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ORIGINAL RESEARCH

Effect of macrophyte vermicompost on growth and productivity of brinjal (*Solanum melongena*) under field conditions

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Abstract
Background Macrophytes (fresh water plants) comprise a diverse group of the flora which play important roles in the maintenance of trophic food chains and biogeochemical processes, but are deleterious when present in excess. However, due to various anthropogenic activities, there is accumulation of nutrients in aquatic ecosystems resulting in massive macrophytic growth. These weeds do not possess any economic value and remain laid on lake shores after harvesting and become a source of odor problem, thus posing a challenge to the lake management authorities regarding their proper disposal. However, vermicomposting turns these macrophytes into materials useful in horticulture/agriculture for restoration of soil fertility, in addition to providing a solution to the nuisance of harvested weeds.
Results The study was conducted to investigate the effect of different rates (2, 4 and 6 t/ha) of macrophyte-based vermicompost on germination, growth and yield of *Solanum melongena* under field conditions. The data revealed that different rates of vermicompost produced varied and significant effect ($P < 0.05$) as compared to the control on germination, growth and yield parameters with maximum value recorded at 6 t/ha, followed by 4 t/ha and the least at 2 t/ha. The dose of 6 t/ha significantly ($P < 0.05$) increased germination (22.56 ± 2.5 %), number of fruits per plant (3.55 ± 0.07) mean fruit weight (73 ± 5.0 g), yield per plant (1.48 ± 0.05 kg) and marketable fruits (28.66 ± 3.0 %) when compared with the control. The study suggests that macrophyte-based vermicompost as a potential source of plant nutrients for sustainable crop production.
Conclusion Macrophyte-based vermicompost is an efficient quality yielder and economy enhancer for sustainable agriculture especially for the communities having vegetable gardens around lakes will benefit by using macrophyte vermicompost, a balanced and low-cost organic fertilizer.

Keywords Fruits · Germination · Macrophytes · *Solanum melongena* · Vermicompost · Yield

Introduction

Conventional farm systems have been characterized by a high input of chemical fertilizer leading to qualitative deterioration of soil as well as agricultural yield (Diacono and Montemurro 2010; Singh et al. 2007). However, a growing awareness of the adverse impacts of inorganic fertilizers on crop production as well as increasing environmental and ecological concerns has stimulated greater interest in the utilization of organic amendments for crop production. Organic manures act not only as a source of nutrients and organic matter, but also increase microbial diversity and activity in soil, which influence soil structure and nutrients turnover, in addition to improvement in other physical, chemical and biological properties of the soil (Albiach et al. 2000; Edmeades 2003). Thus organic amendments/manures are environmentally benign and help in maintaining soil

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fertility as well as agricultural productivity. Among various organic products, vermicompost has been recognized as potential soil amendment.

Vermicompost is a product of non-thermophilic biodegradation of organic material by combined action of earthworms and associated microbes (Pathma and Sakthivel 2013). It is a highly fertile, finely divided peat-like material with high porosity, aeration, water-holding capacity and low C:N ratios (Dominguez and Edwards 2004). Vermicompost is made up primarily of carbon (C), hydrogen (H) and oxygen (O) and possesses remarkable plant growth-promoting properties due to the presence of nutrients in plant-available forms such as nitrates, calcium, phosphorus and potassium (Edwards and Burrows 1988). The enhancement of plant growth by vermicompost may not only be nutritional, but also due to its content of biologically active plant growth-influencing substances (Warman and AngLopez 2010). The presence of plant growth regulators such as auxins, gibberellins, cytokinins of microbial origin (Tomati et al. 1988) and humic acids (Atiyeh et al. 2002) has been reported in vermicompost. Stimulation of root growth (initiation and proliferation of root hair), increased root biomass, enhanced plant growth and development have been reported with the application of vermicompost, because of the presence of humic acids (Tomati et al. 1988; Mylonas and Mccants 1980; Chen and Aviad 1990). Moreover, the positive influences of humic acids on plant growth and productivity, which seem to be concentration specific, could be mainly due to hormone-like activities of humic acids through their involvement in cell respiration, photosynthesis, oxidative phosphorylation, protein synthesis and various enzymatic reactions (Chen and Aviad 1990). Further, humic acids are molecules that regulate other processes of plant development, such as macro and micronutrient adsorption (Gutierrez-Miceli et al. 2008a) and metabolism, which influence protein synthesis. Significant increase in soil enzyme activities such as urease, phosphomonoesterase, phosphodiesterase and arylsulfatase has been associated with the application of vermicompost (Albiach et al. 2000). Vermicomposts also possess disease-suppressing potential on a wide range of phytopathogens (Sahni et al. 2008). Vermicomposts harbour a wide variety of efficient antagonistic bacteria aiding in suppression of diseases caused by devastating soil-borne phytopathogenic fungi (Singh et al. 2008; Pathma and Sakthivel 2012). Several studies also report that vermicompost application suppresses infection by insect pests, repel crop pests and induce biological resistance in plants against pests and diseases due the presence of antibiotics and actinomycetes (Munroe 2007).

There is accumulating scientific evidence that vermicomposts can influence the growth and productivity of plants significantly (Edwards 1998). Various greenhouse and field studies have examined the effects of a variety of vermicomposts on a wide range of crops including cereals and legumes (Souzaa et al. 2013; Chan and Griffiths 1988), vegetables (Doan et al. 2013; Edwards and Burrows 1988; Atiyeh et al. 2000a), ornamental and flowering plants (Edwards and Burrows 1988; Atiyeh et al. 2000b) and field crops (Najar and Khan 2013a; Bhattacharya et al. 2012; Wu et al. 2012; Valdez-Péreza et al. 2011). Most of these investigations have confirmed that vermicomposts usually have significant beneficial effects on plant growth and yield. Vermicomposts, whether used as soil additives or as components of greenhouse bedding plant container media, have improved seed germination and enhanced seedling growth and development with overall increase in plant productivity. The beneficial effects include, but are not limited to stimulation of seed germination (Atiyeh et al. 2000b; Arancon et al. 2007a; Lazcano et al. 2010), activation of growth (Lazcano et al. 2009; Uma and Malathi 2009), protection against pathogens (Singh et al. 2003; Rivera et al. 2004; Zaller 2006), nematodes (Serfoji et al. 2010) and herbivores (Yardim et al. 2006; Arancon et al. 2007b; Edwards et al. 2010), and increasing overall crop productivity (Nattudurai et al. 2013; Gutierrez-Miceli et al. 2007; Singh et al. 2008; Azarmi et al. 2009). Several studies have assessed the effect of vermicompost amendments on the growth of a wide range of marketable fruits cultivated in greenhouses (Arancon et al. 2003, 2004a; Atiyeh et al. 2000c), as well as in fields (Najar and Khan 2013a; Wang et al. 2010; Singh et al. 2008).

Large quantities of macrophytes are harvested from different lakes across the Kashmir Valley. These macrophytes could easily be used in horticulture/agriculture for the restoration of soil fertility or for the production of quality vegetables, as they have good nutrient value, mainly as nitrogen (N), phosphorous (P) and potassium (K). However, in the present form the nutrients are not readily available and the harvested weeds remain on lake shores and become a source of odor problem, thus posing a challenge to the lake management authorities regarding their proper disposal (Najar and Khan 2013b). However, vermicomposting turns these macrophytes into materials useful in horticulture and there would be great savings in primary plant nutrients and, in addition, a solution to the nuisance of harvested weeds. The objective of the study was to evaluate the response of different rates of macrophyte-based vermicompost on germination, growth and yield of *S. melongena* under field conditions.

Materials and methods

The experiment was conducted at the experimental site of Hydrobiology Research Laboratory, Srinagar, Jammu and

Kashmir, India (34°08′N, 74°50′E). The study area lies in the temperate zone, characterized by wet and cold winter and relatively dry and moderate hot summer with mean annual precipitation of about 1100 mm, mainly falling during winter and spring. The hottest months are July and August, when the maximum temperature rises above 30 °C. September has cooler nights and the severe winter sets in about the middle of December. The coldest month is January, with temperature falling below freezing point. The winters vary from year to year; some are severe with very heavy snowfall, while others are mild with moderate snowfall (Najar and Khan 2011, 2014).

Preparation of macrophyte vermicompost

Different macrophytes (fresh water weeds) were collected from Dal Lake, excess water was allowed to drain for 2 days under sunlight (Najar and Khan 2010) and the macrophytes mixed with cattle dung in a 5:1 ratio (6 kg of macrophytes:1.2 kg of cow dung). Healthy and adult individuals of earthworm (*Eisenia fetida*) were allowed to feed on macrophytes which were converted into vermicompost (macrophyte vermicompost) during 60 days' duration (Najar and Khan 2012, 2013b). The physiochemical characteristics of the macrophyte vermicompost are given in Table 1.

Experimental setup

Seeds and plants of *S. melongena* were germinated and grown during 2009 and 2010 to determine the effect of the vermicompost. Field plots were 4 m long and 4 m wide (16 m^2) and separated by 1 m from unplanted areas. The physiochemical characteristics of soil are given in Table 1. Macrophyte based vermicompost was applied at the rate of 0 t/ha (control), 2, 4 and 6 t/ha. The vermicompost was incorporated into the top 15 cm of soil in the whole experimental bed (Arancon et al. 2003; Najar and Khan 2013a). The plots were arranged in a randomized complete block design with four replications for each treatment. All the necessary cultural practices and plant protection measures were followed uniformly for all the treatments during the entire period of experimentation.

Table 1 Physicochemical characteristics of soil and macrophyte vermicompost (mean ± SE, $n = 3$)

Parameter	Soil	Vermicompost
pH	7.2 ± 0.08	7.73 ± 0.13
EC (mS/m)	0.08 ± 0.01	0.98 ± 0.12
Ca (g/kg)	2.64 ± 0.04	16.22 ± 1.37
Mg (g/kg)	0.51 ± 0.01	7.62 ± 1.03
Na (μg/g)	11 ± 0.23	32.03 ± 1.91
K (μg/g)	3.52 ± 0.11	35.31 ± 13.13
P (μg/g)	110 ± 11	586.23 ± 26.65
OC (g/kg)	22.8 ± 1.5	170.58 ± 7.65
ON (g/kg)	1.7 ± 0.2	8.76 ± 0.83

Germination (%)

Seeds of *S. melongena* were sown in the plotted fields and were considered as emerged or germinated when cotyledons project out through the surface of the soil. Germination rate was expressed as the cumulative number of seeds germinating during monitoring days relative to the total number of seeds sown for germination. Seedlings were transplanted at three true leaves stage. Seedlings were planted at a distance of 25 cm between two plants.

Growth parameters and yield parameters

Plants of *S. melongena* were harvested after every fortnight and assessed for growth (shoot length, root length and leaf area) and their respective dry weight. The roots and leaves were cleaned carefully to remove adhering soil and dust particles. Leaves per plant were counted and leaf area (cm^2) was measured by using a leaf area meter (Singh et al. 2007). Plant biomass was dried in an oven at 60 °C for 24 h and the dry weight obtained (Lazcano et al. 2009).

Marketable fruits

All the ripe fruits were harvested, weighed and graded as marketable and non-marketable. Fruits were classified as non-marketable when fruits showed sign of decay due to diseases or insect feeding or any other malformation on the fruit surface (Zaller 2007). Relative proportions of non-marketable fruits were expressed as percentages of the total number of fruits harvested. Marketable fruits do not show any sign of decay. However, non-marketable fruits were not evaluated for specific disease or type of insect feeding.

Data analyses

Data sets were subjected to multivariate statistical techniques: two-way analysis of variance (ANOVA) and Tukey's t test were used as a post hoc analysis to compare the means (Zar 2009). Pearson correlation coefficient (r) was employed to examine the relationship between the vermicomposting application and yield parameters. All the tests were achieved with a significance level $P < 0.05$. Statistical analyses and graphical presentations were performed using SPSS statistical software (Version 16.0).

Results

Application of different rates of vermicompost (2, 4 and 6 t/ha) in *S. melongena* significantly affected the germination of seeds, plant growth and development, marketable fruits and yield during the study period of 120 days.

Germination (%)

Germination was 44.33 ± 2.01 in 6 t/ha, 35.77 ± 2.02 in 4 t/ha and 21.77 ± 2.05 in the control (Fig. 1). The effect of vermicompost was significant ($P < 0.05$) on germination. Application of vermicompost at the rate of 2, 4 and 6 t/ha increased the germination in the respective treatments by 8.33 ± 0.9, 14 ± 1.1 and 22.56 ± 2.5 as compared to the control.

Plant growth parameters

The shoot and root length exhibited a maximum value of 69 ± 1.40 cm and 26.5 ± 1.28 cm in 6 t/ha and least values of 46 ± 1.17 cm and 19.5 ± 1.28 cm in the control, respectively (Fig. 2a, b). Shoot and root length varied significantly among the treatments ($F_3 = 11.59$; 20.01, $P < 0.05$) and during different fortnights ($F_7 = 101.20$; 73.57, $P < 0.05$). Dry weight showed significant variation ($F_3 = 5.80$; 5.88, $P < 0.05$) among the treatments and during different fortnights ($F_7 = 19.60$; 61.98, $P < 0.05$), with higher mean values of 8.62 ± 0.27 g (shoot) and 4.37 ± 0.23 g (root) in 6 t/ha and minimum of 3.42 ± 0.25 g (shoot) and 3.02 ± 0.06 g (root) in the control (Fig. 2c, d). Leaf area was 475.25 ± 7.40 cm^2 in 6 t/ha and 368.25 ± 10.65 cm^2 in the control (Fig. 2e). Application of vermicompost significantly increased the leaf area among the treatments ($F_3 = 8.28$, $P < 0.05$) and also exhibited significant variation during different fortnights ($F_7 = 129.26$, $P < 0.05$). Dry weight of leaves was less in the control with a mean value of 6.92 ± 0.24 g and maximum in the treatment of 6 t/ha with a value of 12.47 ± 0.30 g (Fig. 2f), and differed significantly among the treatments ($F_3 = 6.09$, $P < 0.05$) and during different fortnights ($F_7 = 36.98$, $P < 0.05$).

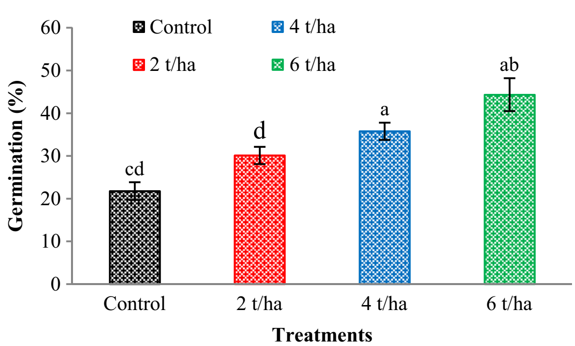

Fig. 1 Effect of macrophyte vermicompost on germination of *Solanum melongena* (mean ± SE, $n = 4$). Significant differences at $P < 0.05$ (Tukey's LSD test) are indicated by *different letters*

Yield parameters

Vermicompost application showed positive correlation with clusters/plant ($r = 0.977$, $P < 0.05$), fruits/cluster ($r = 0.968$; $P < 0.05$), number of fruits/plant ($r = 0.965$; $P < 0.05$), mean fruit weight ($r = 0.988$; $P < 0.05$), yield/plant ($r = 0.965$; $P < 0.05$) and strong positive correlation with marketable fruits ($r = 0.997$; $P < 0.01$), whereas strong negative correlation with non-marketable fruits ($r = -0.997$; $P < 0.01$). Application of vermicompost resulted in 2.83 ± 0.16 clusters/plant in 6 t/ha and 2.5 ± 0.22 in 4 t/ha as compared to 2 ± 0.01 in the control. Thus, the application of vermicompost at the rate of 6 t/ha increased significantly ($P < 0.05$) the number of clusters per plant by 0.83 ± 0.02 and 0.5 ± 0.01 in 6 and 4 t/ha, respectively, when compared with the control (Fig. 3a). Fruits/cluster were observed to be significantly ($P < 0.05$) higher in vermicompost treatments, with a maximum of 4.5 ± 0.60 in 6 t/ha and 2.83 ± 0.30 in 2 t/ha, whereas it was 2.66 ± 0.21 in the control (Fig. 3b) with an overall increase of 1.84 ± 0.03, 1 ± 0.01 and 0.22 ± 0.01 fruits/cluster in the respective treatment. Fruits/plant recorded in the control were 6.83 ± 0.40 and varied significantly ($P < 0.01$) among treatments with a maximum value of 10.33 ± 0.66 in 6 t/ha. Vermicompost application enhanced the fruits/plant value by 0.78 ± 0.08 in 2 t/ha, 1.45 ± 0.09 in 4 t/ha and 3.55 ± 0.07 in 6 t/ha when compared with the control (Fig. 3c). Mean fruit weight (g) was 158.83 ± 5.41 in 6 t/ha, 126 ± 2.58 in 4 t/ha, 101.83 ± 4.09 in 2 t/ha and 85.83 ± 3.35 in the control. There was significant ($P < 0.05$) increase in mean fruit weight among the treatments, with a maximum increase of 73 ± 5.0 g recorded in the treatment of 6 t/ha and least of 16 in 2 t/ha (Fig. 3d). Yield/plant (kg) in the control was 0.49 ± 0.04, whereas among the treatments it was 1.97 ± 0.13 in 6 t/ha and 0.61 ± 0.07 in 2 t/ha (Fig. 3e) with a significant ($P < 0.01$) increase of 1.48 ± 0.05, 0.82 ± 0.01 and 0.12 ± 0.01 in the respective treatments when compared with the control. Marketable fruits (%) were significantly ($P < 0.01$) higher in vermicompost-amended plots: 92.49 ± 1.76 (6 t/ha), 85.13 ± 1.86 (4 t/ha) and 74.30 ± 3.47 (2 t/ha) against 63.83 ± 5.07 in the control (Fig. 4a). Among the amended plots, the maximum increase was recorded in 6 t/ha (28.66 ± 3.0). The effect of vermicompost application was significant ($P < 0.05$) on decrease in yield of non-marketable (%) fruits among the treatments and with the lowest value of 7.49 ± 1.76 (6 t/ha), 14.85 ± 1.86 (4 t/ha) and

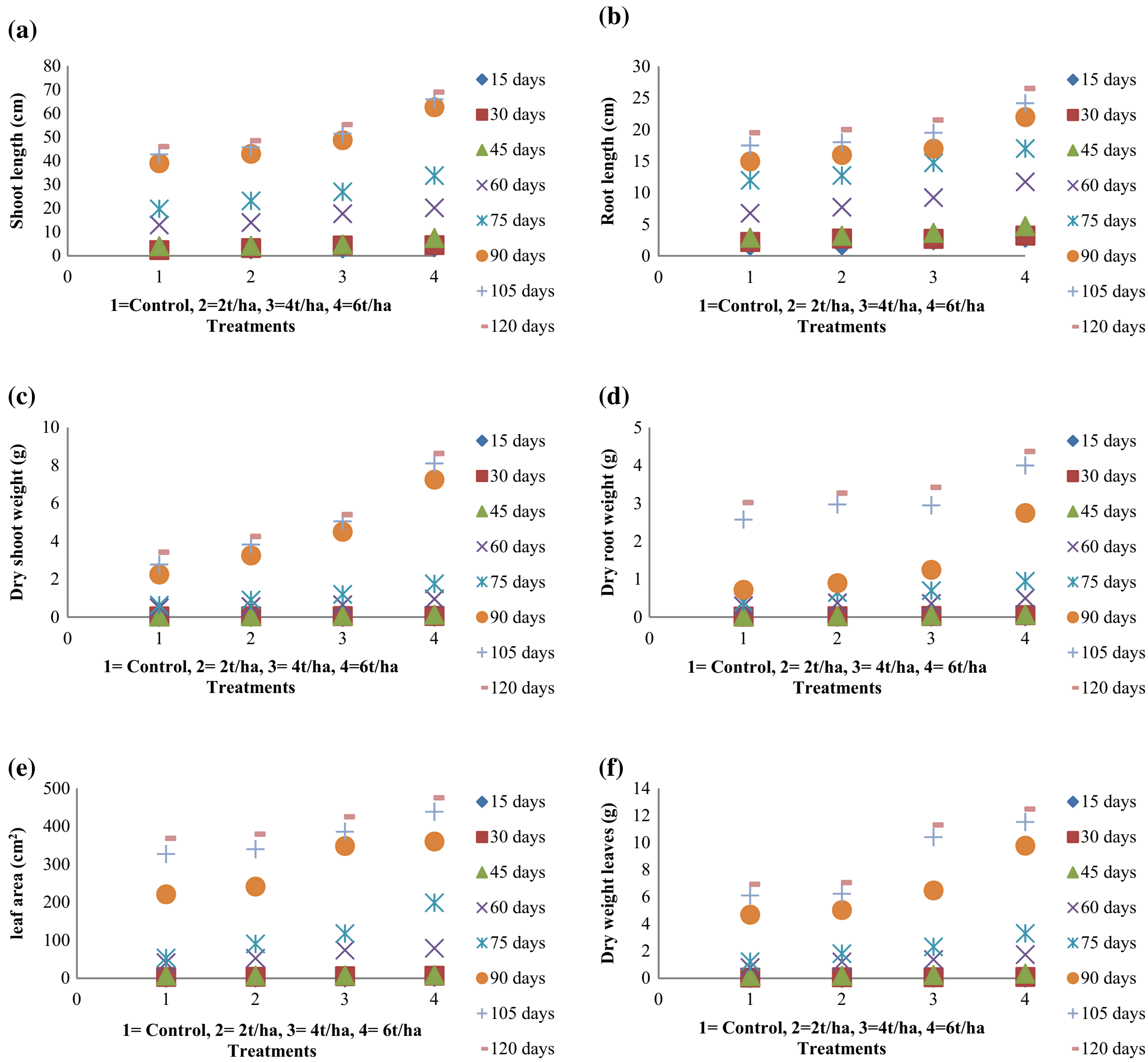

Fig. 2 Effect of macrophyte vermicompost on growth parameters of *Solanum melongena* (mean ± SE, $n = 4$)

25.69 ± 3.47 (2 t/ha). Among the vermicompost treatments, maximum decrease was recorded in 6 t/ha (28.67 ± 2.9) followed by 4 t/ha (21.47 ± 2.1) when compared with the control (Fig. 4b).

Discussion

Application of different rates of vermicompost in *S. melongena* resulted in varied response on germination, plant growth parameters, yield parameters, marketable and non-marketable fruits.

Germination

Vermicompost application resulted in differential effect on the germination of *S. melongena* among different treatments. Vermicompost has been reported to stimulate germination of several horticultural plant species such as green gram (*Phaseolus aureus*) Karmegam et al. (1999) and tomato plants (*L. esculentum*) Atiyeh et al. (2000b). Najar and Khan (2013a) also reported an increase in germination of *L. esculentum* by 10.33 % with the application of macrophyte-based vermicompost. According to Zaller (2007) and Lazcano et al.(2010), increase in seed germination of *Rumex obtusifolius* by 48 % and *Pinus pinaster* by 16 % has been reported with the application of cattle manure and rabbit manure vermicompost, respectively. Germination is an internally regulated process influenced mainly by genotype, although external factors such as light period, temperature, moisture and presence of certain chemical compounds can also alter this process either through promotion or inhibition (Kucera et al. 2005). When all these factors are integrated, it is mediated by signaling

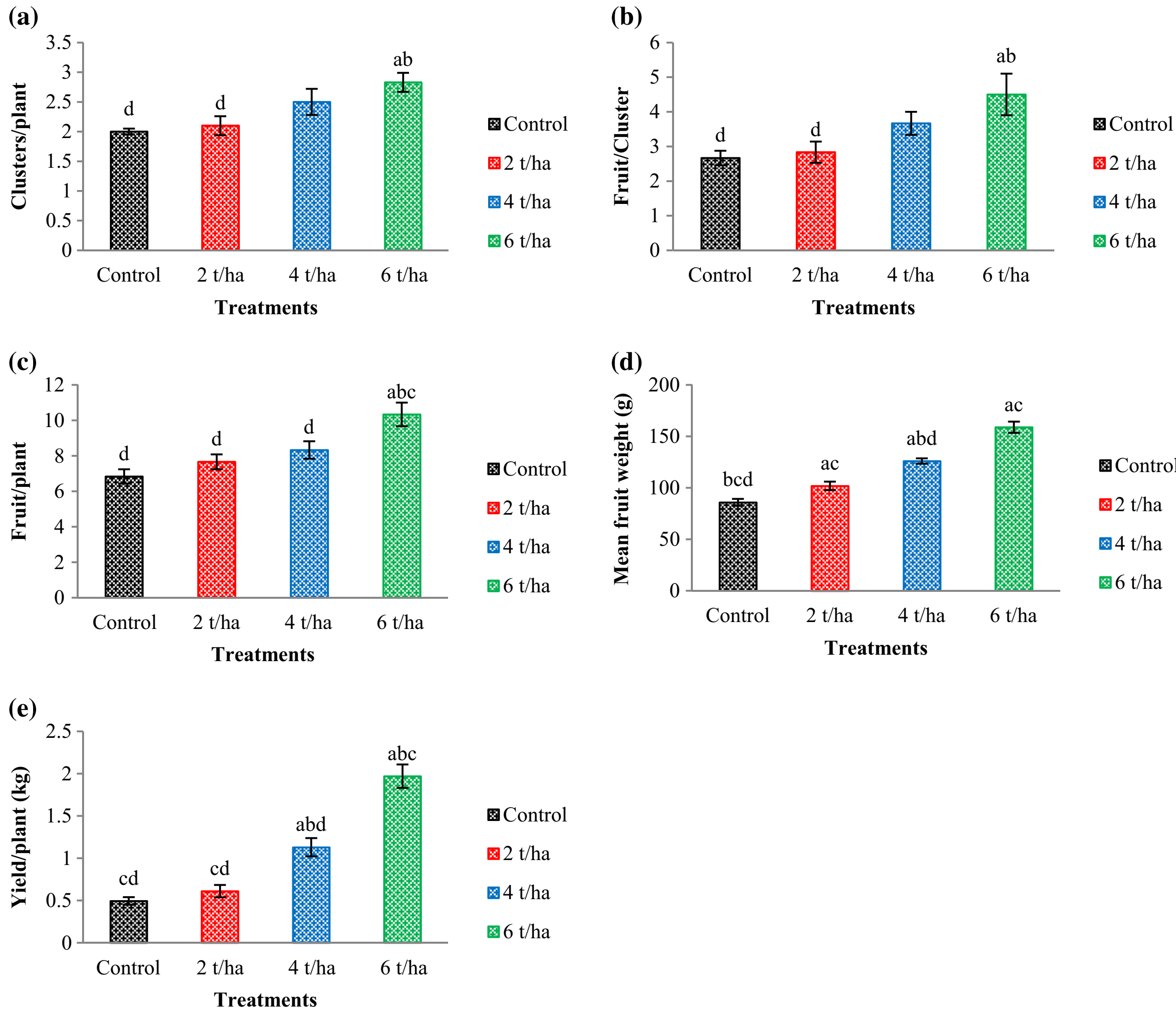

Fig. 3 Effect of macrophyte vermicompost on yield parameters of *Solanum melongena* (mean ± SE, $n = 4$). Significant differences at $P < 0.05$ (Tukey's LSD test) are indicated by *different letters*

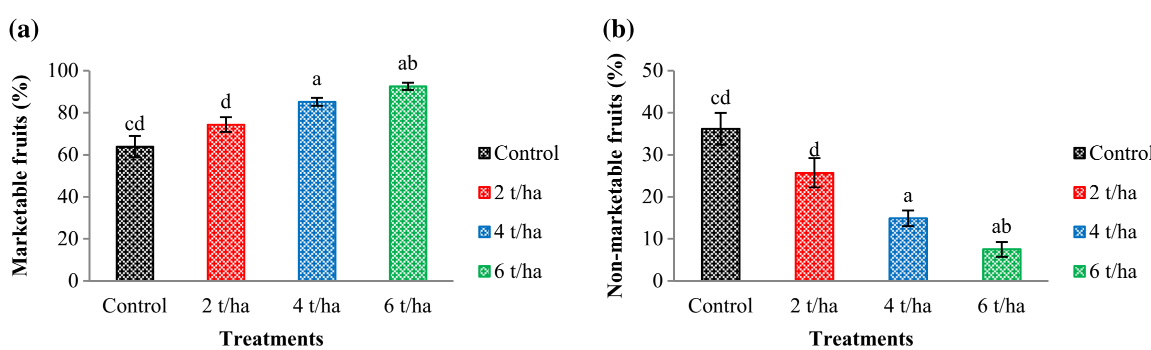

Fig. 4 Effect of macrophyte vermicompost on marketable and non-marketable fruits of *Solanum melongena* (mean ± SE, $n = 4$). Significant differences at $P < 0.05$ (Tukey's LSD test) are indicated by *different letters*

through multiple hormones that either promote or inhibit germination (Finkelstein 2004). The germination rate (%) in *S. melongena* increased with subsequent increase in vermicompost dose. The results corroborate those of Alves and Passoni (1997) that increasing doses of vermicompost application to the potting media of *Licania tomentosa* increased germination as compared to unamended soil. Lazcano et al. (2010) reported changes in the physical properties of the germination media with the incorporation of vermicompost that influence the moisture retention and aeration of the soil, thereby potentially affecting seed germination. Improvement in the soil physical properties with the addition of macrophyte-based vermicompost might have resulted in increased germination rate of *S. melongena*.

Plant growth parameters

Vermicompost has been demonstrated to be a valuable soil amendment that offers slow, but a balanced nutritional release pattern to plants, providing nutrients such as available N, K, Ca, Mg and P that can be taken up readily by plants (Edwards 1998; Edwards and Fletcher 1988). Plant growth parameters like plant length and dry weight; root length and dry weight; number of leaves, area and dry weight were significantly higher in plots amended with different doses of vermicompost. Increase in plant growth with vermicompost application has been reported in different studies. The incorporation of pig manure vermicompost enhanced shoot and root weight, leaf area and shoot:root ratios of tomato and French marigold (Bachman and Metzger 2008). Najar and Khan (2013a) reported significant increase in plant growth (shoot length, root length, leaf area and plant biomass) of *L. esculentum* in plots amended with 6 t/ha macrophyte vermicompost. Joshi and Vig (2010) also reported increase in plant growth parameters (plant height, number of leaves and plant dry biomass) with application of 45 % vermicompost (cattle dung) amended treatment in *L. esculentum*. According to Gupta et al. (2014), addition of cow dung and household-based vermicompost in appropriate quantities to the potting media resulted in increased growth and flowering of marigold seedlings including plant biomass, plant height, number of buds and flowers. Increase in length, biomass, number of seeds, number of shoots in *Vinca rosea* and tillers in *Oryza sativa* has been reported by Reddy (1986) in 50:50 soil to vermicompost mixtures. Tomati et al. (1983) showed positive effects of vermicompost on the growth of *Begonias* sp. and *Coleus* sp. (ornamental plants), especially a stimulation of rooting and time of flowering in plots amended with vermicompost. Plant height of maize increased significantly as compared to the control when grown in soil amended with vermicompost (Gutierrez-Miceli et al. 2008b). Azarmi et al. (2008) reported increase in leaf area and shoot dry weight by 43 and 27 %, respectively, in tomato with 15 t/ha sheep manure vermicompost applications, whereas Atiyeh et al. (2001) reported increase in shoot height of tomato plant with the amendment of 5 % pig manure vermicompost.

The different doses of vermicompost produced different responses in *S. melongena* and among these 6 and 4 t/ha showed maximum positive effect on growth parameters. The results corroborate the findings that different doses of vermicompost caused different responses in the growth parameters of *L. esculentum* plant (Azarmi et al. 2008). Pritam et al. (2010) reported higher number of flowers in treatments with vermicompost amendments, with reduced time taken to transform bud into flower that has been attributed to readily available nutrients and growth-regulating substances present in the vermicompost. According to Ravi et al. (2008) and Taleshi et al. (2011), availability of plant nutrients in vermicompost increases growth and leaf area index of plant, which in turn increases absorption of light leading to more dry matter and yield. The differential response of plants to different doses of vermicompost is due to production of lesser quantity of growth-promoting substances by lower doses of vermicompost than higher doses (Arancon et al. 2004a). Plant root morphology is known to be influenced by water and nutrient availability as well as by external application of hormones (Lopez-Bucio et al. 2003). Vermicomposts have hormone-like activity that aids in greater root initiation, increased root biomass and enhanced plant growth (Bachman and Metzger 2008). According to Forde and Lorenzo (2001), root growth and branching are favored in nutrient-rich environment and in the presence of hormones such as auxins that enable the plant to optimize the exploitation of the available resources which are in turn transformed into photoassimilates and transported again to the root, consequently influencing plant growth and morphology in a systemic manner.

Yield parameters

Vermicompost amendment has influenced the number of clusters/plant, number of fruits/cluster, mean fruit weight and total yield/plant when compared with the control. Atiyeh et al. (2000b) reported increase in tomato fruit yield with the amendments of 10–20 % vermicompost in potting media. Arancon et al. (2004a, 2006) also reported growth and yield improvement in different crops with vermicompost application. The results clearly indicated that the plants receiving vermicompost produced more fruits/cluster, clusters/plant and large-sized fruits with higher total yield than the control. Increase in yield of wheat in cattle dung-based vermicompost-amended soil has been reported by Joshi et al. (2013). According to Arancon et al. (2006), significant increase in plant growth and consequently lesser days to flowering with increase in fruit yield at higher doses of vermicompost amendment were observed. In other similar studies, increases in yield with vermicompost applications in okra, strawberry, eggplant, potato, cucumber cultivars, *Abelmoschus esculentus*, peppers, crossandra, lettuce and Amaranthus species were reported by Singh et al. (2008); Alam et al. (2007); Azarmi et al. (2009); Vijaya and Seethalakshmi (2011); Arancon et al. (2005); Papathanasiou et al. (2012) and Uma and Malathi (2009) respectively. A high level of phosphorous is necessary for plants to produce good yield (Orozco et al. 1996). Vermicompost contains macronutrients, beneficial microorganisms and hormones which influence the growth and yield of plants (Theunissen et al. 2010). Macronutrients play an important role in crop yield based on their role in activation of enzymes for chlorophyll synthesis, growth, fruit ripening and maintenance of the plant enzyme system (Grusak and Della Penna 1999). Vermicompost is known to provide a slow, balanced nutritional release pattern to plants, particularly in terms of release of plant-available N, soluble K, exchangeable Ca, Mg and P (Edwards and Fletcher 1988) which is subsequently used by plants efficiently. Vermicompost application generally improves the soil environment, particularly soil aeration, encouraging the proliferation of roots, which in turn draw more water and nutrient from distant areas and help to introduce and sustain beneficial micro-organisms into the rhizosphere (Padmavathiamma et al. 2008) in sufficient numbers for a longer period.

Marketable and non-marketable fruits

Optimum plant growth and development are essential for better quality yield (Theunissen et al. 2010). The application of vermicompost resulted in increase in marketable fruits and decrease in non-marketable fruits as compared to the control. Further, there was significant increase in marketable fruits with the macrophyte vermicompost when applied at 6 t/ha. The influence of macrophyte vermicompost on the marketable fruits of brinjal may be attributed to balanced plant nutrients present in vermicompost. Increase in vermicompost dose from 2 to 6 t/ha increased marketable fruits significantly, as increased dose provided more plant-available nutrients in the treatments. Singh et al. (2008) reported decreased occurrence of physiological disorders like albinism (4.6 %), fruit malformation (4.1 %) and gray mold (2.7 %) incidence with increase in marketable fruit yield (58.6 %) of Chandler strawberry in the plots amended with 7.5 t/ha vegetable waste-based vermicompost over the control. According to Arancon et al. (2003), there was a significant increase in the marketable fruits of tomato with the application of paper waste-based vermicompost when applied at 5 t/ha. Nath et al. (2011) observed decrease in the nematode population (*Meloidogyne incognita*) with the application of agro-based vermicompost in *S. melongena* and also the marketable fruit yield was consistently greater in vermicompost-treated plots as compared to the control. According to Chandrakumar et al. (2009), decrease in infection of *Leucinodes orbonalis* on *S. melongena* with the application of the vermicompost. Wang et al. (2010) recorded significant increase in marketable weight of Chinese cabbage (*Brassica campestris*) with the application of cow manure vermicompost. Plants treated with vermicompost receive nutrition in a balanced and sustained way than the control (Arancon et al. 2004b) and thus plants produce lesser number of non-marketable fruits.

Edwards et al. (2010) report statistically significant decrease in arthropods (aphids, buds, mealy bug and spider mite) populations and subsequent reduction in plant damage with vermicompost amendment. According to Ramesh (2000), plots amended with vermicompost exhibited decrease in the occurrence of leaf miner (*Aproaerema modicella*) on groundnuts. Further, Edwards et al. (2007) reported considerable suppression of root knot nematode (*Meloidogyne incognita*) and drastic suppression of spotted spider mites (*Tetranychus* spp.) and aphid (*Myzuspersicae*) in *L. esculentum* plants after application of vermicompost. Singhai et al. (2011) recorded appreciable suppression of common scab of potato through application of vermicompost. According to Arancon et al. (2005), vermicomposts provide some essential nutrient elements that are not available in inorganic fertilizers and these could either have increased the plants resistance to pests or made the plants less palatable to the pests, based on the observation that there was decrease in dry weight losses of peppers, tomatoes and cabbage grown with substitutions of different rates of vermicompost in response to the aphid, mealy bug and caterpillar infestations. According to Rao (2002), there were considerable decreases in the population of aphids, coccinellid beetles and spider mites in groundnuts grown on soils amended with vermicompost, compared to those grown on soils amended with inorganic fertilizer. Munroe (2007) reported the presence of chitinase enzyme in vermicompost which breaks down the chitin in the exoskeleton of insects and thus repels many different insect pests. Thus the significant increase in marketable fruit yield of *S. melongena* might be attributed to improved availability of nutrients from macrophyte based vermicompost, in addition to the protection from pests.

Conclusions

The present study reveals that application of macrophyte-based vermicompost is quite beneficial in field-grown *S. melongena* significant higher rate of germination, increased plant growth and yield parameters with higher marketable fruit. Vermicompost application of 6 t/ha resulted in relatively higher productivity and better quality of fruits. The study showed that the growth and yield of *S. melongena* was dose dependent and clearly indicated the advantages of macrophyte vermicompost in quality yield production. Such effects could be attributed to the nutritional status of vermicompost and improvement in soil properties. It encompasses economic aspect also, since faster growth with decreased days for crop maturation and enhanced better quality yield not only result in their early availability in market, but also with higher market values/returns. Thus, macrophyte based vermicompost is an efficient quality yielder and economy enhancer for sustainable agriculture, especially for people/communities having vegetable gardens around lakes. Further large-scale vermicomposting of macrophytes helps in controlling their menace considerably and keeps water bodies clean, along with esthetic improvement.

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