Effect of brown coal-based composts produced with the use of white rot fungi on the growth and yield of strawberry plants

W. Stępien [1], E. Malusà [2,3], L. Sas Paszt [2], G. Renzi [3], J. Ciesielska[2]

Abstract

Composts were produced using brown coal from the Brown Coal Mine in Belchatow (Poland), with the following additions: a) an inoculum of either Pleurotus ostreatus *or* Lentinus edodes *– white rot fungi (1% of the total weight of the compost matrix); b) Vinassa – a by-product of the production of bakery yeasts (10% of the total weight of the compost matrix); c) whey – a dairy by-product (10% of the total volume of the compost matrix).* The *composts were analyzed for nitrogen and carbon content, organic carbon fractions (TEC, HA and FA), and humification indices were calculated.The composts were used in a trial where strawberry plants were grown under field conditions, but in mesocosms made of terracotta pots (about 0.12 m^3) buried in soil.*

The two species of fungi and the two by-products affected differently the decomposition of the organic matrix during the composting process, resulting in composts with different characteristics of the organic matter and different content of mineral elements. Those obtained with Vinassa had the highest N content and the highest amount of soluble organic C forms.

The use of the different composts as soil fertilizers induced a similar overall growth of strawberry plants cv. 'Elsanta'. However, fruit yield was differently affected by the applied treatment. Considering all the parameters measured, the compost obtained with the use of vinassa and Pleurotus ostreatus *were the most promising among the different composts used.*

Keywords: Compost, strawberry, lignino-cellulosic fungi

Introduction

Composted mixtures of vegetable and animal materials are allowed to be used in organic farming. Farms dedicated to horticultural productions are frequently lacking compostable raw materials. The limited availability of classical organic fertilizers (i.e. manure) even in not specialized farms, and scarce information about the effects of new kinds of organic fertilizers like plant extracts (Sas-Paszt et al. 2011) or microbial inocula (Malusà et al. 2007) are serious bottlenecks for the development of the organic horticultural productions in Poland. We are thus evaluating the feasibility of different organic sources, that are included in the list of products allowed to be use in organic farming, as well as new materials that have the potential to be included in Annex I of Commission Regulation (EC) 889/2008, for the production of composts that could be used in organic fruit production.

The aim of the study, carried out within the framework of a project intended to develop new products and technologies for organic fruit production in Poland, was to evaluate the quality of new composts and their effect on the growth and yield of strawberry plants.

[1] Wojciech Stępień Life Science University (SGGW), Warsaw, Poland, Wojciech_Stepien@sggw.pl
[2*] Eligio Malusà Research Institute of Horticulture, Skierniewice, Poland, malusa@inrete.it; corresponding author
[2] Lidia Sas-Paszt Research Institute of Horticulture, Skierniewice, Poland lsas@insad.pl
[2] Jolanta Ciesielska Research Institute of Horticulture, Skierniewice, Poland jwc@inrete.it
[3] Gianluca Renzi CRA-Center for Plant Soil System, Rome, Italy, gianluca.renzi@entecra.it

Materials and Methods

Composts were prepared using brown coal as lignin substrate (Kopalni Węgla Brunatnego Bełchatów, Poland) with the addition of one of the following waste residues and one of the fungus species to produce four different mixtures:

a) Vinassa – a by-product of the production of bakery yeasts (10% of the total mass of the organic matrix)

b) whey – a dairy by-product (10% of the total volume of the compost matrix)

c) an inoculum of either *Pleurotus ostreatus* (pleurotus) or *Lentinus edodes* (shiitake) – white rot fungi (1% of the total weight of the compost matrix)

The addition of the fungi aimed at accelerating the decomposition of the organic compounds found in the brown coal, while the addition of the organic by-products enriched the compost matrix with mineral compounds (especially nitrogen) and amino acids increasing the efficiency of organic carbon transformation and the content of nutrients in the final product.

The composting process lasted 3 months. The products were thus analysed for their N and C content by C-N analyser, and the organic matter was characterized by alkali and acid extraction of the different fractions (C_{ext}, HA and FA) (Dell'Abate et al. 2002), and humification indices were calculated according to Ciavatta et al (1990).

The composts were used in a trial with strawberry plants cv Elsanta grown under field conditions, but in mesocosms made of terracotta pots (about 0.12 m^3) buried in soil. The four composts were compared to untreated (not fertilized) plants. The plants received an amount of compost standardized on the amount of N content in the compost, thus allowing to provide all treatments with an amount equivalent to 80 kg $N \cdot Ha^{-1}$.

Each treatment was applied to 10 plants each grown in a single pot placed on a completely randomized design. Growth was assessed by determining the number and weight of runners and yield was recorded.

Results

The total C content of the four composts was quite similar, ranging from 51.1 to 53% (Tab. 1). The addition of vinassa to the composting matrix doubled the amount of N in the final compost and consequently resulted in a more suitable C:N ratio for fertilization purposes (Tab. 1) .

The characterization of the organic matter of the composts reveled significant differences linked with the kind of fungi used during the composting process and the substance added as a N source in the compost matrix (Tab. 2). The compost obtained with pleurotus contained a higher amount of total C in comparison to the one obtained with shiitake, irrespective of the additional component added (whey or vinassa). With the addition of whey, the compost made with pleurotus contained more organic C in comparison of the similar compost produced with shiitake. On the other hand, total organic C was little affected by the addition of vinassa.

The addition of vinassa affected more the C extractable fraction (C_{ext}) of the compost in comparison with the compost produced with whey as N source (Tab. 2). C_{ext} in the composts with the addition of vinassa was 20% and 250% higher, for pleurotus and shiitake respectively, in comparison to the compost obtained with whey.

The composts obtained with shitake contained a higher fraction of humic and fulvic acids (HA+FA) in comparison to that obtained with pleurotus, irrespective of the additional N-rich ingredient (Tab. 2). However, vinassa induced the formation of a higher concentration of

these fractions with both fungi when compared to the compost obtained with the addition of whey.

The differences in the C fractions of the composts were paralleled by differences in three humification indexes (Tab. 2). The composts obtained with shiitake were characterized by higher values of HR and DH indexes in comparison to the ones produced with pleurotus. However, the compost obtained with the addition of vinassa showed a HU index 2.5 times higher than the compost with whey.

Table 1: C and N content and C:N ratio of the four composts.

Compost	N %	C %	C:N
Brown coal + pleurotus + whey	0,40	51,10	126
Brown coal + pleurotus + vinassa	0,76	51,80	69
Brown coal + shiitake + whey	0,42	53,00	125
Brown coal + shiitake + vinassa	0,86	51,85	60

Table 2: Extractable C, humic and fulvic carbon fractions, and humification indexes of the four composts.

Compost	C_{ext} g kg^{-1}	HA+FA g kg^{-1}	HR %	DH %	HU %
Brown coal + pleurotus + whey	352.60 b	2.30 b	0.27 b	0.65 c	152.30 a
Brown coal + pleurotus + vinassa	422.40 a	2.68 b	0.37 b	0.63 c	156.61 a
Brown coal + shiitake + whey	175.1 c	3.48 a	0.57 a	1.99 a	49.32 c
Brown coal + shiitake + vinassa	451.2 a	3.64 a	0.51 a	0.81 b	122.96 b

The growth of the plants treated with all four composts was higher than the control, but similar among the different treatments (Tab. 3). No differences were found in case of the number of runners among the four composts; however, the weight of the runners was higher in plants treated with composts containing vinassa, and the highest weight was recorded for the plants receiving the compost made with vinassa and shiitake. The production of fruits was higher in the plants treated with the composts made with vinassa, and the highest production was observed in the plants receiving the compost produced with the addition of vinassa and pleurotus (Tab. 3).

Table 3: Growth parameters and yield of strawberry plants cv Elsanta treated with the four different composts.

Treatments	Length of runners cm	Weight of runners g	Total weight of fruits g
Control	246,7 b	10,7 c	36,7 c
Brown coal + pleurotus + whey	333,2 a	15,5 b	89,7 b
Brown coal + pleurotus + vinassa	336,5 a	15,9 ab	104,0 a
Brown coal + shiitake + whey	311,7 a	16,2 ab	76,5 b
Brown coal + shiitake + vinassa	332,7 a	17,2 a	80,7 b

Discussion and conclusions

Differences in the fractions of the organic matter are related to the rate of its mineralization and hydrolysis. The two fungi used to enhance the transformation of the C fraction appear to function differently in this respect, probably due to different enzymatic machineries utilized for lignin hydrolysis (Toumela et al. 2000). The two organic by-products added to the mixture also differently affected the process of hydrolysis of the brown coal and the final composition of the composts, particularly for what concern the N content and C:N ratio. The addition of vinassa allowed to obtain a C:N ratio more suitable for fertilization purposes.

The addition of vinassa resulted also in a higher content of C_{ext} and higher humification indexes in comparison to the composts produced with the addition of whey. The humification rate (HR%) provides quantitative information about the humic substances content normalised with respect to total soluble organic matter, while the degree of humification (DH%) provides the amount of the humified carbon in the extracted organic fraction (Ciavatta et al. 1990). More important, the HU index, which represent the total level of humification, was always higher in the composts obtained with the addition of vinassa, and particularly in those where pleurotus was used. Therefore, the composts obtained with the addition of vinassa presented a more suitable content of humified substances available for the plant. Considering the two white rot fungi, pleurotus allowed to obtain a more degraded compost. Degradation of lignin is carried out by by extracellular enzymes of different fungal species and then converted to phenols and quinones. All degraded fractions are then polymerized by a free-radical mechanism to generate the humus (Varadachari and Ghosh 1984; Horwath and Elliott 1996). The higher value of the HU index is pointing to a better functioning of *P. ostreatus* in the transformation of carbon from the brown coal matrix.

The plants treated with the composts always showed higher growth and yield than the untreated control, which points out the nutritional potential of these products. Nevertheless, the differences found in the chemical structure of the composts affected differently both growth and yield of strawberries. Indeed, even though the number of runners was not changed by the treatments, their total mass was higher in the plants receiving composts produced with the addition of vinassa (in combination with shiitake) in comparison to those produced with whey (with both white rot fungi). The best yield was obtained with the compost made with the addition of vinassa and pleurotus. Taking into account both growth and yield, the latter compost can thus be considered the product showing the best potential as fertilizer for strawberry production. The evaluation in this

respect is still undergoing. It should also be considered that the differences found in the characteristics of the studied composts might affect the soil biological quality and fertility and consequently indirectly influencing plant growth and yield (Bardi and Malusà 2012).

In conclusion, the differences in the chemical composition of the composts and in the effect on strawberry growth and yield are suggesting that for the production of organic composts based on brown coal, the use of *P. ostreatus* and of vinassa is providing a better nutrition of the plants in comparison to compost produced with the addition of *Lentinus edodes* and of whey.

Acknowledgment

The work has been supported by a grant from the EU Regional Development Fund through the Polish Innovation Economy Operational Program, contract N. UDA-POIG.01.03.01-10-109/08-00

References

Bardi L. and Malusá E. (2012). Drought and nutritional stresses in plant: alleviating role of rhizospheric microorganisms. In *Abiotic Stress: New Research* (ed. N. Haryana and S. Punj), pp. 1-57. Hauppauge, NY: Nova Science Publishers, Inc.

Ciavatta, C., Govi, M., Vittori Antisari, L., Sequi, P. (1990). Characterization of humified compounds by extraction and fractionation on solid polyvinilpyrrolidone. *J. Chromatogr.* **509**: 141–146.

Dell'Abate, M.T., Benedetti, A., Trinchera, A., Dazzi, C. (2002). Humic substances along the profile of two Typic Haploxerert. *Geoderma* **107:** 281–296.

Horwath, W.R., Elliott, L.F. (1996). Ryegrass straw component decomposition during mesophilic and thermophilic incubations. *Biology and Fertility of Soils* **21**: 227–232.

Malusà, E., Sas Paszt, L., Popińska, W., Żurawicz, E. (2007). The effect of a substrate containing arbuscular mycorrhizal fungi and rhizosphere microorganisms (*Trichoderma*, *Bacillus*, *Pseudomonas* and *Streptomonas*) and foliar fertilization on growth response and rhizosphere pH of three strawberry cultivars. *Intern. J. Fruit Science* **6**: 25-41.

Sas Paszt, L., Sumorok, B., Malusà, E., Głuszek, S., Derkowska, E. (2011). The influence of bioproducts on root growth and mycorrhizal occurrence in the rhizosphere of strawberry plants cv. 'Elsanta'. *Journal of Fruit and Ornamental Plant Research* **19** (1): 13-33.

Tuomela, M., Vikman, M., Hatakka, A., Itävaara M. (2000). Biodegradation of lignin in a compost environment: a review. Bioresource Technology **72** : 169-183

Varadachari, V., Ghosh, K. (1984). On humus formation. *Plant and Soil* **77**: 305–313.