Effect of composts based on brown coal on the growth of roots of strawberry plants cv. 'Elsanta' and their colonization by arbuscular mycorrhizal fungi

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Abstract

In June 2010, strawberry plants cv. 'Elsanta' were planted in stoneware pots in the Experimental Field of Warsaw University of Life Sciences in Skierniewice. The following fertilization combinations were included in the experiment: control (NPK), brown coal with whey with oyster mushroom, brown coal with Vinassa with oyster mushroom, brown coal with whey with peat, brown coal with Vinassa with peat, brown coal with oyster mushroom, brown coal with whey, brown coal with whey with oyster mushroom with peat, brown coal with whey with shiitake mushroom, brown coal with Vinassa with shiitake mushroom, Brown coal with Vinassa, brown coal with shiitake mushroom, brown coal with shiitake mushroom with peat. The combination of brown coal with whey increased the fresh and dry weight of roots as well as root length and volume compared to the control combination with NPK. The application of brown coal with Vinassa and peat had a positive effect on increasing the root biomass, and the number of roots tips. The use of the composts and brown coal had a positive effect on root growth characteristics and mycorrhizal frequency in the roots of plants cv. 'Elsanta'. The combinations of brown coal with Vinassa and peat and brown coal with whey and oyster mushroom had the greatest impact on root growth and the colonization of the roots of strawberry plants cv. 'Elsanta' by arbuscular mycorrhizal fungi. Application of composts (based on brown coal) alone or in combination with reduced rates of NPK mineral fertilization can be an effective alternative in the growing of fruit and other horticultural crops.

Keywords: mycorrhizal frequency, AMF, root morphology, strawberry

Introduction

Sustainable and pro-ecological cultivation measures are considered as an important element of the Polish and EU's strategy for the development of the agricultural sector. The production of organic fruits has been increasing in recent years. However, the limited availability of traditional organic fertilizers (i.e. manure), and scarce information about the effects of new kinds of organic fertilizers, such as plant extracts (Sas Paszt *et al.*, 2009) or microbial inocula (Malusá *et al.*, 2007), are serious obstacles threatening the future development of the sector. Application of mycorrhizal inocula can increase the species diversity of these fungi in the rhizosphere and consequently improve the growth, yielding and yield quality of cultivated fruit crops (Sas Paszt & Żurawicz, 2005; Sas Paszt & Głuszek, 2007). We are thus evaluating the feasibility of different organic sources that are included in the list of products allowed for 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.

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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.

Material and Methods

Strawberry plants cv. 'Elsanta' were planted in June 2010 in stoneware pots in the Experimental Field of Warsaw Agricultural University in Skierniewice. The experiment is carried out in 12 combinations in 4 replications. In each stoneware pot there were planted 3 strawberry plants.

The following fertilization combinations were used in the experiment:

- Standard (NPK) Control
- Brown coal + whey + oyster mushroom (1 : 0.1 : 0.08)
- Brown coal + Vinassa + oyster mushroom (1 : 0.1 : 0.08)
- Brown coal + whey + peat (1 : 0.1 : 0.1)
- Brown coal + Vinassa + peat (1 : 0.1 : 0.1)
- Brown coal + oyster mushroom (1 : 0.08)
- Brown coal + whey (1 : 0.1)
- Brown coal + whey + oyster mushroom + peat (1 : 0.1 : 0.08 : 0.1)
- Brown coal + whey + shiitake mushroom (1 : 0.1 : 0.08)
- Brown coal + Vinassa + shiitake mushroom (1 : 0.1 : 0.08)
- Brown coal + Vinassa (1 : 0.1)
- Brown coal + shiitake mushroom (1 : 0.08)
- Brown coal + shiitake mushroom + peat (1 : 0.08 : 0.1)

In order to determine the extent of colonization of strawberry roots by mycorrhizal fungi, root samples were taken and submitted for laboratory analysis in June, 2011.

Determination of root growth and morphological parameters:

- Dry weight (Ostrowska *et al.* 1991).
- Root morphological parameters (total root length, root diameter, root surface area, root volume and total number of root tips) – image analysis system with an Epson scanner, controlled by WinRhizo software (Regent Instruments Inc.).

Determination of mycorrhizal frequency:

- Roots were cold-stained using the Phillips & Hayman method (1970).
- Microscopic analysis of the roots – Trouvelot's method (1986).
- Mycorrhizal frequency (F%) and mycorrhizal intensity (both relative – M%, and absolute – m%) were assessed in each root segment.
- The mycorrhizal parameters were calculated using the Mycocalc software: http://www2.dijon.inra.fr.mychintec/Mycocalc-pgr/download.html

All the results were statistically evaluated with analysis of variance. Comparisons of means were at $p \leq 0.05$ with the Duncan test.

Results

The use of the composts based on brown coal had a positive effect on the colonization of the roots of strawberry plants cv. 'Elsanta' by arbuscular mycorrhizal fungi. The highest mycorrhizal frequency (22.22%) was obtained in the roots of strawberry plants cv. 'Elsanta' after the application of brown coal + whey+ shiitake mushroom. Mineral NPK fertilization (control) reduced the occurrence of AM fungi.

Table 1: Comparison of mycorrhizal frequency [F%], relative mycorrhizal intensity [M%] and intensity of the mycorrhizal colonization in the root fragments [m%] in the roots of strawberry plants cv. 'Elsanta' (Experimental Field of Warsaw University of Life Sciences, Skierniewice, 2011).

Experimental treatments	F %	M %	**m** %
(NPK) Control	1.11	0.01	0.33
Brown coal + whey + oyster mushroom	2.22	0.02	0.66
Brown coal + Vinassa + oyster mushroom	15.55	0.38	2.57
Brown coal + whey + peat	7.78	0.12	1.44
Brown coal + Vinassa + peat	15.55	0.20	1.33
Brown coal + oyster mushroom	3.33	0.03	0.33
Brown coal + whey	5.55	0.05	1.0
Brown coal + whey + oyster mushroom + peat	4.44	0.09	2.33
Brown coal + whey + shiitake mushroom	**22.22**	0.40	1.91
Brown coal + Vinassa + shiitake mushroom	21.11	0.30	1.38
Brown coal + Vinassa	3.33	0.03	1.0
Brown coal + shiitake mushroom	10.0	0.1	1.0
Brown coal + shiitake mushroom + peat	0.0	0.0	0.0

The highest fresh weight of roots was obtained in the combination with brown coal + whey, where root weight was higher by 26% compared to the control (Table 2). The other combinations with brown coal used in the experiment did not increase significantly the weight of roots. Also, root dry weight of the plants composted with brown coal with the addition of whey had the highest value (Table 2).

Brown coal used in the combinations: brown coal + Vinassa + peat and brown coal + whey + shiitake mushroom contributed to an increase in the number of root tips by more than 23%. With the other composts from brown coal and additives there was also an increase in the number of root tips, but not as significant as in these two combinations mentioned (Table 2).

Root surface area was affected most favourably by the use of brown coal + whey + shiitake mushroom, which increased this parameter by 30% (Table 2).

The use of the composts from brown coal and additives had no effect on increasing the diameter of the roots nor their volume.

In comparison with the NPK control, the use of brown coal + Vinassa + peat and brown coal + whey increased root length by more than 31%, while brown coal with the addition of whey and shiitake mushroom increased root length by 56% (Table 2).

Table 2: Effect of composts based on brown coal on the growth parameters of the roots of strawberry plants cv. 'Elsanta' (Experimental Field of Warsaw University of Life Sciences, Skierniewice, 2010.)

Combination	**Root fresh weight** [g/L of soil]	**Root dry weight** [g/L of soil]	**Number of root tips** [per L of soil]	**Root surface area** [cm^2/L of soil]	**Root diameter** [mm/L of soil]	**Root volume** [cm^3/L of soil]	**Root length** [cm/L of soil]
(NPK) Control	3.0 a-c	0.76 b	1398.4 a-d	129.05 a-d	0.52 d	1.70 b-d	782.20 ab
Brown coal + whey + oyster mushroom	2.0 a	0.43 a	1339.9 a-c	104.60 ab	0.40 a	1.04 a	831.69 a-d
Brown coal + Vinassa + oyster mushroom	3.1 bc	0.80 b	1567.5 a-d	134.88 a-d	0.45 a-c	1.54 a-d	937.36 a-d
Brown coal + whey + peat	3.1 bc	0.73 b	1596.5 a-d	125.73 a-d	0.45 a-c	1.42 a-d	886.15 a-d
Brown coal + Vinassa + peat	2.8 a-c	0.76 b	**1725.6 cd**	141.14 b-d	0.43 ab	1.56 a-d	**1025.58 b-d**
Brown coal + oyster mushroom	2.5 ab	0.63 ab	1651.2 b-d	131.86 a-d	0.45 a-c	1.48 a-d	931.51 a-d
Brown coal + whey	**3.8 c**	**0.90 b**	1614.7 a-d	152.71 cd	0.47 a-d	1.80 cd	**1029.45 cd**
Brown coal + whey + oyster mushroom + peat	3.2 bc	0.76 b	1593.5 a-d	131.60 a-d	0.49 b-d	1.60 a-d	863.67 a-d
Brown coal + whey + shiitake mushroom	3.2 bc	0.86 b	**1744.7 d**	**168.80 d**	0.43 ab	1.85 d	**1227.04 d**
Brown coal + Vinassa + shiitake mushroom	2.5 ab	0.73 b	1478.9 a-d	126.57 a-d	0.44 av	1.38 a-d	925.91 a-d
Brown coal + Vinassa	2.6 ab	0.76 b	1164.5 a	114.70 a-c	0.47 b-d	1.34 a-c	788.53 a-c
Brown coal + shiitake mushroom	2.5 ab	0.80 b	1352.0 a-d	125.09 a-d	0.45 a-c	1.39 a-d	895.06 a-d
Brown coal + shiitake mushroom + peat	2.8 a-c	0.76 b	1263.6 ab	99.89 a	0.51 cd	1.29 ab	615.34 a

Discussion and Conclusions

Brown coal is a new medium in plant cultivation. This material is used as a soil improver or as a medium in soilless cultures (Bartczak *et al.* 2007). Brown coal is a good source of humic compounds and mineral nutrients. However, during mineralization of clean brown coal it contributed no N in an available form (Robertson & Morgan 1995). Products derived from brown coal and added to the soil can decrease the negative influence of soil aluminium on plant root growth (Yazawa *et al.* 2000). Earlier reports showed that pure brown coal, as opposed to peat or wood chips, is not a good substrate for growing plants. Brown coal in a mixture with rockwool has been used in strawberry cultivation as a soilless growth medium (Bartczak *et al.* 2007) and found to cause the lowest growth in comparison with clean rockwool or peat-pine bark mixture. Starck and Oswiecimski (1985) observed that tomato plants var. Revermun cultivated on brown coal medium produced a significantly lower yield than plants cultivated on pine bark or peat. Asli & Neumann (2010) showed that humic acid at 1g L^{-1} inhibited shoot and leaf growth in maize but did not reduce root growth.

There are not many reports on composted brown coal used as a fertilizer in crop cultivation. In our study, we used composts derived from brown coal with several nitrogen sources (e.g. whey) and with two different species of lignin degrading fungi. Whey as a by-product of the dairy industry is a good source of organic nitrogen compounds. Brown coal used as a growth medium supplement has a positive impact on plant growth, eg. in tomatoes (Gagnon & Berrouard 1994). Humic substances have a protective effect on aminoacids and the protein complex, preventing its further decomposition in the soil (Trojanowski 1973). Shiitake and oyster mushroom were used as compost amendments because they have a good lignin degrading properties (Tuor *et al.* 1995; Boyle 1998; Cohen *et al.* 2002).

In our study, some of the composts derived from brown coal increased the frequency of mycorrhizal occurrence in strawberry roots and increased the number and biomass of roots. The highest mycorrhizal frequency was obtained in the roots of strawberry plants cv. ‘Elsanta’ after composting with brown coal + whey + shiitake mushroom. Mineral NPK fertilization (control) reduced the occurrence of AM fungi in the roots of strawberry plants.

The highest fresh weight of roots was obtained in the plants fertilized with the compost based on brown coal + whey, where root fresh weight was higher by 26% compared to the NPK control. The dry weight of roots of the plants composted with brown coal + whey was also the highest. The use of the composts from brown coal modified root growth characteristics. In comparison with the NPK control, the use of brown coal + Vinassa + peat and brown coal + whey increased root length by more than 31%, while brown coal with the addition of whey and shiitake mushroom increased root length by 56%.

Composts based on brown coal can be an effective alternative in sustainable fertilization of strawberry plants compared to fertilization with mineral NPK fertilizers, due to their enhancing influence on plant growth development and yielding (presented in another abstracts to the conference Ecofruit 2012 by Stępień et al. 2012). These compost can also be used in combination with the reduced rates of mineral fertilizers in fruit crop species cultivation.

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