (200-2000 μm)], with a pH of 7.8, organic mater 0.11%, N-No3 2.9 ppm, P (Olsen) 2.2 ppm, and K 156 ppm (0-30 cm depth)] used in this study was collected from experimental agriculture farm of Zabol University. The soil was collected from the first 10cm of the soil surface, air-dried and afterwards sieved at 2mm.

Commercial city refuse vermicompost used in this study, produced in the professional compost factory in the city of Mashhad, Iran. The vermicompost is obtained by the action of Californian red earthworm (Eisenia fetida). Cattle manure supplied by an animal husbandry in Zabol, Iran. Vermicompost were air dried, sieved for two particle sizes (<0.075 mm and <2 mm) and stored in plastic bottles. The basic physiochemical properties of the vermicompost tested are summarized in Table 1.

Experiment layout and potting mixture treatments

The experimental design used was a completely randomized design (CRD) with six potting mixtures replicated four times. The potting mixtures consisted of a garden soil, and of substitutions of soil with different concentrations of city refuse vermicompost. Eucalyptus seedlings were germinated and grown in plastic pots, containing garden soil substituted with 0% (control), 10%, 20%, 30%, 40%, or 50% (by volume) vermicompost. The mixture of organic fertilizer with soil was done by hand to obtain better homogeneity.

The pot experiment started the 23 of January 21012 and lasted until the 18 of May 20012. Plastic pots with 20 cm in diameter and 19 cm in height were filled out with 1.8 dm3 of each substrate, and 25 seeds of eucalyptus were sown at a depth of approximately 1 cm, and they were watered as needed with tap water.

The pots were placed in a greenhouse under high humidity and mist until emergence. Seeds were considered emerged when the cotyledons came through the surface of the potting substrate. The seed germination was monitored regularly every day after placing the seed in the soil until the germination was complete, and the germination rates in each potting mixture (percentage of seeds germinating per day) were determined. At 20 d after planting, the seedlings were thinned to 3 plants per pot.

At the end of the pot experiment when plants reached commercially ready to move (117 days), after the measurement of plant height and number of leaves and lateral branch the whole plants were cut at the soil surface. Leaves were removed from plants total leaf area of plants was measured using a leaf area meter (Li-Cor Instruments, USA). All leaves and stems of plants were weighed to determine fresh shoot weights, placed into paper bags, oven-dried at 60 °C for 72 h and weighed again for dry shoot weights. Leaf chlorophyll content, an indication of N uptake by the plants, was determined using SPAD 502 meter (Minolta Corporation, Japan).

Analysis of Plant, Growth Media and vermicompost

Harvested samples of plant were washed and oven dried at 55 °C for 72 h and the dried plant parts were ground to powder. A lot of 1.0 g powder of each plant sample was digested with 10 N HNO3, and sample-digests were subjected to element analysis by an atomic absorption spectrophotometer (model, Shimadzu AA-670); and for determining Na and K contents, a flame photometer (model, JENWAY-PFP7) was used.

The pH (1:1) of each soil sample (5 g, dry basis) was measured with a pH meter (DMP 200, DMS). The electrical conductivity of soil samples were determined by a digital conductivity meter (Digison model D1-909) [21]. Nitrogen estimations were done by the Kjeldahl method, and available phosphorous was measured by the Olsen method.

Potassium was estimated by Ammonium acetate method [4]. Ca, Mg, Cu, Fe, Mn, Cu, Zn, Ni, Cd, Pb, Co and Cr in soil were analyzed by atomic absorption spectrophotometry (model, Perkin-Elmer 3030) [24]. For measuring these elements in compost, compost was digested by Nitric Acid and Perchloric [20] and then extract were used to measuring elements according to standard methods. Amount of phosphorus in the samples was measured with a spectrophotometer (model, WAP) and potassium by the flame photometer (model, JENWAY-PFP7). Micro and macro nutrients content were determined by Atomic-emission spectrometry.

Statistical analyses

The data were treated by analysis of variance (ANOVA) using SAS 9.2 for Windows (SAS Institute Inc., Cary, NC, USA, 2003). All assumptions for normality and constant variance were tested and validated. Significant differences were assessed by the Duncan's test at $p < 0.05$.

Results

Seed germination and early seedling growth

The substitution of garden soil with 20%, 30%, and 40% city refuse vermicompost increased the rates of germination of eucalyptus seeds significantly by 12.9%, 12.3%, and 14.7%, respectively, over those in the garden soil controls (Table 3). Eucalyptus seedlings grown in potting mixtures containing 50% city refuse vermicompost had more leaves and weighed more than those grown in the garden soil controls. Even with a relatively small concentration of city refuse vermicompost (10% by volume) in the container medium, the dry weights of city refuse seedlings increased significantly (30.8%) over those of plants grown in the garden soil controls (Table 2). On the other hand, seedlings grown in 100% city refuse vermicompost were significantly shorter, had fewer leaves, and weighed less than those in garden soil controls (Table 2). These results agree with those of Subler et al. (1998) who reported that the addition of 10% or 20% of vermicomposted pig manure to a standard commercial potting medium increased the weights of tomato seedlings significantly, after three weeks of growth in plug trays in the greenhouse.

Plant vegetative growth

The results of the vegetative growth parameters (stem height, collar diameter, and panicle length) as affected by the different city refuse incorporation rate are presented in Table 2.
Stem height, collar diameter, and panicle length differ among different incorporation rate. In this study, incorporation with 50% city refuse vermicompost produced the largest plants (height: 88.33 ±3.06 cm, collar diameter: 5.28 ±0.12 cm, and panicle length: 9.10 ± 2.0 cm). Plants fertilized with 50% city refuse vermicompost had 19 greater height, 5 greater collar

diameter, and 25 greater panicle length compared to those at the control.

There was a consistent tendency for the eucaliptus seeds to germinate faster, often significantly so ($P \leq 0.5$), when there were larger amounts of vermicomposts in the mixtures, seedlings often emerging even as early as 6 days after sowing, in all vermicompost substitution treatments (Fig. 1a–c). Eucalyptus germinated poorest in 80, 90 and 100% city refuse vermicompost 20, 10 and 0%/garden soil mixtures. However, eucalyptus grown in mixtures containing 10–60% city refuse vermicompost, produced significantly larger ($P \leq 0.05$) shoot dry weights than those grown in garden soil only (Fig. 2a) independent of nutrient supply. Eucalyptus grown in a mixture of 40% city refuse vermicompost and 60% garden soil produced larger shoot dry weights, which were significantly greater than the shoot dry weights of eucalyptus grown in garden soil with substitutions of 10, 20, 30, 50 and 0% city refuse vermicomposts, independent of nutrient supply.

Nutrient concentrations in plants

Mean concentrations of micronutrients, macronutrients, and heavy metals in the dry matter after the treatments are presented in Tables 4 and 6.

Higher concentrations of total macronutrients (N, P, K, Ca, Mg, and Na) in plants were monitored in the plants grown on plots fertilized with 40% city refuse vermicompost; the constant trend in their concentrations in decreasing order was as follows: 40%, 50%, 30%, 20% and control.

Total concentrations of micronutrients (Zn, Mn, Fe, B, Cu) and heavy metals (Cd, Ni, Pb) in plants after raw sewage effluent treatments were significantly higher than those found after 50% incorporated treatments, whereas those with 10% vermicompost and control treatments had the lowest concentrations. The concentrations of the above mentioned micronutrients and heavy metals in the plants did not differ significantly because of this treatments. Although not significant, plants sprayed with Mn and Zn had, in most cases, the lowest concentrations of all measured micronutrients and heavy metals, whereas the plants fertilized with 50% vermicompost exhibited the greatest concentrations of micronutrients and heavy metals, except for Mn and Zn. Concentrations of Zn and Mn were drastically higher in the plants that received Zn or Mn as foliar applications. Ni and Pb were not detected in plant tissues.

Discussion

The data presented demonstrate considerably accelerated rates of germination of eucalyptus, in response to all of the three types of vermicomposts produced from city refuse, that we tested in the current greenhouse experiments, independent of nutrient availability. Paper waste vermicompost produced the fastest seedling emergence, to even as early as 6 days after sowing, in response to substitutions of 10–90% paper waste or food waste vermicomposts into 90– 10% MM360. The greatest germination of petunia seedlings in cattle manure vermicomposts was in response to substitutions of 50–100% food or paper waste vermicompost into 50–0% MM360. We have reported in previous publications that vermicomposts increased the seedling emergence of other ornamentals and vegetables compared with those grown in control commercial plant growth media, MM360 (Atiyeh et al., 2000a,b; Atiyeh et al., 2001a,b).

Edwards and Burrows (1988) also reported that a wide range of vegetables and ornamentals germinated earlier and better in mixing with vermicomposts than in commercial plant growth media. Subler et al. (1998) stated that marigolds germinated much earlier and grew faster for the first 2 weeks of growth in a standard commercial potting media substituted with 10 or 20% of vermicomposted pig manure. Buckerfield et al. (1999) reported similar increased germination trends of radishes in 0–100% mixtures of vermicompost and sand although some vermicompost application rates tended to inhibit germination initially.

In our current experiments, all three types of vermicompost caused very significant increases in rates and amounts of petunia growth in terms of shoot and root dry weights (Figs. 2–4). Increases in rates of shoot and root growth in response to all of the vermicomposts were much greater at lower substitution rates of vermicompost into MM360 than at higher ones. Atiyeh et al. (2000b) reported that marigold seedlings grown in a growth medium substituted with 20% pig manure vermicompost grew faster than those in MM360. Roots and shoot weights of marigolds were also significantly greater.

Growth was slower in media with some substitution rates, such as that by cattle manure vermicompost at higher rates of substitution, but became evident only in the later stages of seedling growth where sometimes the shoot dry weights and root dry weights of eucalyptus were affected negatively at the higher vermicompost substitution rates. For instance, shoot growth was significantly slower in eucalyptus planted into MM360 substituted with either 70% cattle manure vermicompost, from 70 to 100% food waste vermicomposts or 70, 90 and 100% paper waste vermicomposts, compared to those that were grown in MM360 substituted with only 40% cattle manure, food waste and paper waste vermicomposts. Some of the lower growth rates in response to large rates of substitution of vermicomposts, particularly cattle vermicomposts, could be attributed to the higher salt content (i.e. electrical conductivity) or excessive nutrient levels in the more concentrated mixtures. In previous experiments we have concluded that some of slower growth rates of plants at high rates of substitution of vermicomposts was a response to higher concentrations of plant growth hormones such as auxins and humic acids produced by microorganisms in vermicomposts (Arancon et al., 2006b). When auxins are applied at high concentrations, they can reduce the rates of growth and development of plants (Hopkins and Huner, 2004) as well as increasing growth at lower concentrations.

Earlier research at OSU, substitutions of 30 or 40% pig manure vermicomposts into 70 or 60% MM360 reported increased numbers of flowers of another flowering crop , marigolds (Atiyeh et al., 2002). In the current experiments, all three types of vermicomposts produced significantly more flowers in response to substitutions of 20, 30 and 40% cattle manure or food waste vermicomposts and 40% paper waste vermicompost into corresponding amounts of MM360 and there was an overall trend for the lower substitution rates of vermicomposts to increase petunia flowering more than the higher rates. These increases in germination at lower substitution rates of vermicomposts into MM360 improved growth and flowering stages of the plant and provided economic increases in numbers of petunia flowers. Atiyeh et al. (2000c) reported more marigold flower buds in MM360 substituted with pig manure vermicompost.

Mechanisms of beneficial effects of vermicomposts

Some possible factors that improved the germination, growth and flowering of eucalyptus could include vermicomposts producing improvements in the physical

Table 1 – Physico-chemical properties of used soil in this experiment

Fe	Mn	Zn	Cu	K	P	Organic matter (%)	Total N (%)	EC (m mohs/cm)	pH	Soil particles (%)			Soil texture
Absorbable (mg kg^{-1})										Clay	Silt	Sand	
65.47	15.32	2.23	3.34	453.43	6.65	1.08	0.12	1.40	7.7	47.3	42.1	10.6	Silty clay

Table 2 – Physicochemical properties of used vermicompost in this experiment

pH	C/N ratio	N (%)	P	K	Mn	Cu	Zn	Fe
			mg kg^{-1}					
7.78	11.32	0.60	1732.91	5451.43	331.76	87.65	65.98	6543.65

Table 3- Mean simple effects of different organic fertilizers and drought on area per pot and morphological traits of basil

Different fertilizer	Leaf area per (cm^2) pot	Dry weight (g pot^{-1})	Plant height (cm)	branches No. plant^{-1}	Leaves No. plant^{-1}
Compost	135a	19.0a	51b	4.4a	10.1a
Vermicompost	127b	16.3c	49b	4.2b	9.5b
Manure	128b	17.8b	59a	4.3ab	9.4b
Biofertilizer	124b	18.5a	42c	4.1b	9.3b
Inorganic N + P	129b	18.2ab	44c	4.5a	9.5b
Control	85c	11.8d	37d	3.7c	7.6c
Drought stress (bar)					
-0.3	141a	19.2a	53a	5.1a	10.7a
-4	121b	16.4b	44b	4.2b	9.2b
-8	102c	15.2b	44b	3.3c	7.8c

* Values followed by the same letter within the same columns do not differ significantly at p =5% according to DMRT.

Table 4 - Mean squares of different organic fertilizers and drought on area per pot and morphological traits of basil

SOV	DF	Leaf area per (cm^2) pot	Dry weight (g pot^{-1})	Plant height (cm)	Branches No. plant^{-1}	Leaves No. plant^{-1}
Replication	2	324.32	112.12	187.19	12.47	32.45
Different fertilizer (A)	5	2234.65**	1131.13**	1454.45**	543.65**	915.36**
Drought stress (B)	3	1166.88**	357.76**	593.65**	112.32**	487.54**
A*B	15	532.66*	180.65**	312.34*	81.76^{ns}	198.18^{ns}
Error		64.35	19.26	29.76	11.76	34.65

ns: not significant; (*) and (**) represent significant difference over control at $p<0.05$ and $p<0.01$, respectively.

Table 5- Mean simple effects of different organic fertilizers and drought on essential oil percentage and essential oil yield of basil.

Different fertilizer	Essential oil percentage	Essential oil yield
Compost	1.5a	285b
Vermicompost	1.5a	277b
Manure	1.7a	303a
Biofertilizer	1.5a	244c
Inorganic N + P	1.6a	291b
Control	1.6a	189d
Drought stress (bar)		
-0.3	1.6a	307a
-4	1.5a	246b
-8	1.6a	243b

* Values followed by the same letter within the same columns do not differ significantly at p =5% according to DMRT.

Table 6- Mean squares of different organic fertilizers and drought essential oil percentage and essential oil yield of basil.

SOV	DF	Essential oil percentage	Essential oil yield
Replication	2	0.004	341.347
Different fertilizer (A)	5	4.881^{ns}	**816.655
Drought stress (B)	3	1.361^{ns}	**341.239
A*B	15	0.029^{ns}	5.250^{ns}
Error		0.0002	4.876

structure of the growth medium such as aeration and drainage. It could also have been due to biological effects such as increases in beneficial enzymatic activities, increased populations of beneficial microorganisms, or the presence of biologically active plant growth-influencing substances such as plant growth regulators or plant hormones in the vermicomposts (Grappelli et al., 1987; Tomati and Galli, 1995; Subler et al., 1998) and humic acids (Arancon et al., 2006a). Krishnamoorthy and Vajranabhiah (1986) showed that earthworm activity could promote the production of cytokinins and auxins in organic waste dramatically. They also demonstrated strong positive correlations between earthworm populations and amounts of cytokinins, and auxins in field soils and reported that auxins and cytokinins produced by interactions between earthworms and microorganisms, could persist in soil for up to 10 weeks but degraded rapidly if exposed to sunlight. Atiyeh et al. (2002) suggested that plant hormones such as IAA, kinetins and gibberellins are relatively transient in soil because of their solubility and rapid breakdown in ultraviolet light.

Humic substances have been shown to increase yields of corn, oats, soybean, peanuts, clover, chicory plants and other tropical crops (Cacco and Dell'Agnola, 1984; Hayes and Wilson, 1997; Albuzio et al., 1994; Lee and Bartlett, 1976; Muscolo et al., 1993, 1996, 1999; Mylonas and Mccants, 1980; Nardi et al., 1988; Valdrighi et al., 1996). In our laboratory, we reported that applications of a range of humic acids, that had been extracted from vermicomposts, and then added to MM360, with all needed nutrients, increased the overall growth of tomatoes and cucumbers significantly in a very similar pattern to the effects of a range of vermicomposts (Atiyeh et al., 2002; Arancon et al., 2006a). However, plant growth hormones can become adsorbed onto the complex structure of humic acids that are produced very rapidly in vermicomposts (Canellas et al., 2000) and may have acted in conjunction with them to influence plant growth since humates have also been shown to increase plant growth. In this situation plant growth hormones that are adsorbed on to humates would persist in soil and would be released slowly from humates and have much more effects on plant growth over a considerably longer period. In support of this hypothesis, Canellas et al. (2000) identified exchangeable auxin groups attached to humic acids, extracted from cattle manure vermicompost, following a detailed structural analysis. These complexes enhanced root elongation, lateral root emergence and plasma membrane H+- ATPase activity of maize roots.

Vermicompost is reported to have hormone-like activity, and this has been hypothesized to result in greater root initiation, increased root biomass, enhanced plant growth and development, and altered morphology of plants grown in vermicompost amended media (Edwards, 1983, 1985; Grapelli et al., 1985; Satchell et al., 1984; Tomati et al., 1988). Indeed the presence of substances with hormone or hormone-like activity in vermicompost has been reported. Using phytohormone bioassays, compounds with gibberellin, cytokinin and auxin-like activity have been detected in vermicomposted urban and sewage waste (Grapelli et al., 1985).

Several researchers have reported that VC enhances seed germination. (Alves and Passoni, 1997; Edwards and Burrows, 1988). However, we did not observe an increased germination percentage or promotion of germination rates by VC. That there were no effects of VC on germination may be due to the fact that the seed used in our experiments were from fresh seed lots from a commercial seed company having high reported germination percentages. Our results do not preclude the possibility that VC may have a positive effect on germination of seeds that have deteriorated or reduced viability.

A candidate for such a non-nutritional growth-promoting compound is humate. Earthworms contribute to the biological processes that produce humus or humus-like substances (Hartenstein, 1982; Stoudt, 1983). Humus or humates are believed to stimulate plant nutrient uptake and metabolism, have an influence on protein synthesis, and show hormone-like activity (Barton and Ruocco, 1981; Poapst et al., 1970; Tichy and Phuong, 1975; Vaughan and McDonald, 1971). Vermicompost has been reported to have 40–60% higher levels of humic compounds than conventional composts (Dominguez et al., 1997). Atiyeh et al. (2002) observed that growth of tomato and cucumber was enhanced when treated with up to 500 mg/kg humic acids derived from VC.

Conclusions

From the findings, it can be concluded that the organic amendments of soil increased the nutrient supply and plant productivity at different magnitude depending on the quality of residue used and its mode of application. The addition of vermicompost in media mixes of 10% VC and 20% VC had positive effects on plant growth. The greatest growth enhancement was on seedlings during the plug stage of the bedding plant crop cycle. Growth increases up to 40% were observed in dry shoot tissue and leaf area of marigold, tomato, green pepper, and cornflower. The increased vigor exhibited was also maintained when the seedling plugs were transplanted into larger containers with standard commercial potting substrates without vermicompost. Additionally, there were benefits apparently resulting from the nutritional content of the vermicompost. All of the plugs were produced without the input of additional fertilization. The potential exists for growers to use vermicompost-amended commercial potting substrates during the plug production stage without the use of additional fertilizer.

References

1. Abbaas, M. M. 2002. Effect of some heavy metals in the irrigation water on growth and chemical constituents of some timber trees. Unpublished Ph.D.'s thesis. University of Cairo, Cairo, Egypt.
2. Ali, H. M., E. M. El-Mahrouk, F. A. Hassan and M. H. Khamis. 2010. Growth, Chemical Compositions and Soil Properties of Tipuana speciosa Irrigated with Sewage Effluent. Paper presented at the 25th Meeting of Saudi Biological Society, Nanotechnology in Life Sciences, Alasa City at King Faisal University.
3. APHA–AWWA–WEF. 1995. Standard Methods for the Examination of Water and Wastewater (19th ed.). Washington DC. APHA-AWWA-WEF.
4. Azevedo, C. M. S. B. 1998. Nitrogen transfer using 15N as a tracer in an integrated aquaculture and agriculture system. Unpublished Ph.D.'s thesis. University of Arizona, Tucson, Arizona.
5. Berbec, S., C. Szewczuk and D. Sugier. 1999. The effect of irrigation with municipal sewage on the catching and growth rate of poplar trees. Folia Universitatis Agricultural 77: 27-31.
6. Bouwer, H. and E. Idelovitch. 1987. Quality requirements for irrigation with sewage water. Journal of Irrigation and Drainage Engineering 113: 516–535.
7. Bozkurt, M. A. and T. Yarilga. 2003. The effects of waste water sludge applications on the yield, growth, nutrition

and heavy metal accumulation in apple trees growing in dry conditions. Turkish Journal of Agriculture and Forestry 27: 285–292.

8. Brouwer, J. and J. M. Powell. 1998. Increasing nutrient use efficiency in West-African agriculture: the impact of micro-topography on nutrient leaching from cattle and sheep manure. Agriculture, Ecosystems & Environment 71: 229-239.

9. Chambers, B., S. Royle, S. Hadden and S. Maslen. 2002. The use of biosolids and other organic substances in the creation of soil-forming materials. Journal of the Chartered Institution of Water and Environmental Management 16: 34-39.

10. Chapagain, B. P. and Z. Wiesman. 2004. Effect of Nutri-Vant-PeaK foliar spray on plant development, yield, and fruit quality in greenhouse tomatoes. Scientia Horticulturae 102: 177-188.

11. El-Fouly, M. M., O. A. Nofal and Z. M. Mobarak. 2001. Effects of soil treatment with iron, manganese and zinc on growth and micronutrient uptake of sunflower plants grown in high-pH soil. Journal of Agronomy and Crop Science 186: 245–251.

12. Emongor, V. E. and G. M. Ramolemana. 2004. Treated waste water effluent (water) potential to be used for horticultural production in Botswana. Physics and Chemistry of the Earth 29: 1101–1108.

13. Feigin, A., I. Ravina and J. Shalhevet. 1991. Irrigation with Treated Sewage Effluent: Management for Environmental Protection., Berlin: Springer-Verlag.

14. Guo, L. B. and R. E. H. Sims. 2000. Effect of meat works effluent irrigation on soil, tree biomass production and nutrient uptake in Eucalyptus globulus seedlings in growth cabinets. Bioresource and Technology 72: 243-251.

15. Hassan, F. A., L. I. EL-Juhany, A. A. EL-Settawy and M. S. Shehata. 2002. Effects of irrigation with sewage effluent on the growth of some forest trees species, physical and chemical properties of the soil. Paper presented at the second Conference on Sustainable Agricultural Development. Fayoum, Eygypt.

16. Hayes, A. R., C. F. Mancino, W. Y. Forden, D. M. Kopec and I. L. Pepper. 1990. Irrigation of turfgrass with secondary sewage effluent. II. Turf quality. Agronomy Journal 82: 943–946.

17. Joshi, H. C., N. Kalra, R. Choudhary and A. Chaudhary. 1998. Land application of waste waters from distilleries problems and prospects. Paper presented at the International Specialized Conference on Water Quality and its Management, New Delhi. India.Kalra, Y. P., D. G. Maynard and F. G. Radford. 1988. Microwave digestion of tree foliage for multi-element analysis. Canadian Journal of Forest Resource 19: 981–985.

18. Kaneker P., M. S. Kumbhojkar, V. Ghate, S. Sarnaik and A. Kelkar. 1993. Evaluation of Acacia nilotica and Casuarina equisetifolia forest for tolerance and growth on microbially treated dyestuff wastewater. Environmental Pollution 81: 47-50.

19. Madej´on, P., T. Maran´on and J. M. Murillo. 2006. Biomonitoring of trace elements in the leaves and fruits of wild olive and holm oak trees. Science of the Total Environment 35: 187–203.

20. Marschner, H. 1986. Mineral Nutrition of Higher Plants. London: Academic Press.

21. Mohammad, M. J. and M. Ayadi. 2004. Forage yield and nutrient uptake as influenced by secondary treated wastewater. Journal of Plant Nutrition 27: 351–365.

22. Pathak, H., H. C. Joshi, A. Chaudhary, R. Chaudhary, N. Kalra and M. K. Dwiwedi. 1999. Soil amendment with distillery effluent for wheat and rice cultivation. Water, Air and Soil Pollution 113: 133–140.

23. Pescod, M. B. 1992. Wastewater treatment and use in agriculture. Bull FAO 47: 125, Rome.

24. Santos, C. L. V., A. Campos, H. Azevedo and G. Caldeira. 2001. In situ and in vitro senescence induced by KCl stress: nutritional imbalance, lipid peroxidation and antioxidant metabolism. Journal of Experimental Botany 52: 351–360.

25. Sharma, R. K., M. Agrawal and F. Marshall. 2007. Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India. Ecotoxicology and Environmental Safety 66: 258–266.

26. Smith, J. H. and J. R. Peterson. 1982. Recycling of nitrogen through land application of agricultural, food processing, and municipal wastes. In F. J. Stevenson, (Eds.), Nitrogen in Agricultural Soils (pp. 791–831)., Madison, WI. ASA, CSSA, SSSA.

27. Sreenivasulu, N., M. Miranda, H. S. Prakash, U. Wobus and W. Weschke. 2004. Transcriptome changes in foxtail millet genotypes at high salinity: Identification and characterization of a PHGPX gene specifically up-regulated by NaCl in a salt-tolerant line. Journal of Plant Physiology 161: 467-477.

28. Wang, X. J. and S. Tao. 1998. Spatial structures and relations of heavy metal content in wastewater irrigated agricultural soil of Beijing’s Eastern farming regions. Bulletin of Environmental Contamination and Toxicology 61: 261–268.