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COST Action Urban Agriculture Europe Freelance STSM: Sustainable Substrates for Urban Agriculture made from Urban Wastes

23/03/2015 to 17/05/2015

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1 Introduction

The composition of European urban soils is determined by a legacy of centuries of settlement and very destructive wars. Physical and chemical properties of urban soils are highly influenced by technogenic materials, such as gravel and construction debris, that were introduced to them e.g. during post war reconstruction. As well recent land use legacies, such as contamination due to the use as a dump site or compaction due to construction activities, have an impact soil properties in urban regions.

Also, as addressed by the European Comission (2013) the rate of soil sealing in Europe due to the spread of urban areas or growth of settlements is still increasing. In this way fertile soils are being sealed from use.
Due to these characteristics Urban Agriculture needs to make use of alternative substrates as plant growth media for example in raised beds or containers (EPA, 2011). Those substrates should not be imported from rural surroundings and in this way degrade and exploit other ecosystems.
Instead, by processing of urban waste to fertile growing substrates, Urban Agriculture could sustain productivity by diminishing environmental impact through waste disposal to landfills. Furthermore Urban Agriculture could also operate on sealed surfaces, in containers, or contribute to the restoration or remediation of contaminated urban soils.

Various studies, searching for peat substitutes, have confirmed the suitability of composted organic waste as growth media (Abad et al., 2001; Benito et al., 2005; Verdonck, 1988). However plain organic matter as growth media is sensitive to high nutrient losses through leaching and high decomposition rates and can have poor water holding capacities due to their physical structure. With the aim to reduce nutrient losses via leaching the organic matter can be mixed with a mineral component that can also be obtained from urban waste, such as demolition debris containing Ca, Mg and other essential mineral nutrients.

Figure 1: Experimental set up in the green house, plant pots filled with urban wastes as growth substrates

(Nehls et al., 2013) have identified that bricks can contribute to urban soils in a beneficial way by increasing the soils water holding capacity as well as being a source for nutrients, such as K, Mg, Ca and S.

It was the aim of this short term scientific mission to design and produce plant substrates from different urban organic and mineral wastes and to conduct a plant pot experiment in order to analyse and compare the capability of the substrate to promote biomass production. Characteristics, that guarantee biomass production, such as rootablity and nutrient supply were assessed.

2 Materials and Methods

2.1 Urban Wastes

For the production of the growth substrates composted organic wastes were mixed together with ground bricks from demolition debris to a base substrate. The base substrate was amended with additional fresher organic wastes and ash for different treatments.

Two different composts from a local composting company were employed: one food waste compost (FWC) and one green waste compost (GWC). Both composts are British Standards Institution's Publicly Available Specification 100 (BSI PAS100) accredited composts (Earthcare Technical Scotland, 2010) produced on large scale. The GWC feedstock is purely from plant material from parks gardens or households, whereas the FWC contains a wider range of input materials that are determined by a great heterogeneity of kitchen wastes from households and companies. Table 1 provides an overview of the GWC properties.

Table 1: GWC properties as provided by producer (Earthcare Technical Scotland, 2010)

compost parameter	unit	typical value
pH (in H_2O (1:5))		7.6
C/N ratio	-	13.1
electr. Conductivity	µSv/cm	1076
N	mg/l	5193
P	mg/l	855
K	mg/l	3132
Mg	mg/l	1033
S	mg/l	582

Bricks were used as the mineral component in the growing substrate. They were obtained from a landfill for demolition debris in Berlin.
Additionally, a variety of fresher organic wastes were used as amendments to the substrates. These amendments were leaf mould (LM) from a local park, beer waste (BW) in form of processed barley from a local brewery and vermi compost, produced in a private household. Also ash from a wood burning unit, used in a local park for heating greenhouses, was added together with the amendments. The organic amendments were applied by replacing a share of the basic organic material (GWC or FWC) by the fresher organic material and the ash was added on top. In the following the amendments will be referred to as treatments (T1 – T5). Table 2 gives an overview of all amendments that were applied.

Table 2: Overview of amendments, that were applied to the growth substrates, LM= leaf mould, VC= vermi compost, BW = beer waste

T1	no amendment
T2	ash
T3	LM + ash
T4	VC + ash
T5	BW + ash

2.2 Producing Substrates

Before producing the substrates, all materials were air dried and sieved to 5-6 mm . Three different ratios of organic and mineral waste were prepared in order to determine a range of ratios that could be employed as a growth substrate. The amount of material was measured in vol-%. The smallest amount of organic material added to to bricks was 10 %. The second mixture contained 50 % of organic material whereas the third mixture was from organic material only (100 %). Figure 2 gives an overview of all substrates that were produced.

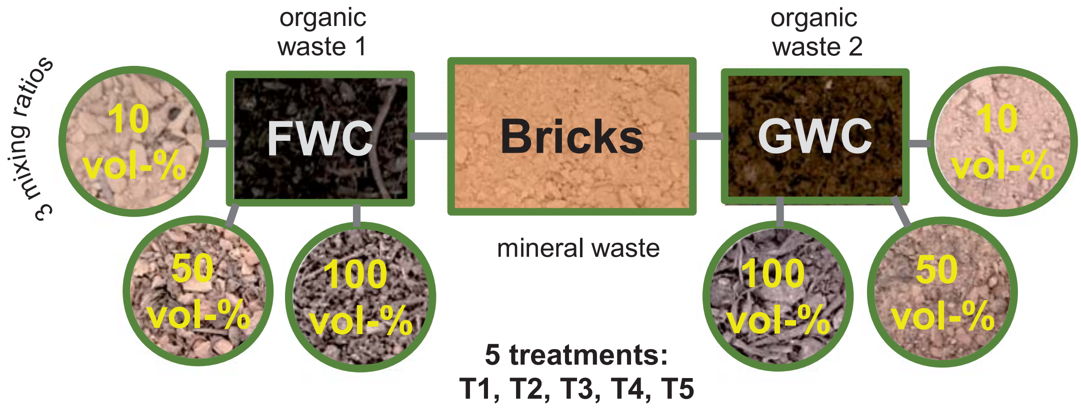


Figure 2: Overview of all created substrates: 3 different mixing ratios from bricks together with 2 basic organic materials (food waste compost (FWC) and green waste compost (GWC), each combination amended with 5 different treatments, compare Table 2. Total number of different mixtures: 30

For each treatment (T1 - T5) a fresher organic material replaces half of the amount of the organic material. For the case of a 50 vol-% GWC substrate amended with treatment T4, 50 vol-% would be bricks, 25 vol-% would be GWC and 25 vol-% would be VC. Additionally 1 vol-% of ash would be added.

The materials were put together as shown in the examples in Figure 3 and mixed thoroughly to realize a homogenized substrate. Each substrate was equally distributed to 3 plastic nursery pots of 0.3 l volume, with each pot beeing a replicate. In total there were 30 different substrate mixtures and in addition a plain control soil, the control soil amended with ash, as well as pure bricks.

(a) GWC + ash (b) FWC + VC + ash (c) FWC + BW + ash

Figure 3: Composition of substrates containing 10 vol% of organic material and 90 vol% of bricks. Different treatments (compare table 2): a) plain green waste compost + ash (T2), b) food waste compost with vermi compost (T4), c) food waste compost and beer waste (T5)

2.3 Plant Pot Experiment

All produced substrates, as described in the section above were employed in a plant pot experiment of 30 days duration, conducted in a greenhouse. The results were compared to the performance of a real soil (control), taken from an allotment plot.

All pots were saturated and drained until no more water was leaching, before the beginning of the plant pot experiment. Approximately 100 seeds of rye grass (*Lolium perenne*) (0,31 g seeds) were equally distributed on the substrates surfaces.

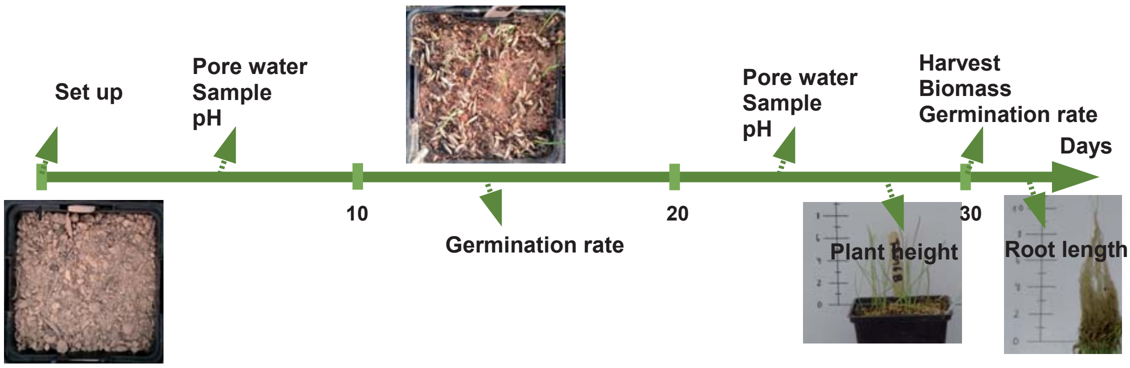


Figure 4: Timeline of the course of the plant pot experiment

Watering of the pots was done regularly in time intervals of three days. When watering the weight of the pots was filled up to 80 % of their weights after drainage.

Throughout the duration of the experiment the Temperature was observed daily and number of germinated seeds was counted twice. Two times during the experiment pore water samples were taken using Rhizon samplers (standard model: 2.5 mm diameter and a mean pore size of 0.15 µm . The first sample was taken on day 6 before germination occurred and the second was taken on day 24 from vegetated pots. The pH of the pore water samples was assessed right away whereas the chemical analysis of the samples, using IPC MS (inductively-coupled-plasma mass-spectrometry) is still in progress.

2.4 Assessment of Biomass Production

In order to compare the substrates capability of biomass production, the plant height, plant mass (fresh and dry) as well as the root length were assessed.
At the end of the plant pot experiment the biomass of each pot was harvested and its weight was measured of the fresh biomass. After being dried for 3 days at 30 ° C the weight was assessed again.
After the experiment all roots were carefully extracted from the pots and their length was measured. Also the root weight was assessed after drying them 3 days at 30° C in the drying room.

2.5 Respiration

Parallel to the plant pot experiment each substrate composition in the mixing ratio 50 % was also assessed regarding their respiration characteristics. CO_2 respiration measurements were conducted using the SRC-1 closed system chamber together with the EGM-4 environmental Gas Monitor for CO_2. All pots were saturated with deionized water and drained until no more water was leaching. The pots were kept in the Growth room at 60% humidity and darkness. The respiration was measured at different temperatures in a range of at 10 ° C in order to calculate the Q10 value for the substrates. It provides information on the temperature sensitivity of the processes in the substrate that set free CO_2 (Yiqi and Zhou, 2010) when degrading the organic matter in the mixtures.

3 Results and Discussion

3.1 Physical Properties

Mixing the substrates with different shares of organic material led to obvious differences in the bulk densities, as illustrated in Figure 5. Pure bricks show the highest bulk density (1.32 g/cm^3). Adding 10 vol-% of organic material diminished the bulk density not signifactly ($p = 0.42$), whereas adding 50 % resulted in a significantly diminished bulk density to lower then 1 g/cm^3($p = 0.0085$). Comparing the pure composts it can be observed that food waste compost has a lower bulk density than green waste compost. However in the mixtures with bricks, this difference can be levelled (compare the bulk density of the 10 %-mixtures in Figure 5).

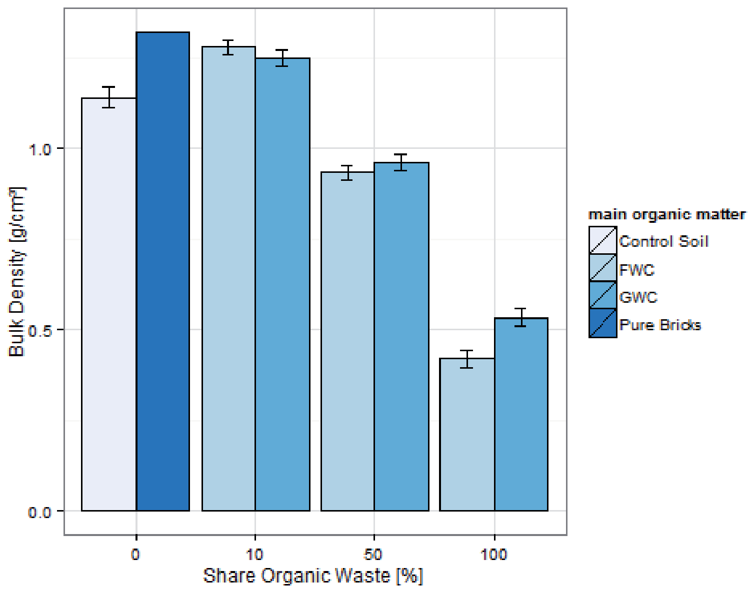
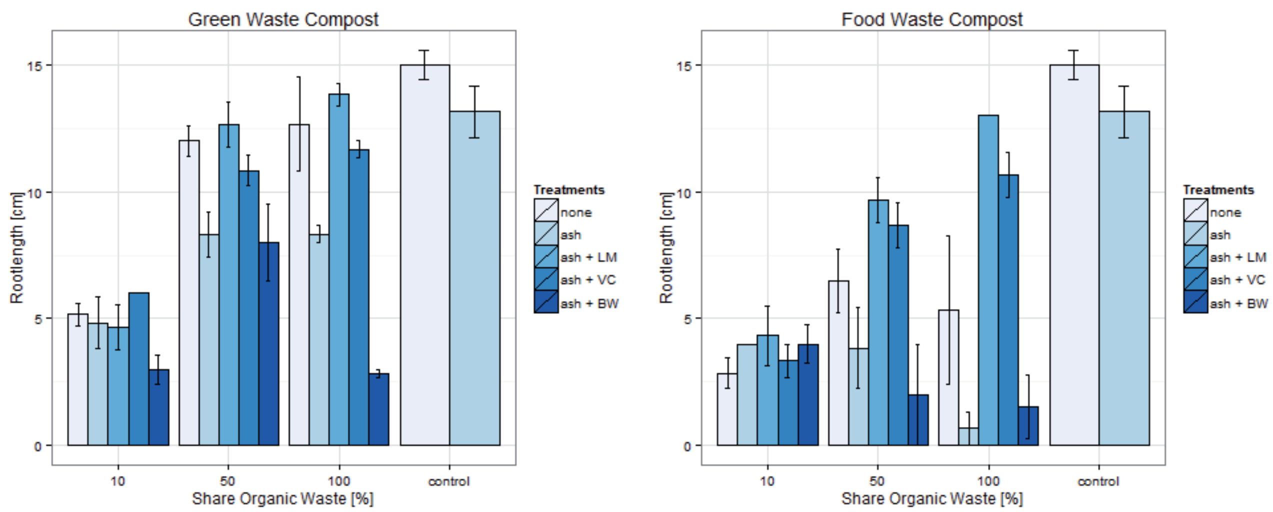


Figure 5: Bulk Densities of different substrate mixtures

The impact of the substrates bulk densities becomes obvious when analysing the results of the root length of each pot. As Figure 6 shows, the plants in those pots with lower bulk densities develop longer roots. This is only valid for the mixtures but not for the real soil, as it has a comparably high bulk density ($1.14\,g/cm^3$) and favours the longest roots.



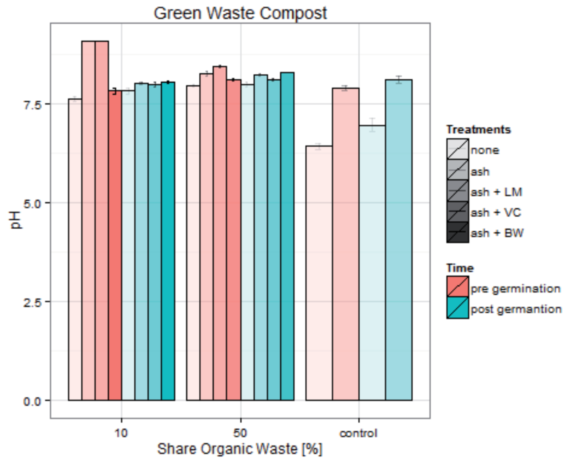
(a) (b)

Figure 6: Rootablity of substrate mixtures

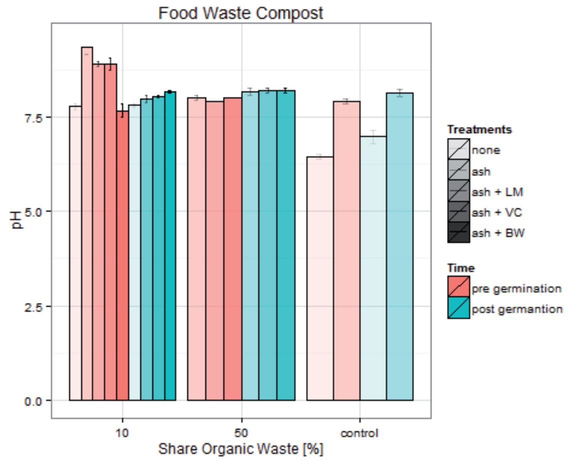
3.2 Chemical Properties

The first results about the chemical properties of the substrates are the pH values of the sampled pore water.

Not all Rhizon samplers were able to extract pore water and pure compost substrates were not sampled. The obtained pore water show high pH values (7.5 and higher). Nearly all treatments (T1 - T5) resulted in higher pH values because they where always applied together with ash.



(a)



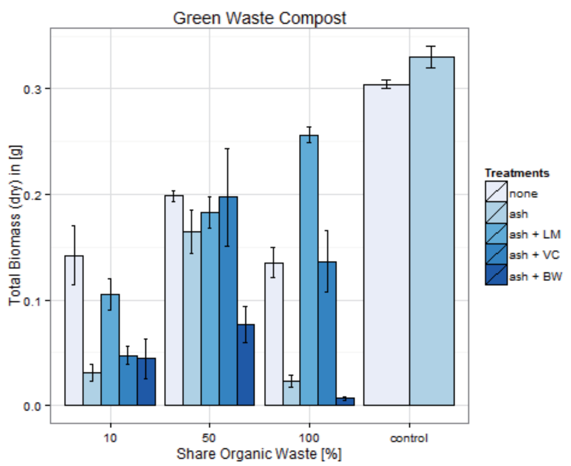
(b)

Figure 7: Total weights of biomass produced in different substrate mixtures. a) Mixtures from green waste composts, b) Mixtures from food waste compost

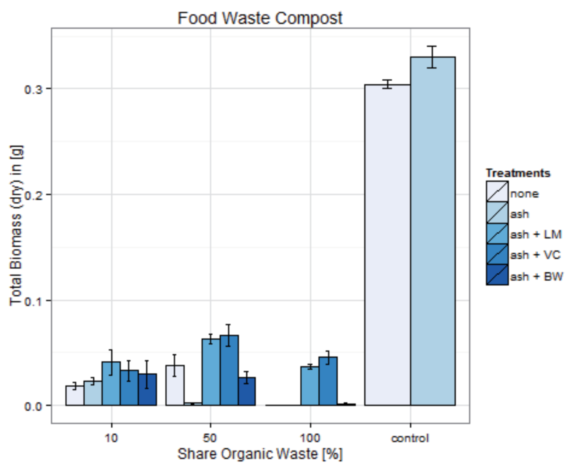
The high pH values guarantee that possibly present contaminants e.g. contained in the bricks are not soluble and can't be taken up by the plants.
Further analysis of the pore water samples will provide data on the composition of the pore water. Macro and micro nutrients (e.g. N,P, K, C, Ca) as well as possible contaminants shall be considered in the analysis.

3.3 Biomass Production

The assessment of the Substrates productivity included the measurement of the plants height as well as the weight of the harvested Biomass.



(a)



(b)

Figure 8: Capability of growth susbtrate to promote biomass production. Total biomass (dry): weight of harvested and dried rye grass + weight of extracted and dried roots

As Figure 8 illustrates, those mixtures that employed GWC were more productive than those with FWC. Whereas the FWC mixtures show relative to the control soil only up to 20 % of productivity, the GWC mixture are able to perform up to 65 %. Figure 9 shows photographs of the 3 replicates of those mixtures that showed the highest productivity among all mixtures in front of the height measurement scale, in decreasing order.

The best over all performance shows the GWC 50 vol% mixture. Those mixtures that employ only 10 vol-% of organic waste show smaller productivity in both cases, for FWC and GWC.

(a) control + ash

(b) control

(c) GWC 100 vol% + leaf mould + ash

(d) GWC 50 vol% + vermi compost + ash

Figure 9: Pots with highest biomass production (decreasing from top to down) Measurement of plant height

The results of the chemical analysis of the pore water samples might deliver further explanation for these differences.

Among the amendments beer waste does not appear beneficial to the productivity. Extracting the roots from the pots, the beer waste mixtures appeared to be mouldy, which could be seen as a pointer to the reason for it's limited performance. Also the amendment with ash only appears to reduce the substrates productivity. A possible explanation can be a diminished water holding capacity due to the hydrophobic characteristic of ash.

4 Conclusions and Further Work

The experiment, conducted during this short term scientific mission, proved that certain kinds of urban wastes can be processed to a growth substrate that promotes plant growth and shows promising results in biomass production. Ground bricks seem to work as a suitable mineral waste component that supports water holding characteristics of the substrate mixture. In order to guarantee a good rootability the share of bricks in the substrate should be in the magnitude of 50 vol-%. The experiment showed that composted food waste is not suitable for being further processed while green waste compost showed promising results.

Employing urban wastes as a growth substrate in urban agriculture may function as an impulsion for the urban metabolism and contribute to the recycling of nutrients in urban areas. As a further research suggestion an experiment could be conducted, that reveals the long term performance of the growth substrate in order to determine the long term sustainability of it. Also other crops should be considered in further research.

Some analysis are still in progress and their results could therefore not be included in this report. All results of this STSM will be further evaluated and published in a scientific paper that will be written in cooperation with Luke Beesley (James Hutton Institute) and Thomas Nehls (Technische Universität Berlin).

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