Elsevier Editorial System(tm) for Scientia Horticulturae
Manuscript Draft

Manuscript Number:

Title: On farm production of compost from nursery green residues and its use to reduce peat for the production of olive pot plants

Article Type: Research Paper

Section/Category: Substrates and soilless cultivation

Keywords: Green compost; N mineralization kinetics, Nursery; Olive; Peat; Substrates

Corresponding Author: Prof. Gabriele Chilosi,

Corresponding Author's Institution: Università degli Studi della Tuscia

First Author: Maria Pia Aleandri, Dr.

Order of Authors: Maria Pia Aleandri, Dr.; Gabriele Chilosi; Massimo Muganu, Prof.; Annamaria Vettraino, Prof.; Sara Marinari, Prof.; Marco Paolacci, Dr.; Elena Luccioli, Dr.; Andrea Vannini, Prof.

Abstract: The increasing environmental concerns about the use of peat as a non-renewable resource in growing substrates has led to the search for alternative materials. The aim of the present work was to develop a circular chain system based on the "on farm" production of green compost in nursery from residues of pruning of woody plants and of grass mowing to replace peat in the composition of potting mixes. Composting process, carried out in a nursery located in Central Italy, was evaluated by the analysis of the succession of microbial communities and monitoring of temperature. The potential of green nursery compost in the replacement of different percentages of peat in potting mixes used for the cultivation of olive pot-plants was assessed by the estimation of the nitrogen mineralization potential and the detection of olive tree growth parameters. Results showed that initial mesophilic phase of composting occurred within three weeks followed by the thermophilic phase, which lasted for about 26 weeks and then by the second mesophilic phase. The potential of N mineralization varied with decreasing amount of peat present in the substrate. Plants cultivated in mixes obtained with reduced percentage of peat showed a regular development of growth parameters (plant height and stem diameter) during the whole cultivation cycle. Our results show that the widespread production and use of this renewable resource can provide the partial substitution of peat in potting mixes with the potential to consistently reduce the economic and environmental costs of nursery industry.

Suggested Reviewers: Lassaâd Belbahri
University of Neuchâtel, Switzerland
lassaad.belbahri@unine.ch
expert in Olive oil mill wastewaters

Stephen Woodward
University of Aberdeen,UK
s.woodward@abdn.ac.uk
expert in rhizosphere biology

Annamaria D'Onghia

Istituto Agronomico Mediterraneo, Bari, Italy
donghia@iamb.it
expert in growth substrates and compost

Michael Raviv Raviv
, Agricultural Research Organization, Volcani Center, Israel
mraviv@volcani.agri.gov.il
expert in growth substrates and compost

Marta Benito
Universidad Politécnica de Madrid
marta.benito@upm.es
expert in growth substrates and compost

Cover Letter

Dear Editors,

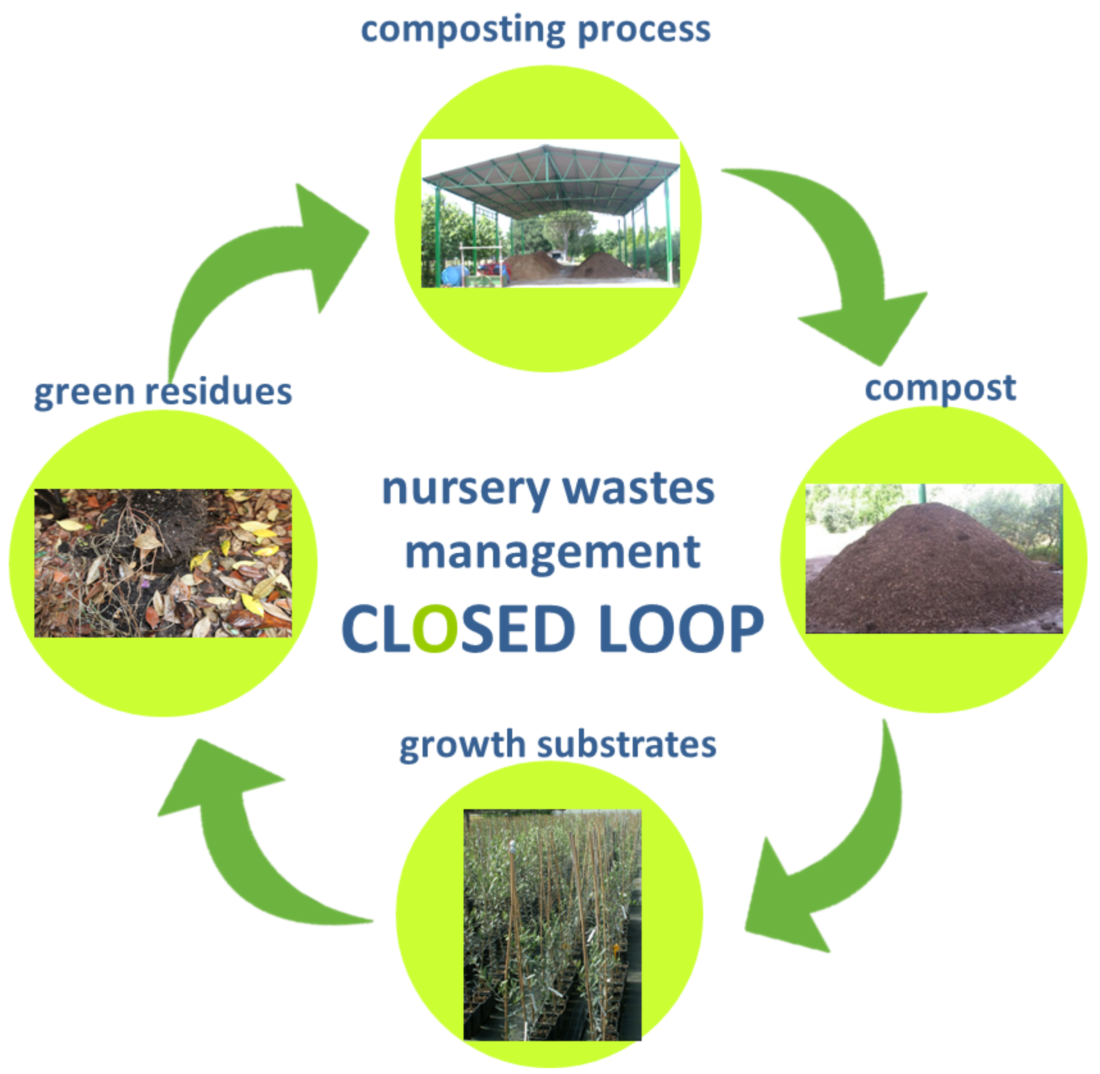
Please find enclosed a manuscript entitled: " **On farm production of compost from nursery green residues and its use to reduce peat for the production of olive pot plants** " which I am submitting for consideration of publication as an article in “Scientia Horticulturae”.

All authors have approved the manuscript and agree with its submission to “Scientia Horticulturae”.

Sincerely,

Gabriele Chilosi

Graphical Abstract (for review)



Graphical abstract

Highlights

- "on farm" production of green compost in nursery from residues from internal activity was developed
- Composting process was analysed by the succession of microbial communities and temperature
- Plants cultivated in mixes obtained with compost and reduced percentage of peat showed a regular development
- The potential of N mineralization varied with decreasing amount of peat present in the substrate
- The compost was found to be a suitable component of mixed-peat substrates for olive plants growth

On farm production of compost from nursery green residues and its use to reduce peat for the production of olive pot plants

Maria Pia Aleandri[a], Gabriele Chilosi[a,*], Massimo Muganu[b], Annamaria Vettraino[a], Sara Marinari[a], Marco Paolocci[b], Elena Luccioli[b], Andrea Vannini[a]

[a]Dept. for Innovation in Biological, Agro-food and Forest systems (DIBAF), University of Tuscia, Via S. Camillo de Lellis I-01100 Viterbo, Italy.
[b]Dept. of Agriculture, Forests, Nature and Energy (DAFNE), University of Tuscia, Via S. Camillo de Lellis I-01100 Viterbo, Italy
∗Corresponding author. Tel.: +39 761 357479; fax: +39 761 357479; E-mail address: chilosi@unitus.it (G. Chilosi)

ABSTRACT

The increasing environmental concerns about the use of peat as a non-renewable resource in growing substrates has led to the search for alternative materials. The aim of the present work was to develop a circular chain system based on the “on farm” production of green compost in nursery from residues of pruning of woody plants and of grass mowing to replace peat in the composition of potting mixes. Composting process, carried out in a nursery located in Central Italy, was evaluated by the analysis of the succession of microbial communities and monitoring of temperature. The potential of green nursery compost in the replacement of different percentages of peat in potting mixes used for the cultivation of olive pot-plants was assessed by the estimation of the nitrogen mineralization potential and the detection of olive tree growth parameters. Results showed that initial mesophilic phase of composting occurred within three weeks followed by the thermophilic phase, which lasted for about 26 weeks and then by the second mesophilic phase. The potential of N mineralization varied with decreasing amount of peat present in the substrate. Plants cultivated in mixes obtained with reduced percentage of peat showed a regular development of growth parameters (plant height and stem diameter) during the whole cultivation cycle. Our results show that the widespread production and use of this renewable resource can provide the partial

substitution of peat in potting mixes with the potential to consistently reduce the economic and environmental costs of nursery industry.

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1. Introduction

The production of high quality pot-plants depends by several factors including the optimization of physical, chemical and microbiological properties of potting mixes (Grigatti et al., 2007). Peat is the most utilized organic substrate for the preparation of potting mixes because of its positive agronomic characteristics such as constant chemical and physical properties, high water retention capacity, optimal porosity, controlled pH (Pane et al., 2011). In Italy, peat is imported with costs becoming more expensive, reaching in 2012 a total value of 59 MIL euro (ISTAT, 2013). Peat represents one of the major costs for nursery production sensibly affecting the final cost of the plants. Moreover, in recent years, environmental concerns about peat extraction in wetland ecosystems have risen. Peat lands cover 3% of the Earth's land surface but boreal and subarctic peat lands store about 15–30% of the world's soil carbon as peat (Limpens et al., 2008). Therefore, there is an international effort to evaluate other organic substrates alternative to peat for the composition of potting mixes with comparable quality (Raviv et al., 1998; Benito et al., 2005; Raviv, 2005; Herrera et al., 2008; Pane et al., 2011; Altieri et al., 2014). Composting is an aerobic process, during which a mixture of organic substrates is degraded by a diverse microbial communities, transferring the organic matter into a stabilised end-product (Insam and de Bertoldi, 2007), which represents a potential alternative to peat (Boldrin et al., 2009). Advantages of composts as ingredients of growing media include their environmental benefits, nutritional contribution, potential positive impact on soil microbiota, and suppressiveness against soil-borne diseases (Tejada et al., 2009; Knapp et al., 2010; Boldrin et al., 2010; Fuchs, 2010; Yogev et al., 2010; Tejada and Benítez, 2011). Potential limitations include high bulk density, salinity, residual phytotoxicity, pH and rate of residual degradation with time (Raviv, 2009). Therefore, the effect of compost might vary depending on the parent waste and production process, and therefore it cannot be generalized (Benito et al., 2006; Lazcano et al., 2009; Rainbow, 2009; Negre et al., 2012; Morales-Corts et al., 2014).

Cultural practices in nurseries generate a consistent amount of residues resulting from mowing and pruning activities whose disposal represents nowadays a relevant economic cost. The ‘on farm’ composting of these residues may result in a final product, the green compost, potentially useful in replacing peat in potting mix, and for mulching.

The production of olive pot-plants is estimated in Italy at 200.000 units per year, representing one of the main sources of income for the Italian nursery industry (CIVI, 2013). The possibility to replace peat with an alternative substrate for nursery olive production could therefore lead to a substantial economic and environmental benefit.

In 2010 a study has been initiated to assess the feasibility of a circular chain system aiming to utilize green wastes from nursery activities (mowing and pruning) to produce ‘on farm’ green compost and to evaluate its beneficial effect for commercial plants growth and production. This approach is the basis of the concept of the ’circular economy‘, which keep the added value in products for as long as possible and eliminates waste [UE COM (2014) 398 final]. Moving towards a more circular economy is essential to deliver the resource efficiency agenda established under the Europe 2020 Strategy for smart, sustainable and inclusive growth [COM (2010)2020, COM(2011)21].

The aims of the present work were: i) to evaluate a close-cycle production of 'on farm' compost from residues produced by the nursery activities, ii) to evaluate the composting process performance by the analysis of physical parameters and the microbial communities succession, iii) to assess the potential of compost as an alternative to peat in potting mixes used for plant cultivation, by the estimation of the nitrogen mineralization potential and the assessment of growth parameters having olive as model plant.

2. Material and methods

2.1 Compost Production

Green Nursery Compost (GNC) was produced during 2010 from residues derived from ordinary operations of pruning and mowing within the nursery farm "Orticoltura Pistoiese" located in the Province of Viterbo, Italy (42°27'00.9"N 12°05'52.9"E). The composting plant comprised a concrete platform (70 m^2) equipped with a drainage system and covered by a permanent roof. The woody matrices, derived from hardwood and conifer residues (85% of *Platanus* x *acerifolia*, *Tilia* spp, *Pinus* spp.) were subjected to chipping and added with turf mowing (15%). The mixture was then piled on the platform and composting started. The pile was periodically turned over and watered. Temperature was monitored weekly using a digital soil thermometer (HI 93510 Thermistor Thermometer, Hanna Instruments, Inc., USA) at six different points (depth 80 cm) of the pile throughout the whole composting process.

2.2 Patterns of microbial community during the composting process

Progress of the composting process was monitored by patterns and succession of the resident microbial communities. Sampling was carried out weekly by collecting 4 samples of 0.5 Kg each from the pile. Samples were sifted with a 2 cm sieve to remove the coarse fractions, immediately transported to the lab and stored at 4°C prior to analysis. The samples were mixed thoroughly, divided into subsamples (10 g) and appropriate serial dilutions were made in sterilized distilled water to count colonies and calculate the microbial colony forming units (CFU) (Hirte, 1969). Aliquots (0.1 mL) of each dilution were spread with a glass rod in Petri plates containing the required medium. Ten plates were used per dilution. In order to calculate the fungal CFU, samples were plated on potato dextrose agar (PDA) (Oxoid, Unipath Ltd, Basingstoke, England), added with streptomycin sulphate (0.01 g L^{-1}). Mesophilic and thermophilic bacteria were cultivated on Plate Count Agar-PCA at 30°C and 55°C for 72 h, respectively (Federici et al., 2011).

2.3 Compost maturity test and chemical characteristics of mature compost

The germination index (GI) was calculated according to Zucconi et al. (1985) to estimate GNC maturity. Deionized water was added to the compost samples to attain a moisture content equivalent to 85% (wet weight) and after a contact period of 2 h, the aqueous extracts were obtained by centrifugation and filtration through a 0.45 μm membrane filter. The concentrated extracts together with three dilutions (25%, 50% and 75% in deionized water) were used as germination media. A Whatman filter paper placed inside a 9 cm diameter, sterilized, disposable Petri dish was wetted with 1 mL of each germination solution and 10 *Lepidium sativum* L. seeds were placed on the paper. Deionized water was used as a control and five replicates were set out for each treatment. The Petri dishes were placed in sealed plastic bags to minimize water loss while allowing air penetration, and were then kept in the dark for 2d at 20°C. After the incubation period the number of germinated seeds and the primary root length were measured and expressed as a percentage of the control (germination index).

Analyses of mature GNC were carried out to detect the following chemical parameters according to analysis Official Methods (ANPA, 2001): pH, carbon:nitrogen (C:N) ratio, electrical conductivity (EC), total organic carbon (TOC), total nitrogen (TN).

2.4 Determination of physical and chemical characteristics and kinetics of nitrogen mineralization in potting mixes

To assess the performance of increasing amounts of GNC in the composition of nursery potting mixes, three growing media with 25% (B) and 50% (C) and 100% (D) of GNC as peat replacement were prepared. Peat-based potting medium used in the nursery farm (60% peat, 40% pumice + Osmocote 10-11-18 NPK) was used as control growing medium (A) (Table 1). The different potting mixes were analysed by the detection of the following physico-chemical parameters according to official methods (MIPA, 1997): pH, electrical conductivity (EC), real and apparent density and total porosity. Nitrogen mineralization was assessed following the method of Stanford and Smith (1972) with a 30-weeks aerobic incubation. Ten grams of GNC were incubated at 28°C in a combined filtration–incubation container. Compost water content was maintained at 60% water holding capacity (WHC) during all the incubation period.

The mineral N produced was leached at predetermined intervals (after 2, 4, 8, 12, 16, 22 and 30 weeks) with 50 mL 0.01 M $CaSO_4$. In order to prevent any limiting effects due to the absence of other nutrients, after each leaching 20 mL of a nutrient solution, minus N, was added to the compost (0.002 M $CaSO_4$, 0.002 M $MgSO_4$, 0.005 M $Ca(H_2PO_4)_2$, 0.0025 M K_2SO_4). After each leaching, ammonium ($N\text{-}NH_4^+$) and nitrate ($N\text{-}NO_3^-$) produced during the incubation time were determined colorimetrically, following the procedures of Anderson and Ingram (1993) and Cataldo et al. (1975), respectively. The kinetic parameters of N mineralization, such as mineralized N (N_m) and potentially mineralizable N (N_0), obtained from the first order kinetic model [$N_m = N_0(1 - e^{-Kt})$], were expressed as nitrate ($N\text{-}NO_3^-$) and ammonium ($N\text{-}NH_4^+$) production during t days. The ratio of N_0 to total N (N_{tot}) was calculated in order to assess the mineralization degree of total nitrogen in the potting mixes. In the mineralization kinetic model, *k* is the rate constant of labile pool mineralization (Marinari et al., 2010).

2.5 Cultivation trials

Agronomical trials were performed to assess the suitability of potting mix compositions for the growth of olive trees (*Olea europea*, cv Frantoio). The experiment was carried out during 2011 and 2012. Olive plants, propagated from cuttings, were grown in greenhouse on five litres plastic pots. Four repetitions of 12 plants were used for each potting mix. The growth of olive plants was analysed during the two years cycle of nursery cultivation, and the following parameters were determined for each potting mix: stem height and diameter; shoots and roots fresh and dry weights determined at the end of cultivation period; total leaf area (ΔT Area Meter, Delta-T Devices, Cambridge, UK) ; leaf biomass.

2.6 Statistical analysis

The experiments were repeated twice. Data were subjected one-way ANOVA analysis. Tukey's post-test was employed subsequently to identify pairs of results with significantly different means. Both ANOVA and post-test were performed by Graph-Pad Prism 4.0 (San Diego, CA, USA)

3 Results

3.1 Temperature and microbial succession during the composting process

The evolution of bulk temperatures during active composting is showed in Figure 1. Initial phase of composting (mesophilic phase, 25-40°C) occurred within three weeks followed by a consistent increase of the temperature, which lasted for about 26 weeks and coincided with the thermophilic phase (35-65°C) (Insam et al., 2010). Then temperature progressively decreased (second mesophilic phase) attaining constant values close to external temperature from the 48th week onward. Outside air temperature was consistently lower than that monitored within the pile. Moreover, during the composting process internal and external temperature was positively correlated ($r_{x,y}$ = 0.78).

Succession of total culturable bacteria and fungi is reported in Fig. 2 A-C. The number of thermophilic and mesophilic bacteria varied during the different composting stages. The early thermophilic phase coincided with the increase of total CFU of both thermophilic bacterial and fungal species. Subsequently, in the evolution of thermophilic phase, total CFU of thermophilic bacteria and fungi dropped down, while that of mesophilic bacteria consistently increased. The onset of the second mesophilic phase coincided with the proliferation of fungal species.

3.2 Compost characteristics

Within 48 weeks the GNC reached a GI value greater than 50% and, therefore, it was considered adequately mature and phytotoxin-free, according to Zucconi et al. (1981).

Chemical characteristics of the GNC at the end of composting period are shown in Table 2. At the end of composting process the value of pH (6.37) agrees with established values for plant cultivation and electrical conductivity (0.92 mS cm^{-1}) showed values that are suitable for the cultivation of pot plants (Sullivan and Miller, 2001). The values of total nitrogen and of organic C showed the good potential of GNC as fertilizer and organic amendment.

3.3 Physical and chemical characteristics and N mineralization kinetics in potting mixes

Chemical characteristics of the potting mixes are shown in Table 3. The increase of GNC in the composition of potting mixes resulted in an increase of electrical conductivity (EC) and pH. Concerning physical parameters the values of total porosity slightly decreased with the increase of GNC percentage in potting mixes.

Soil nitrogen mineralization was measured as N-NO_3 and N-NH_4^+ release during 30 weeks of incubation of potting mixes with different rate of peat substitution (Fig. 3). The results indicate that different amounts of N-NO_3 and N-NH_4 were released during incubation of the potting mixes. In control A (60 % peat) and B (45% peat, 15% GNC) substrates the main form of N produced during incubation was N-NH_4. Conversely, in C (30% peat, 30% GNC) and D (60% GNC) substrates, the amount of N-NH_4 released was consistently lower. Furthermore, in potting mix D the highest release of N-NO_3 in the early stages of the mineralization process occurred compared to other mixes with a decline from the 14^{th} week onward. The percentage of potentially mineralizable N to total N of potting mixes (N_0/Ntot) declined with decreasing amount of peat present in the substrate (Fig. 4).

3.4 Olive trees growth

Olive plants showed a statistically similar increase of growth parameters in the potting-mixes A-B-C during the two years cultivation period, in particular the values of plant height detected in October 2011 and 2012 (Table 4). Instead, the D mix determined a significantly lower plant growth. Statistically similar values of trunk diameter were detected in plants growth in A and B potting mixes. With respect to the biomass allocation between shoots and roots at the end of cultivation period, a declining trend was evident for both roots and stem with decreasing amount of peat present in the substrate, although differences among A, B and C were not significant (Fig. 5). Total leaf area and leaf biomass detected at the end of the experiment, did not show significant differences between A and B growing media, while mix C and D determined a significantly lower values of these parameters (Fig. 6).

4. Discussion

The present study showed the feasibility of a nursery circular system producing green compost from plant biomasses residual of the nursery activities. Furthermore, it has been demonstrated how monitoring activities carried out during the composting process might provide easy to use indicators of the quality of the aerobic digestion and maturation processes. Monitoring of the microbial succession is an important measure in the effective management of the composting process as microorganisms play key roles in the transformation of the raw material and the occurrence of certain groups of microorganisms reflects the quality of maturing compost (Ryckeboer et al., 2003a; Vivas et al., 2009). The composting process involves the aerobic exothermic microbial decomposition of the initial substrate. The length of the different composting phases depends on the nature of the organic matter being composted and the efficiency of the process, which is determined by several factors such as starting material, O_2 supply, moisture content, active turning and outside temperature (Ryckeboer et al., 2003b). Present data show the C/N ratio of GNC was higher than optimum (>40) (Tuomela et al, 2000). In this condition, nitrogen was a limiting factor, thus determining a slow rate of degradation process. Despite this criticism, the different composting phases were clearly distinguishable. During the thermophilic phase, which followed a short initial mesophilic phase, microbial activity was mainly due to thermophilic bacteria and fungi that are important degraders of substrates rich in cellulose and lignin such as that under investigation (Insam et al., 2010). Total mesophilic bacteria increased during thermophilic phase probably facilitated by the relatively low temperatures (around 50°C) during this phase. The second mesophilic phase was characterized by an increased number of fungal species, probably degraders of starch and cellulose (Ryckeboer et al., 2003b).

The results from the cress-seed germination bioassay showed a GI greater than 50% which, according to Zucconi et al. (1981), indicates a phytotoxin-free compost. Hence, the material resulting from the composting process was suitable for substituting peat in potting mixes.

The values of pH and electric conductivity increased with the increase of the GNC in potting mixes, in a range considered suitable for olive cultivation (Gajdos, 1997; Fernàndez and Moreno, 2000) except for the electrical conductivity value of thesis D considered too high for optimal plant growth.

In the present study, total porosity slightly decreased with the increase of GNC in potting mixes. A similar trend was reported by Edwards et al. (2011) by substituting increasing percentages of vermicompost to Standard Commercial Potting Media MM 360. However, values were kept very close to the ideal total porosity value of 85% as suggested by de Boodt and Verdonck (1972).

The N_0/Ntot ratio in the four substrates progressively decreased from A to D. This result suggests a less mineralization degree of nitrogen in GNC with respect to that present in peat. The different N_0/Ntot ratio in GNC and peat might be due to the origin of organic nitrogen forms and/or to the composition of microbial communities involved in organic matter transformation process. The release of inorganic nitrogen from chemical fertilizer was not a key determinant, since significant differences of N_0/N_{tot} were obtained among the potting mixes with the same dose of chemical fertilizer. In C and D substrates composition N-NO_3 increased as N-NH_4 decreased probably because nitrification process occurred when pH value of substrates was over 6.0. In fact, the nitrification rate commonly declines with reduction of substrate pH (Focht and Verstraete, 1977; Benke et al., 2012). It is likely that peat, as an acid component of the potting mix, might have inhibited the nitrification rate, but not the release of ammonium originated from the mineralization process (Focht and Verstraete, 1977; Khalil et al., 2005; Molina, 1985). In mixes containing GNC the process of mineralization has resulted in a faster release of N-NO_3 from N-NH_4 with a peak at the 4th week as in the case of potting mix D, probably due to a positive effect of GNC on the growth of nitrifying microbial population

Compost from green residues has been found to be a suitable component for growing media (Hartz et al., 1996; Spiers and Fietje, 2000; Benito et al, 2005; Benito et al., 2009). In particular, a peat-based media partially amended with green compost derived from municipal biosolids was found to be effective in improving olive seedling growth when added at low percentages to the peat-based media (Mugnai et al., 2007). Our results show that the partial replacement of peat with GNC produced olive plants of similar agronomical and commercial quality than the peat–pumice substrate during the two-year trial. This was probably due to the N-kinetic of the mixtures, which provided the long term availability of N for plant uptake diversified in both nitric and ammonium and the optimal values of physical parameters for growth since the beginning of cultivation and throughout the first year of cultivation. By contrast, quality of plants grown in D was lower than plants in the other substrates, although this mix had a relatively high N-NO_3 level. This could be explained by the low value of total porosity and concomitant increase in EC value detected in mix D, which could be responsible of the low growth of the plant root system, with a consequent influence on the regular development at shoot level (Larcher and Scariot, 2009), as proved also by the reduction of total leaf area compared to other substrates.

5. Conclusion

On farm composting and the use of the end-product to the partial substitution of peat in nursery activity allows reducing the environmental and economic costs in the production of potted plants. Moreover, the use of compost can have an important added value for the nursery production due to the possibility of being assigned the ecolabel brand that is recognized at EU level (Decision 2007/64/EC).

GNC was found to be a suitable component of mixed-peat substrates for olive plants, providing a 15% or 30% of peat substitution, with results comparable to that obtained using standard peat-based mixture. In a context of close-cycle production of on farm compost with crop residues produced during the nursery activities, our results show that the widespread production and use of this renewable organic compost, can provide the partial substitution of peat in potting mixes with the potential to consistently reduce the economic and environmental costs. A further research is needed with the aim of completing the total replacement of peat with a renewable substrate with a lower C/N ratio and higher fertilizing ability, such as compost from organic urban waste and sewage sludge.

Acknowledgments

This study was carried out within the programme ‘Development of a production chain of quality nursery plants with "zero emissions" and tools for certification of their growing cycle ', financed by the Ministry of Agriculture, Food and Forestry, Italy. A special thanks to Orticoltura Pistoiese for the kind collaboration in preparing compost and providing compost material for the analyses.

References

Altieri, R., Esposito, A., Baruzzi, G., Nair, T., 2014. Corroboration for the successful application of humified olive mill waste compost in soilless cultivation of strawberry. Int. Biodeterior. Biodegradation 88, 118-124.

Anderson, J.M., Ingram, J.S.I., 1993. Colorimetric determination of ammonium, in: Anderson, J.M., Ingram, J.S.I. (Eds.), Tropical Soil Biology and Fertility: A Handbook of Methods. 2nd edn. CAB International, Wallingford, UK, pp. 73–74.

ANPA, 2001. Metodi di analisi del compost. ANPA Handbook Manuali e linee guida 2001/3, Roma, Italy. http://www.isprambiente.gov.it/it/pubblicazioni/manuali-e-linee-guida/metodi-di-analisi-del-compost (in Italian). Accessed 21 April 2015.

Benke, M.B., Goh, T.B., Karamanos, R., Lupwayi, N.Z., Hao, X., 2012. Retention and nitrification of injected anhydrous NH_3 as affected by soil pH. Can. J. Soil Sci. 92, 589-598.

Benito, M., Masaguer, A., De Antonio, R., Moliner, A., 2005. Use of pruning waste compost as a component in soilless growing media. Bioresource Technol. 96, 597-603.

Benito, M., Masaguer, A., Moliner, A., De Antonio, R., 2006. Chemical and physical properties of pruning waste compost and their seasonal variability. Bioresource Technol. 97, 2071-2076.

Benito, M., Masaguer, A., Moliner, A., Hontoria, C., Almorox, J. 2009. Dynamics of pruning waste and spent horse litter co-composting as determined by chemical parameters. Bioresource Technol. 100, 497-500.

Boldrin, A., Andersen, J.K., Møller, J., Christensen, T.H., Favoino, E., 2009. Composting and compost utilization: accounting of greenhouse gases and global warming contributions. Waste Manag. Res. 27, 800-812.

Boldrin, A., Hartling, K.R., Laugen, M., Christensen, T.H., 2010. Environmental inventory modelling of the use of compost and peat in growth media preparation. Resour. Conserv. Recy. 54, 1250-1260.

Cataldo, D.A., Haroon, M., Schrader, L.E., Young, V., 1975. Rapid colorimetric determination of nitrate in plant tissue by nitration of salicylic acid. Commun. Soil Sci. Plant Anal. 6, 71–80.

CIVI, 2013. CIVI (Centro Interprofessionale per le attività vivaistiche) http://www.civi-italia.it/ (in Italian). Accessed 21 April 2015.

de Boodt, M.A.V.O., Verdonck, O., 1972. The physical properties of the substrates in horticulture. Acta Hort. 26, 37-44.

Edwards, C.A., Subler, S., Aracon, N., 2011. Quality criteria for vermicomposts, in Edwards, C.A., Arancon, N.Q., Sherman, R. (Eds.), Vermiculture Technology: Earthworms, Organic Wastes and Environmental Management, CRC Press, Boca Raton, pp. 287–302.

Federici, E., Pepi, M., Esposito, A., Scargetta, S., Fidati, L., Gasperini, S., Cenci, G., Altieri, R., 2011. Two-phase olive mill waste composting: Community dynamics and functional role of the resident microbiota. Bioresource Techn. 102, 10965-10972.

Fernández, J.E., Moreno, F., 2000. Water use by the olive tree. J. Crop Prod. 2, 101-162.

Focht, D.D., Verstraete, W., 1977. Biochemical ecology of nitrification and denitrification. Adv. Microb. Ecol. 1, 135–214.

Fuchs, J.G., 2010. Interactions between beneficial and harmful microorganisms: from the composting process to compost application, in: Diaz, L.F., de Bertoldi, M., Bidlingmaier, W. (Eds). Microbes at work. From wastes to resources. Springer-Verlag, Heidelberg, pp. 213-230.

Gajdoš, R., 1997. Effects of two composts and seven commercial cultivation media on germination and yield. Compost Sci. Util. 5, 16-37.

Grigatti, M., Giorgonnim M.E., Ciavatta, C. 2007. Compost-based growing media: Influence on growth and nutrient use of bedding plants. Bioresource Technol. 98, 3526-3534.

Hartz, T.K., Costa, F.J., Schrader, W.L. 1996. Suitability of composted green waste for horticultural uses. HortScience 31, 961–964.

Herrera, F., Castillo, J.E., Chica, A.F., López Bellido, L., 2008. Use of municipal solid waste compost (MSWC) as a growing medium in the nursery production of tomato plants. Bioresource Technol. 99, 287-296.

Hirte, W.F., 1969. The use of dilution plate method for the determination of soil microflora. The qualitative demonstration of bacteria and actinomycetes. Zentrall. Bakteriol. Parasitenkd. Infektionskr. Hyg. 123, 167–178.

Insam, H., de Bertoldi, M., 2007. Microbiology of the composting process, in: Diaz, L.F., de Bertoldi, M., Bidlingmaier, W., Stentiford, E. (Eds) Compost science and technology. Elsevier, Oxford, pp 25–48.

Insam, H., Franke-Whittle, I., Goberna, M., 2010. Microbes in aerobic and anaerobic waste treatment, in: Diaz, L.F., de Bertoldi, M., Bidlingmaier, W. (Eds). Microbes at work. From wastes to resources. Springer-Verlag, Heidelberg pp. 1-34.

ISTAT (2013) Commercio estero e attività internazionali delle imprese, ISTAT Edizione 2013, Rome, Italy (in Italian).

Khalil, M.I., Hossain, M.B., Schmidhalter, U., 2005. Carbon and nitrogen mineralization in different upland soils of the subtropics treated with organic materials. Soil Biol. Biochem. 37, 1507–1518.

Knapp, B.A., Ros, M., Insam, H., 2010. Do Composts Affect the Soil Microbial Community? in: Insam, H., Franke-Whittle, I., Goberna, M. (Eds.) Microbes at work. From wastes to resources. Springer-Verlag, Heidelberg, pp. 271-291

Larcher, F., Scariot, V., 2009. Assessment of partial peat substitutes for the production of Camellia japonica. Hort. Sci., 44, 312-316.

Lazcano, C., Arnold, J., Tato, A., Zaller, J.G., Domínguez, J., 2009. Compost and vermicompost as nursery pot components: effects on tomato plant growth and morphology. Span. J. Agric. Res. 7, 944-951.

Limpens, J., Berendsem F., Blodau, C., Canadell, J.G., Freeman, C., Holden, J., Roulet, N., Rydin, H., Schaepman-Strub, G., 2008. Peatlands and the carbon cycle: from local processes to global implications–a synthesis. Biogeosciences 5, 1475-1491.

Marinari, S., Lagomarsino, A., Moscatelli, M.C., Di Tizio, A., Campiglia, E., 2010. Soil carbon and nitrogen mineralization kinetics in organic and conventional three-year cropping systems. Soil Till. Res. 109, 161-168.

MIPA, 1997. Ministero delle Politiche Agricole, Osservatorio Nazionale Pedologico e per la Qualità del Suolo, Metodi di analisi fisica del suolo. Franco Angeli, Milan, Italy (in Italian).

Molina, J.A.E., 1985. Components of rates of ammonium oxidation in soil. Soil Sci. Soc. Am. J. 49, 603–609.

Morales-Corts, M.R., Gómez-Sánchez, M., Pérez-Sánchez, R., 2014. Evaluation of green/pruning wastes compost and vermicompost, slumgum compost and their mixes as growing media for horticultural production. Sci. Hortic. 172, 155-160.

Mugnai, S., Azzarello, E., Mancuso, S., Pandolfi, C., Masi, E., 2007. Investigating the possibility of peat substitution in olive nurseries by green compost. Adv. Hort. Sci. 21, 96-100.

Negre, M., Monterumici, C.M., Vindrola, D., Piccone, G., Perrone, D.G., Tomasso, L., Montoneri, E., 2012. Horticultural and floricultural applications of urban wastes originated fertilizers. Compost Sci. Util. 20, 150-155.

Pane, C., Spaccini, R., Piccolo, A., Scala, F., Bonanomi, G., 2011. Compost amendments enhance peat suppressiveness to *Pythium ultimum*, *Rhizoctonia solani* and *Sclerotinia minor*. Biol. Control 56, 115–124.

Rainbow, A., 2009. The use of green compost in the production of container nursery stock in the UK: challenges and opportunities. Acta Hort. 819, 27-32.

Raviv, M., Zaidman, B.Z., Kapulnik, Y., 1998. The use of compost as a peat substitute for organic vegetable transplants production. Compost Sci Util, 6, 46-52.
Raviv, M., 2005. Production of high-quality composts for horticultural purposes: a mini-review. HortTechnology 15, 52-57.
Raviv, M., 2009. The future of composts as ingredients of growing media. Acta Hort. 891, 19–32.
Ryckeboer, J., Mergaert, J., Coosemans, J., Deprins, K., Swings, J., 2003a. Microbiological aspects of biowaste during composting in a monitored compost bin. J. Appl. Microbiol. 94, 127-137.
Ryckeboer, J,, Mergaert, J., Vaes, K., Klammer, S., De Clercq, D., Coosemans, J., Insam, H., Swings, J., 2003b. A survey of bacteria and fungi occurring during composting and self-heating processes. Ann. Microbiol. 53, 349-410.
Spiers, T.M., Fietje, G., 2000. Green waste compost as a component in soilless growing media. Compost Sci. Util. 8, 19–23.
Stanford, G., Smith, S.J., 1972. Nitrogen mineralization potentials of soils. Soil Sci. Soc. Am. Proc. 36, 465–472.
Sullivan, D.M., Miller, R.O., 2001. Compost quality, attributes, measurements, and variability in: Stoffella, P.J., Kahn, B.A. (Eds.), Compost Utilization in Horticultural Cropping Systems. Lewis Publ., Boca Raton, FL. pp. 95-119.
Tejada, M., Hernandez, M.T., Garcia, C., 2009. Soil restoration using composted plant residues: effects on soil properties. Soil Till. Res. 102,109–117.
Tejada, M., Benitez, C., 2011. Organic amendment based on vermicompost and compost: differences on soil properties and maize yield. Waste Manag. Res. 29,1185–1196.
Tuomela, M., Vikman, M., Hatakka, A., Itävaara, M., 2000. Biodegradation of lignin in a compost environment: a review. Bioresource Technol. 72, 169-183.
Yogev, A., Raviv, M., Hadar, Y., Cohen, R., Wolf, S., Gil, L., Katan, J., 2010. Induced resistance as a putative component of compost suppressiveness. Biol. Control 54, 46-51.
Vivas, A., Moreno, B., Garcia-Rodriguez, S., Benítez, E., 2009. Assessing the impact of composting and vermicomposting on bacterial community size and structure, and microbial functional diversity of an olive-mill waste. Bioresource Technol. 100, 1319-1326.
Zucconi, F., Monaco, A., Forte, M., de Bertoldi, M., 1985. Phytotoxins during the stabilization of organic matter. in: Gasser, J.K.R. (Ed.), Composting of agricultural and other wastes. Elsevier Applied Science Publishers, London, UK, pp.73-86.

Figure captions

Fig. 1 External and internal temperature during the composting process of the raw biomass.

Fig. 2 Changes of the microbial community expressed as Colony Forming Units (CFU) during the composting process of raw biomass. (A) thermophilic bacteria, (B) mesophilic bacteria, (C) fungal species.

Fig. 3 Nitrogen (μg N gr^{-1}) mineralization kinetics in the potting mixes containing compost as peat substitute. (A) standard 60% peat + 40% pumice; (B) 45% peat + 15% compost + 40% pumice; (C) 30% peat + 30% compost + 40% pumice; (D) 60% compost + 40% pumice. Bars indicate standard error (n = 3).

Fig. 4 Percentage of potentially mineralizable N (N_0) to total N (N_{tot}) of potting mixes A-D. (A) standard 60% peat + 40% pumice; (B) 45% peat + 15% compost + 40% pumice; (C) 30% peat + 30% compost + 40% pumice; (D) 60% compost + 40% pumice. Means and standard deviation are reported. Different letters denote significant differences at post-ANOVA Tukey test (P<0.05). Bars indicate standard deviation.

Fig. 5 Aerial part (■) and root (▩) biomass (g dry matter $plant^{-1}$) of olive plants grown in the potting mixes A-D at the end of the trial in 2012. (A) standard 60% peat + 40% pumice; (B) 45% peat + 15% compost + 40% pumice; (C) 30% peat + 30% compost + 40% pumice; (D) 60% compost + 40% pumice. Means and standard deviation are reported. Within each series, values with different letters indicate significant differences at post-ANOVA Tukey test (P<0.05).

Fig. 6 Total leaf area (cm) (■) and foliar biomass (g dry matter $plant^{-1}$) (▩) of olive seedlings grown in the potting mixes A-D at the end of trial in 2012. (A) standard 60% peat + 40% pumice; (B) 45% peat + 15% compost + 40% pumice; (C) 30% peat + 30% compost + 40% pumice; (D) 60% compost + 40% pumice. Means and standard deviation are reported. Within each series, different letters denote significant differences at post-ANOVA Tukey test (P<0.05).

Table(s)

Table 1
Composition of the of the potting mixes with increasing percentage of compost.

Potting mix	formulation			
	peat %	compost %	pumice %	fertilizer kg m^{-3}
A	60	0	40	2.50
B	45	15	40	2.50
C	30	30	40	2.50
D	0	60	40	2.50

Table 2
Main chemical characteristics of compost GNC at the end of composting process. Means and standard deviation are reported.

parameter	value
pH	6.37 ± 0.05
Electrical conductivity (mS cm^{-1})	0.92 ± 0.15
Total Nitrogen (%)	0.88 ± 0.03
Carbon (%)	47.7 ± 1.50
C/N	54.2 ± 1.80

Table 3

Main physical and chemical characteristics of the potting mixes used for olive cultivation. (A) standard 60% peat + 40% pumice; (B) 45% peat + 15% compost + 40% pumice; (C) 30% peat + 30% compost + 40% pumice; (D) 60% compost + 40% pumice. Means and standard deviation are reported.

Parameter	**Potting mix**			
	A	**B**	**C**	**D**
pH	5.75 ± 0.02	5.94 ± 0.02	6.33 ± 0.01	6.57 ± 0.03
Electrical conductivity (mS/cm)	0.52 ± 0.05	0.68 ± 0.04	1.03 ± 0.04	1.19 ± 0.03
Apparent density (g cm^{-3})	0.41 ± 0.04	0.43 ± 0.07	0.44 ± 0.07	0.45 ± 0.05
Real density (g cm^{-3})	2.32 ± 0.08	2.30 ± 0.10	2.28 ± 0.04	2.28 ± 0.06
Total porosity (% vol)	83.10 ± 1.20	82.30 ± 1.60	81.50 ± 1.40	80.10 ± 2.10

Table 4

Average values of plant height and trunk diameter of olive plants grown in the substrates (A-D) amended with increasing amount of compost in substitution of peat at the last rating of 2011 and 2012, and percentage of annual increase. Different letters in the same column denote significant differences at post-ANOVA Tukey test (*P*<0.05).

potting mix	plant height (cm)				
	2011	**Δ (%)**	**2012**	**Δ (%)**	**Δ (%) total**
A	109,4 a	60.3	125.5 a	14.7	83.9
B	104.3 a	45.9	121.7 a	16.9	70.2
C	96.3 ab	53.2	114,1 a	18.5	81.5
D	74.6 b	25.1	85.0 b	13.8	42.4

potting mix	trunk diameter (cm)				
	2011	**Δ (%)**	**2012**	**Δ (%)**	**Δ (%) total**
A	8,5 ab	29.0	9,4 a	11.4	43.8
B	8,5 a	32,1	9,4 ab	9.5	44.6
C	7,7 abc	32.1	8,7 bc	12.4	48.5
D	7,0 c	23,4	7,5 c	10.4	36.3

Figure(s)

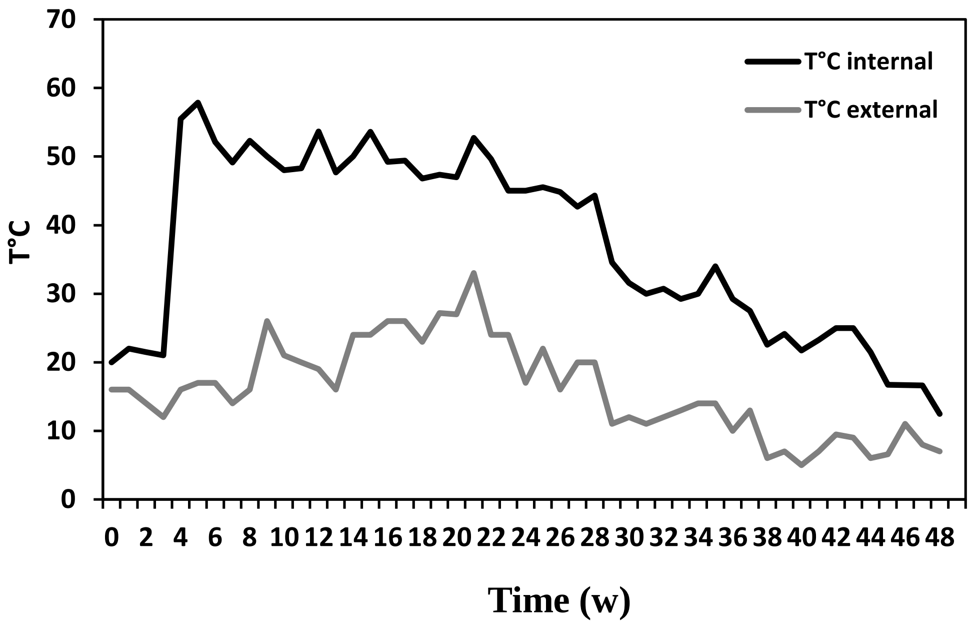


Fig. 1.

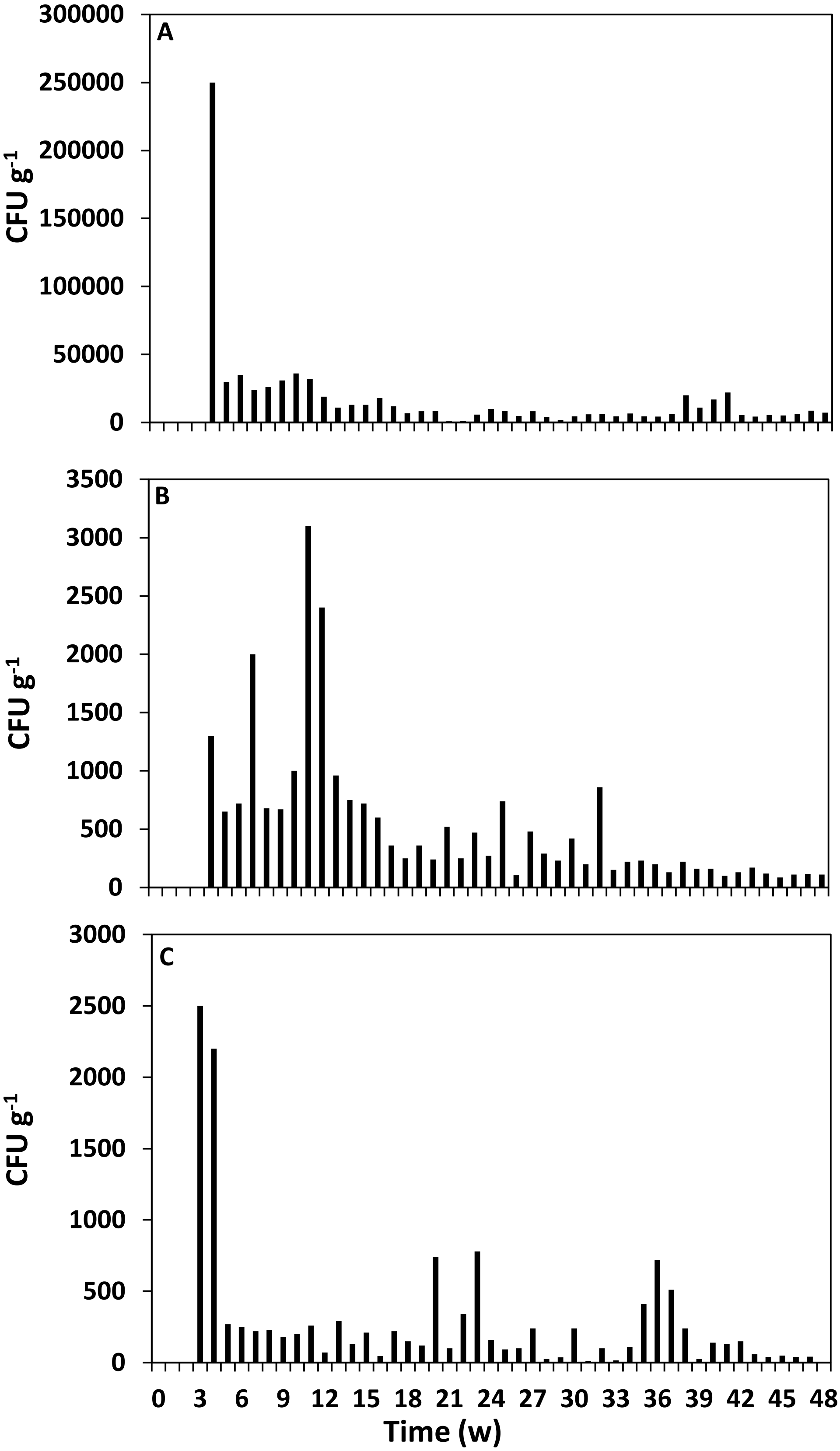
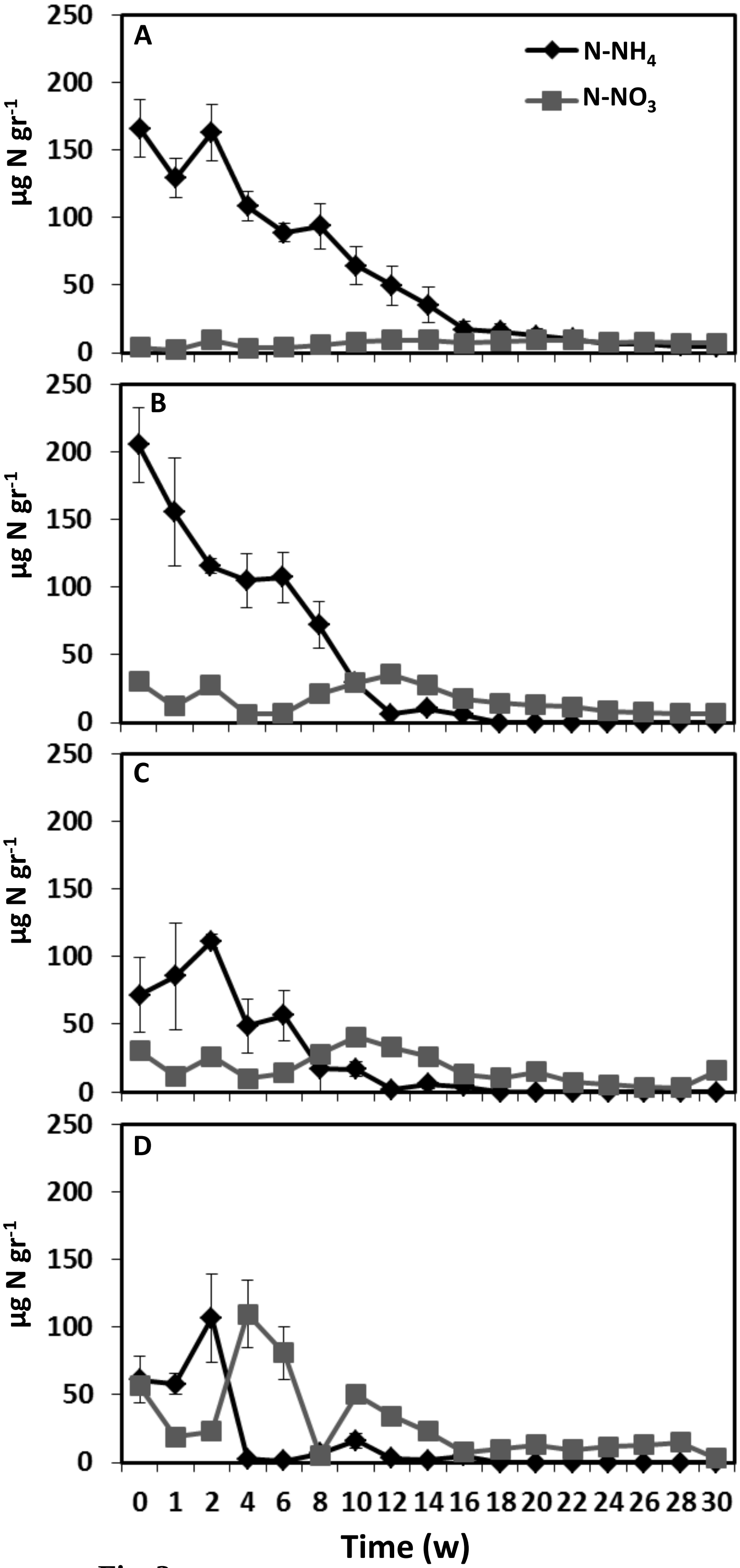

A
B
C
CFU g-1
Time (w)
0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48
300000 250000 200000 150000 100000 50000 0
3500 3000 2500 2000 1500 1000 500 0
3000 2500 2000 1500 1000 500 0

Fig. 2



A
B
C
D
N-NH4
N-NO3
μg N gr-1
250
200
150
100
50
0
0 1 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Time (w)

Fig. 3

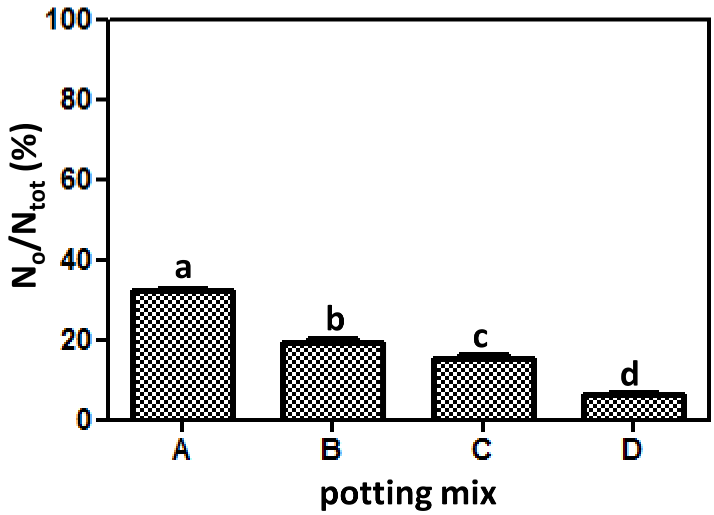


Fig. 4

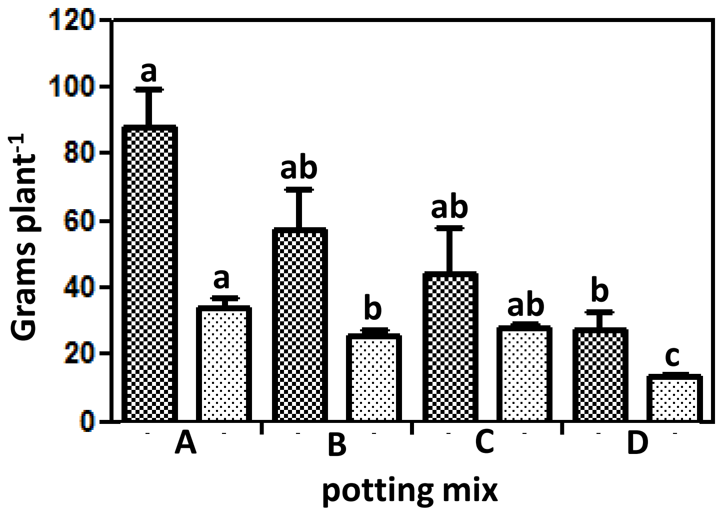

120
100
80
60
40
20
0
Grams plant-1
a
a
ab
b
ab
ab
b
c
A
B
C
D
potting mix

Fig. 5

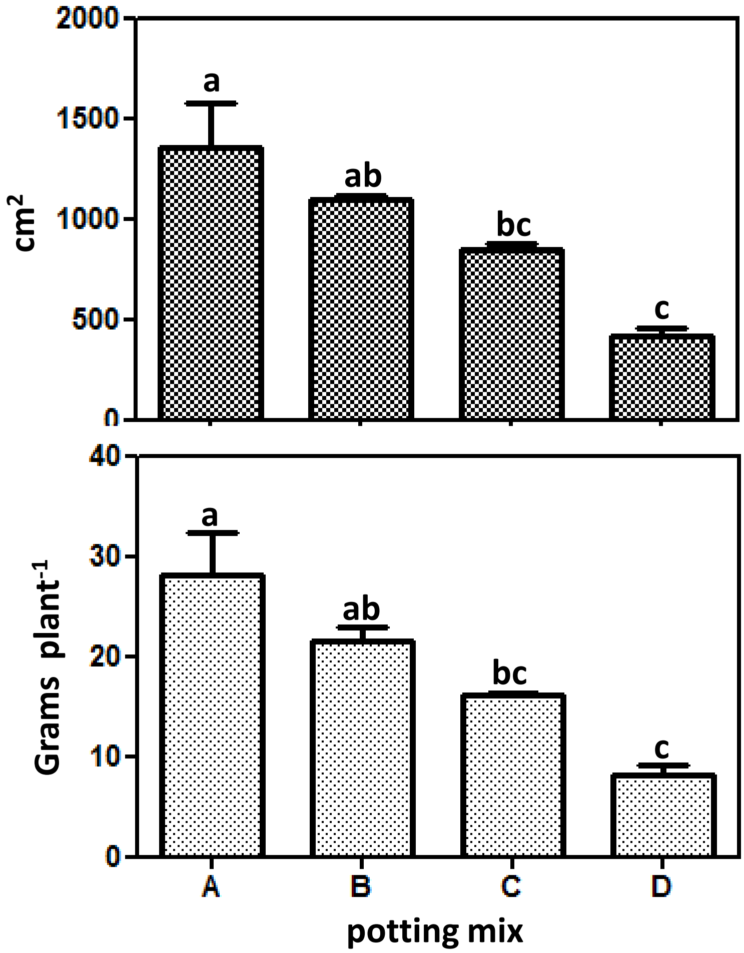

2000
1500
1000
500
0
cm2
a
ab
bc
c
40
30
20
10
0
Grams plant-1
a
ab
bc
c
A
B
C
D
potting mix

Fig. 6