LifeMedGreenRoof Project

Identification of ideal growing media for Malta and Italy

Actions A1 & A2

LIFE12ENV/MT/000732

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Introduction

Action A1 and A2 were conducted in parallel for most of the activities.
In Italy green roof technology is widespread and has been around for some time. In 2007, the Italian green roof norm UNI 11235:2007 was published and is currently being updated. This means that in the field of substrates there is a basic experience that led the major commercial companies to create, propose and use their own mixes that seem to have acceptable performance. However, more must be done to identify and understand the performance of new materials and to create growing media for specific botanical and microclimatic conditions.

For Malta, where green roofs are practically inexistent, there is no previous knowledge of the subject matter and the geographical condition limits somewhat the possibility of self-sufficiency in the field of growing media production.

So, for the above reasons, most of the laboratory activities were common to the two actions, such as components (consolidated or innovative) and commercial mix characterizations, while the creation and testing of experimental substrates were conducted specifically to meet the needs of the two different climatic demonstration sites (Malta – A1, Italy – A2).

To achieve the objectives of these preparatory actions laboratory tests were carried out since November 2013 on commercial growing media, single components, new experimental mixes and new components. To identify the samples to be submitted for laboratory testing, an investigation in each of the two different countries was conducted in order to identify the presence of usable material. In Malta, during the first partner meeting, it was possible to visit some companies and analyse different materials which could be tested to verify their possible use within a growing media mix. Such materials consisted of mineral component (from the construction industry), and organic matter. This organic matter was composed of undefined low quality 'compost' made from very heterogeneous raw material.

In Italy major manufacturers of green roof substrates were involved in order to obtain samples and components to be subjected to laboratory tests. The response was sufficiently positive, in particular with regards to the growing media samples although it was more difficult to receive samples of individual components. However, MAC's technical know-how in this area guaranteed optimal knowledge about the individual components that make up the actual commercial substrates. MAC therefore had the capacity to create new mixes notwithstanding this issue.

Despite the difficulty of identifying innovative components suitable for green roof growing media interesting and relevant goals were achieved. In addition to the ability to sustain vegetation (agronomic properties), a green roof growing media should possess certain essential characteristics including: stability over time (low organic matter content), high permeability, adequate water retention capacity, absence of phytotoxic chemicals, and absence of contaminants that may be transported in water run-off.
Generally, the major components for a green roof substrate include:
as mineral components: sand, pumice, lapillus, expanded clay, perlite, crushed bricks, some volcanic materials
as organic component: peat, green compost, coconut fiber, wood fiber, composted bark.

Generally, to obtain different properties in a specific growing media, it is possible to act both on the choice of components and on their percentage use. The identification of a new component to insert in a growing media is not obvious and generally requires years of research and experimentation.

Thanks to previous MAC activity and experience on this topic, it has been possible to focus on a very innovative material, called biochar. Biochar has been the subject of international research and experimentation in different areas (agriculture, energy, environment, mitigation of climate change) for the last 15 years, but its use in horticulture growing media is only very recent. Its use in green roof growing media (that are different from horticulture substrates) has been rarely valued, and it is possible to affirm that we are among the first (if not the first) to test and validate its use in this field.
Biochar is a very heterogeneous material. Its composition and chemical make-up is dependent on the biomass used to produce it and on the technological process used to produce it. Many different kinds of biochar have been tested during the course of this project to evaluate their potential for new solutions of green roof growing media.

All the above activities were carried out as part of the 'Preparatory Actions' pertaining to growing media selection (as better detailed below) and permitted to achieve the proposed deliverables: "Identification of at least 2 experimental growing media for the Maltese demonstration green roof and 2 new experimental growing media for the Italian demonstration green roof".

Laboratory testing

Until December 31, 2014, 61 samples had been registered and tested at the MAC laboratory. The samples were composed of the follows: 18 biochar, 11 commercial green roof growing media, 13 individual components, and 19 experimental growing media. In addition to these official samples, preliminary tests were conducted to gather information to verify the procedures adopted.

Complete results of laboratory tests are given in tabular form in Annex 2:
biochar results: data regarding the innovative material investigated
growing media and components results: data regarding commercial growing media, consolidated components, experimental growing media tests.

The analytical methods used are listed in the Annexes (column "method"). Priority was given to the European standards (adopted in Italy as UNI EN Standard); if European standards are not available, official national standards or methods recognized in other states (particularly in Germany) were adopted.

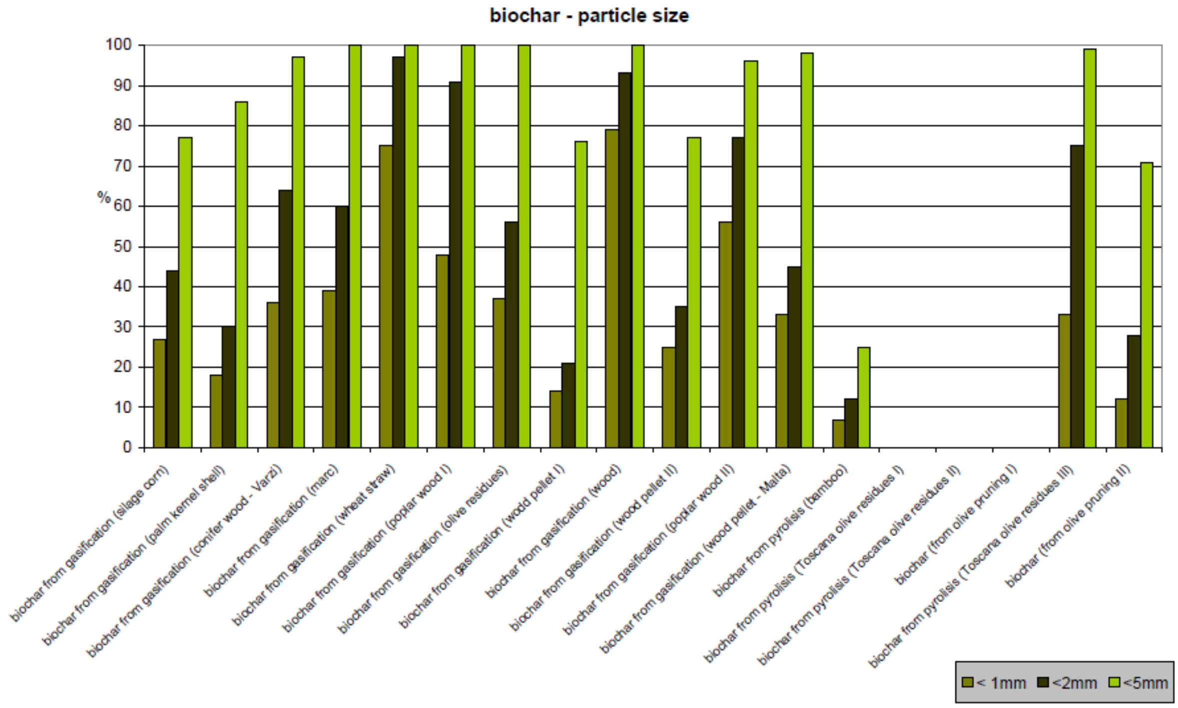
Below is a summary of the most significant results achieved which were crucial in identifying the first experimental substrates to be tested in the two demonstration sites.

With regards to the characterization tests on biochar, consideration was given to the essential properties of green roof growing media. Characterization focused mainly on
(a) particle size (fine particles have to be avoided: the influence of particle size of the component on the growing media had to be understood; the influence of particle size on the particle size curve of a specific growing media also had to be understood).
(b) chemical properties (to identify the main agronomic properties and nutrient components),
(c) the presence/absence of potential contaminants (related to the provenience of material), and
(d) bioassays (to verify the presence of potential phytotoxicity effects; germination, growth inhibition or stimulation, and to evaluate the better percentage use).

Generally, best results have been obtained from wood biochar (gasification process of different kind of wood), but other kinds of biochar also proved suitable, (biochar obtained from agricultural waste), having interesting properties for the purpose of the project.

Particle size

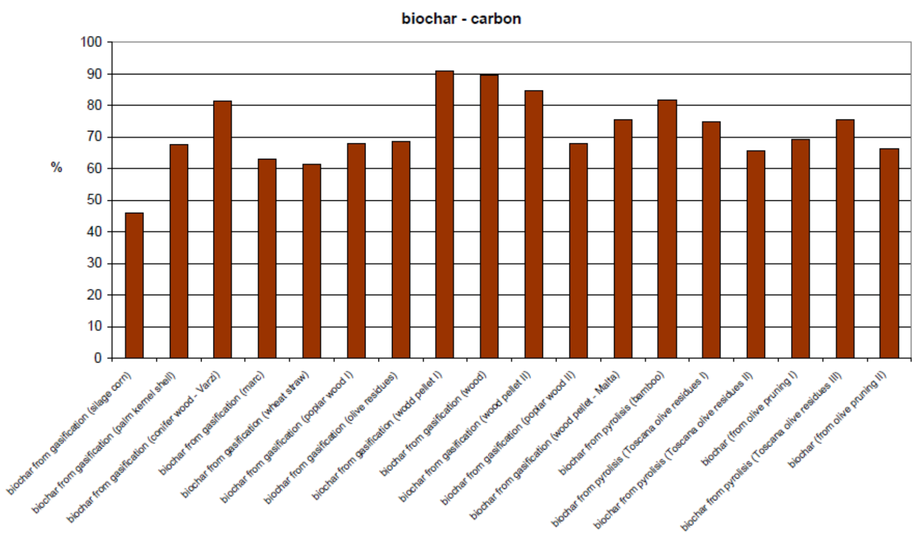
For biochar to be used in a green roof substrate, a low presence of fine particle size is essential. Some biochar such as those from wheat straw and generic wood biomass do not meet this requirement with more than 70% fine particles recorded as can be observed in the following graph. Best results were produced from palm kernel shell biochar, wood pellet biochar, bamboo biochar, and olive pruning biochar, with less than 20% of fine fraction.



Above: Percentage particle size in different biochar types

Carbon content

The following graph confirms that generally biochar has high carbon content. The highest values were produced from wood biomass biochar and bamboo biochar (more than 80% carbon content). Meanwhile lowest values were registered for biochar obtained from residues of agricultural crops (corn and wheat residues) and from marc biochar.

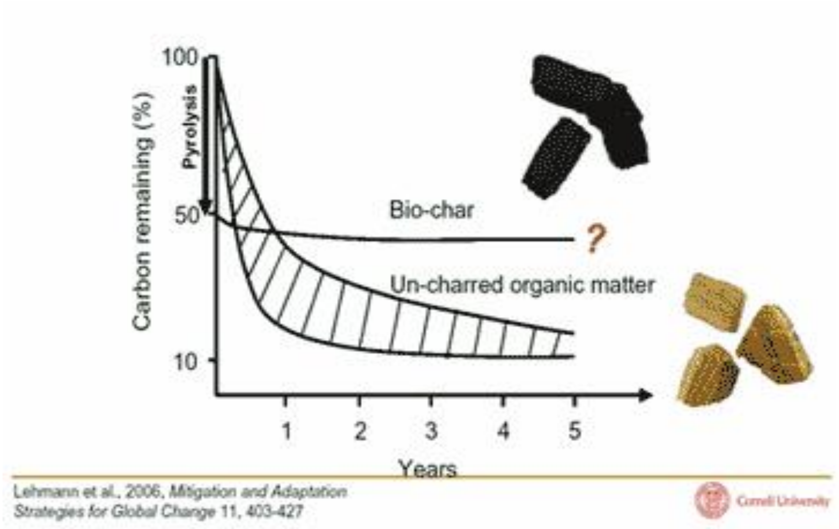


Above: Percentage carbon content in different biochar types

Stability of carbon

The stability of carbon over time is another important factor to be considered. The stability of biochar is of fundamental importance in the context of biochar use for environmental management. The two main reasons for this statement are: (1) stability determines how long carbon applied to soil, as biochar, will remain in the soil and contribute to the mitigation of climate change, and (2) stability will determine how long biochar will continue to prove beneficial to soil, plant, and water quality (Lehmann et al., 2006). From a green roof application aspect, biochar carbon stability is important to ensure the performance of growing media in the long term.

Biochar production and application to soil can be, in many situations, a viable strategy for climate change mitigation. Conversion of biomass carbon to biochar carbon via pyrolysis can lead to sequestration of about 50% of the initial carbon compared to the low amounts retained after burning (3%) and biological decomposition (see figure below).



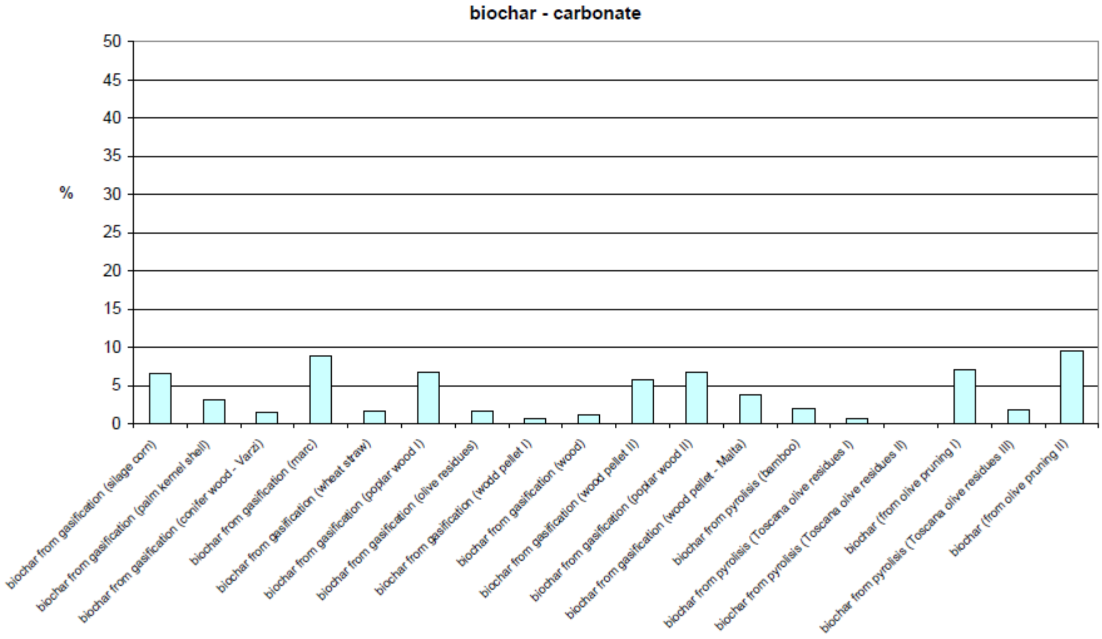
Above: Biochar stability

Mean Residence Time (MRT) and Molar ratio

The Mean Residence Time (MRT) of different biochar has been found to fall mostly in the centennial to millennial scales, but not all biochar exhibit this property.

Hydrogen to organic carbon molar ratio (H:C) (Enders et al., 2012; IBI, 2012) and oxygen to carbon molar ratio (O:C) (Spokas, 2010) reflect physical-chemical properties of biochar related to stability, as the proportion of elemental compounds (H and O) relative to carbon (C) present in biochar. Increasing production temperatures lead to lower H/C and O/C ratios (Krull et al., 2009; Spokas, 2010), as the abundance of C relative to H and O increases during the pyrolysis process. Materials with low H/C and O/C values are graphite-like materials (i.e. soot, black carbon, activated carbon), which exhibit high stability compared to uncharred biomass, which possesses high H/C and O/C values and low resistance to degradation.

In the H:C ratio, C refers to “organic” carbon (total carbon content minus the inorganic carbon content from carbonate). In the graph below, it is possible to observe how carbonates are generally low in biochar tested for this project, so that the inorganic carbon fraction is low.



Above: Carbonate content in Biochar

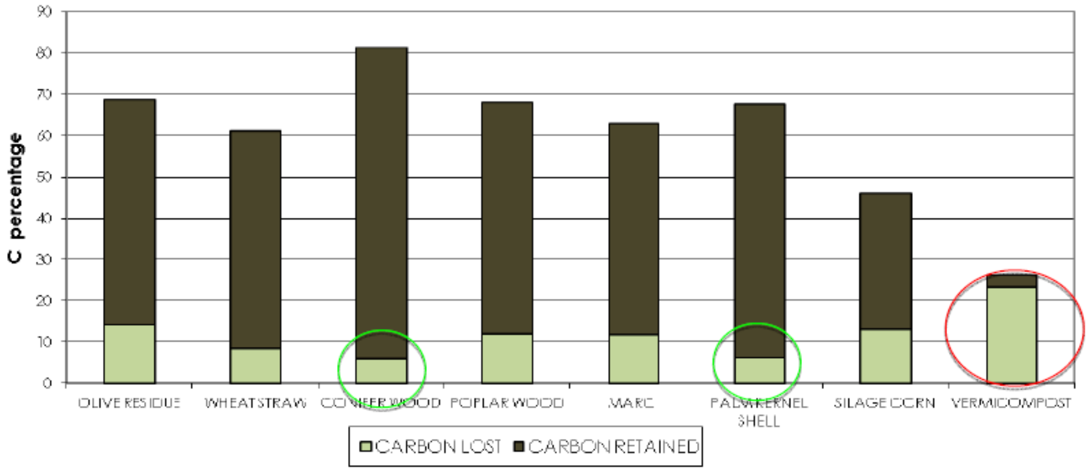
H:C ratio is generally used to verify stability of carbon biochar. Ratio values <0,7, biochar carbon is considered stable. The following table illustrates H:C values for some of the biochar tested in this project.

BIOCHAR	TOTAL (ORGANIC) CARBON (DUMAS METHOD)	H:C RATIO (DUMAS METHOD)
	% DM	-
CONIFER	81.1	0.5
POPLAR	67.3	0.5
WHEAT STRAW	61.1	0.5
MARC	62.1	0.4
OLIVE RESIDUES	68.5	0.5
PALM KERNEL SHELL	67.1	0.5
SILAGE CORN	45.2	0.4

MEAN VALUES – COEFFICIENT OF VARIATION ALWAYS <0.5

Above: Carbonate content in Biochar

All values show how biochar obtained from a gasification process can be considered stable and, therefore, suitable for its use in green roof growing media. Results from chemical reactivity tests using strong dichromate oxidation confirms the stability of carbon biochar compared to other organic material, such as vermicompost (refer to the graph hereunder).

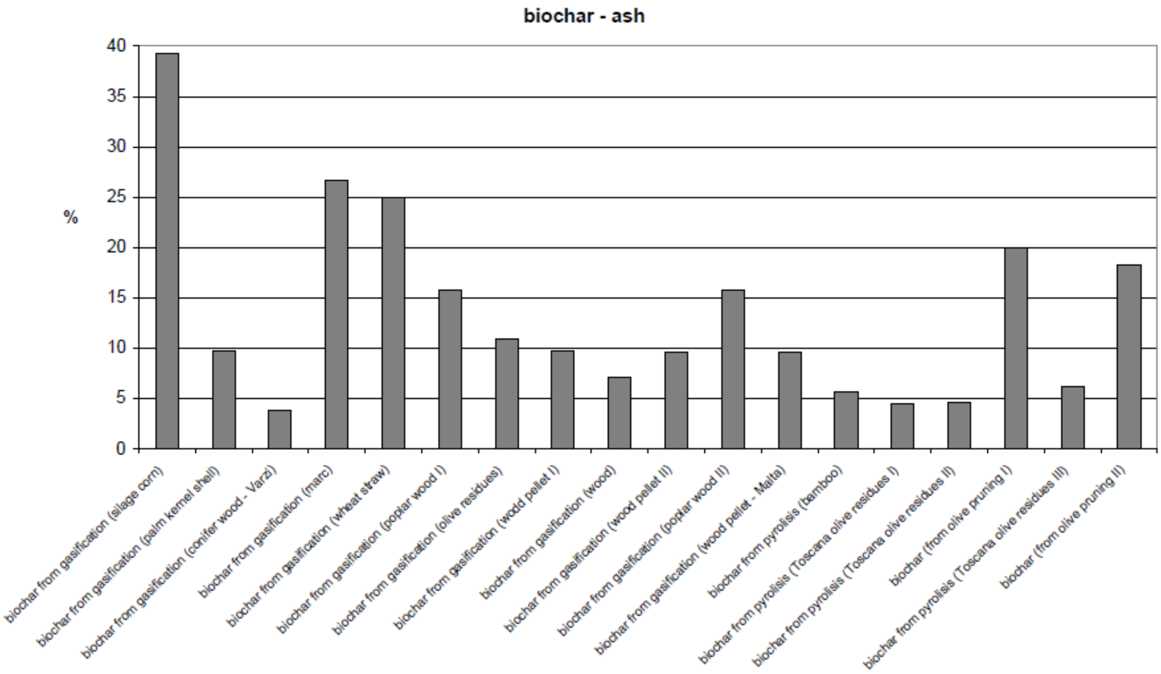


Above: Results from reactivity tests using strong dichromate oxidation

Other considerations

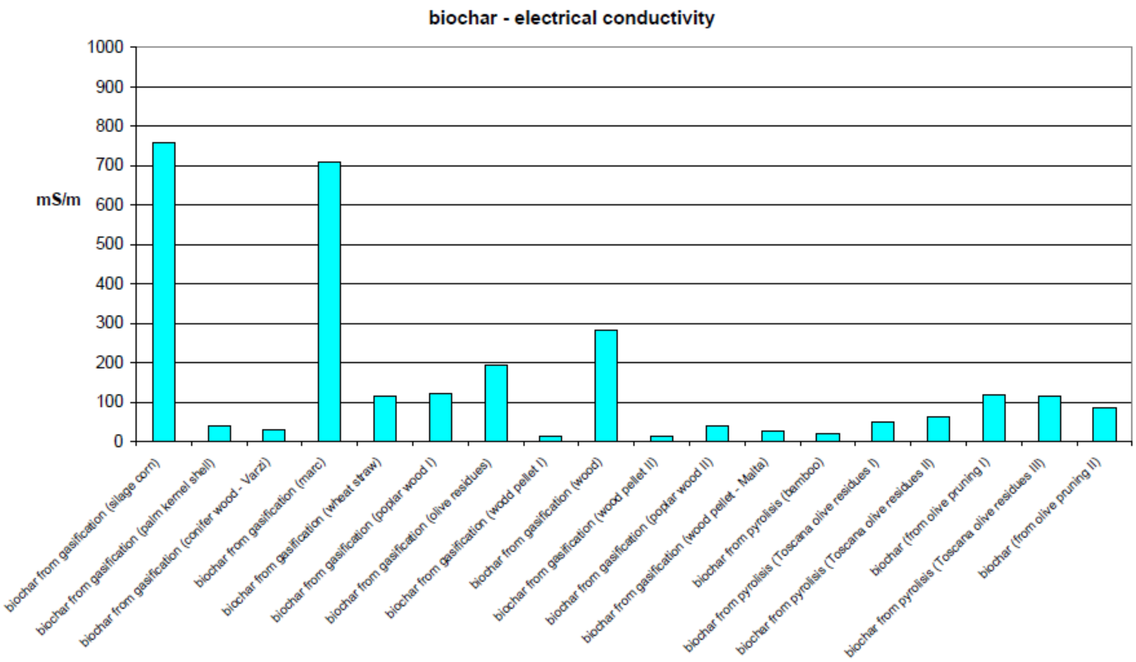
Ash content

Low ash content and low salinity are other properties required for biochar use in green roof.
Ash content results (refer to the graph below) show that wood biochar, bamboo biochar and olive residues biochar have very low values (positive property).



Above: Percentage ash content

On the contrary, silage corn biochar and marc biochar have high ash content. This is generally due to high salinity values (see graph below). Such high ash contents mean that such biochar is not suitable for use in green roof technology.

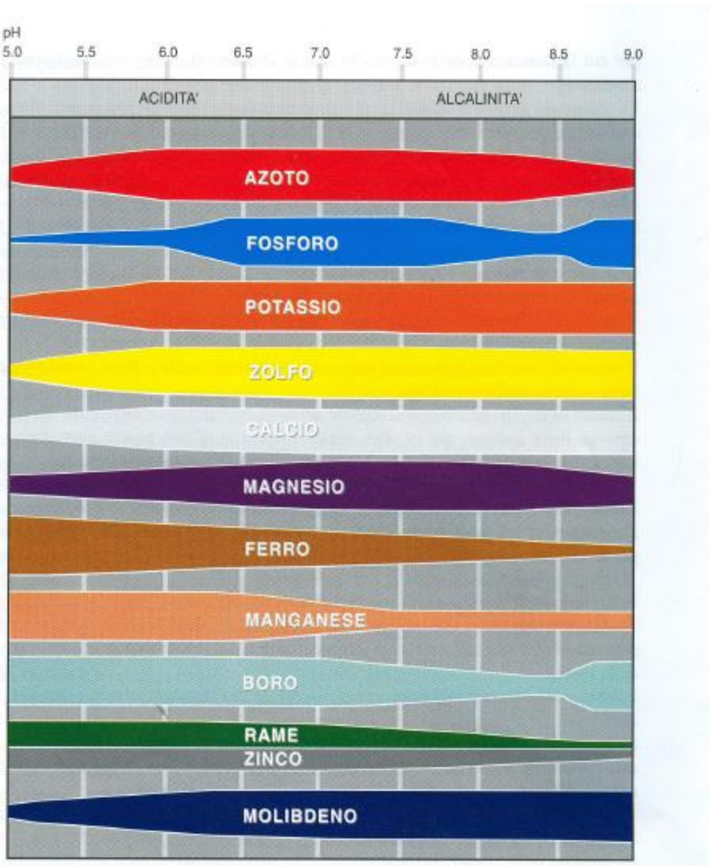


Above: Electrical conductivity

pH

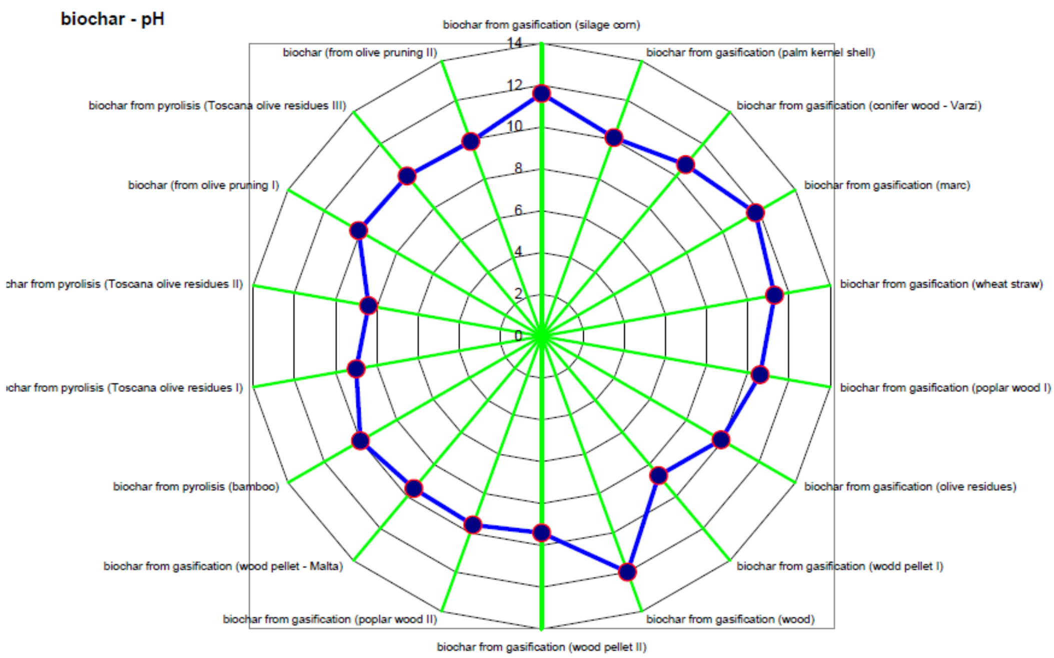
pH is generally the first value checked in a growing medium mainly because pH levels are correlated to the availability of nutrients for vegetation and to microorganism activity.

The following figures show the availability of nutrients in organic growing media at different pH values. In the range of pH 6,0–7,5 there is maximum availability of nutrients although certain plant species prefer acidic media, others prefer alkaline.



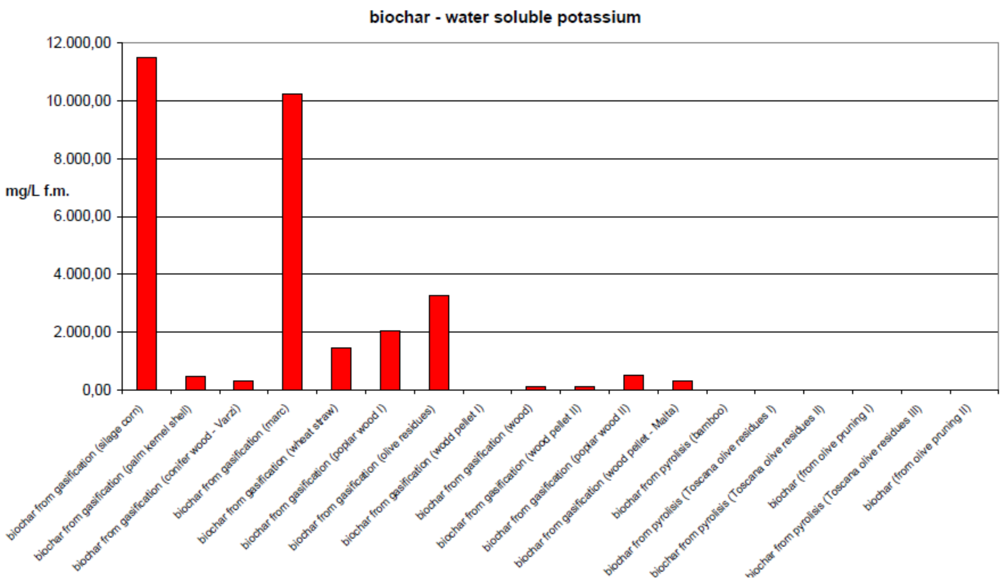
Above: Availability of nutrients in organic growing media at different pH values

Biochar is generally alkaline, with a pH value above 8,0 (see figure below). However, biochar pH value is not a limiting property. Biochar added to acid soils contribute to a rise in pH, however in a neutral-alkaline soil, there is no pH influence. Moreover, on the basis of our direct experience, a partial addition of wood biochar with low ash content in an acidic growing medium for rhododendron cultivation (acid-loving plant species) did not cause negative effects. In effect, when it comes to biochar the value of ash content is more important than pH value. A high ash content value may cause problems related to the increase in pH value of growing media.



Above: pH values of different biochar types

As shown in the following graphic, ash content is generally correlated to high water soluble potassium content. This may be phytotoxic.



Above: Water soluble potassium in various biochar

Biochar test have been carried out between the end of 2013 and summer 2014 (new samples are to be tested in 2015 and result recorded in the next report).

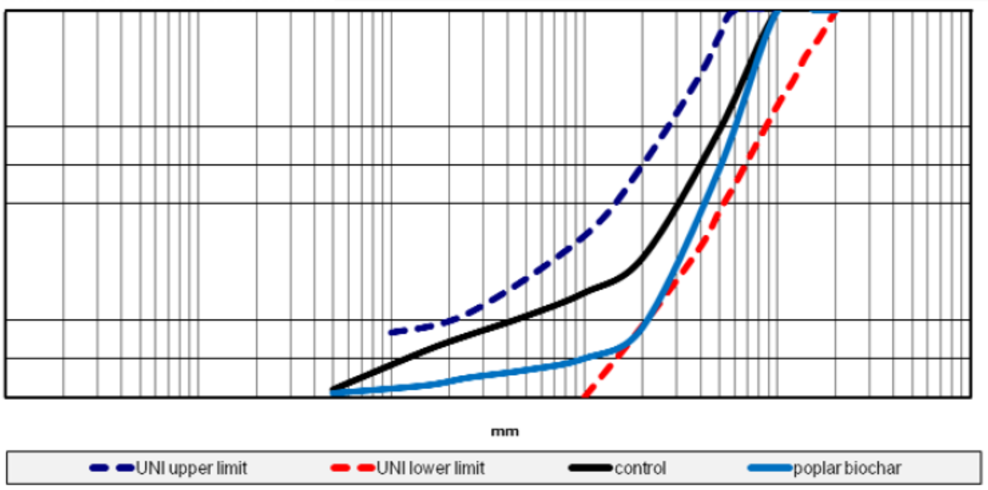
Such biochar has also been used in experimental mixes with commercial substrates since the end of 2013 and in pilot growing media since spring 2014, to test their initial performance in growing media. Such tests were carried out not only for laboratory characterization of the mix, but also to verify specific performances related to permeability and water retention capacity. The results of these tests were presented during two conferences (see Annex A). Hereunder are some values of the preliminary results. They illustrate values related to a commercial growing medium used as a control compared to the same product with 10% poplar biochar added.

PARAMETER	VALUE OF TEST	VALUE OF CONTROL
Dry Bulk Density	813 kg/m3	847 kg/m3
Permeability	10.60 mm/min	11.43 mm/min
Water Retention (pF1)	42.25 % v/v	48.12 % v/v
Air capacity (pF1)	25.85% v/v	18.86% v/v
pH (H2O)	8.5	7.6
Salinity	8.0 mS/m	4.0mS/m
Organic matter (*)	5.67%	4.58%
C.E.C	11.9meq/100g	11.5 meq/100g

Above: Biochar increases air capacity, pH value, and organic matter content

Organic matter

With regards to organic matter, it has to be specified that this parameter is determined by loss of ignition at 450°C. It is important to note that at this temperature, biochar loses volatile material, which is generally and erroneously considered as organic matter (this volatile material is simply carbon). When a material such as charcoal is present in a substrate, it is necessary to identify its quantity so as to correct organic matter values. To carry out this correction the stability of biochar carbon must be known.
Moreover, biochar addition to growing media reduces the fine fraction of the mix (see graphic below).

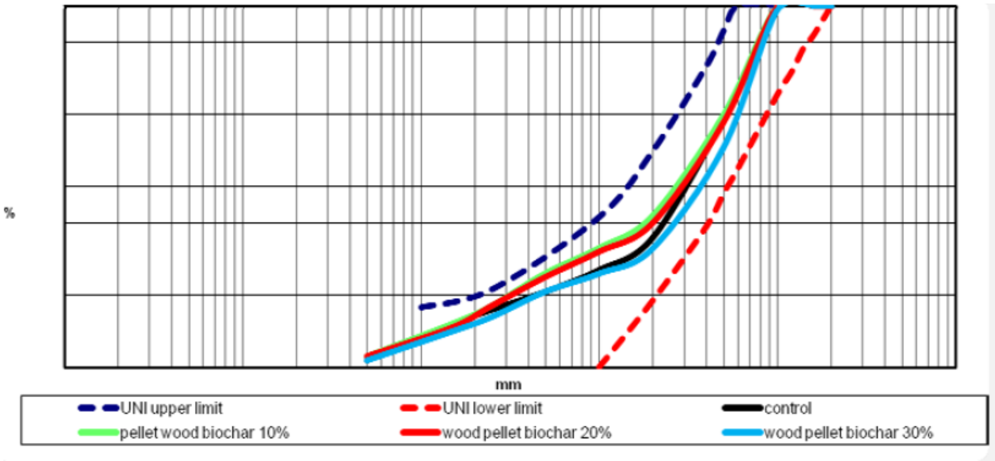


Above: Comparison between fine fraction in poplar biochar and control

Wood pellet biochar was used in different amounts in the commercial growing media. The table below shows the influence on particular parameters. Compared to the control (commercial growing media without biochar), bulk density decreased, while pH, salinity and CEC values increased proportionately to the increase in biochar quantity. On the contrary, air capacity decreased with the increase in biochar and water retention increased.

PARAMETER	10% biochar	20% biochar	30% biochar
Dry Bulk Density	825 kg/m3	812 kg/m3	798 kg/m3
Permeability	8.19 mm/min	14.48 mm/min	12.69 mm/min
Water Retention (pF1)	52.21 % v/v	55.43 % v/v	58.14 % v/v
Air capacity (pF1)	14.96% v/v	10.66% v/v	8.16 % v/v
pH (H2O)	8.0	8.3	8.7
Salinity	7.0 mS/m	8.0mS/m	10.0mS/m
Organic matter (*)	7.67%	13.08%	16.70%
C.E.C	12.75 meq/100g	12.98 meq/100g	16.42 meq/100g

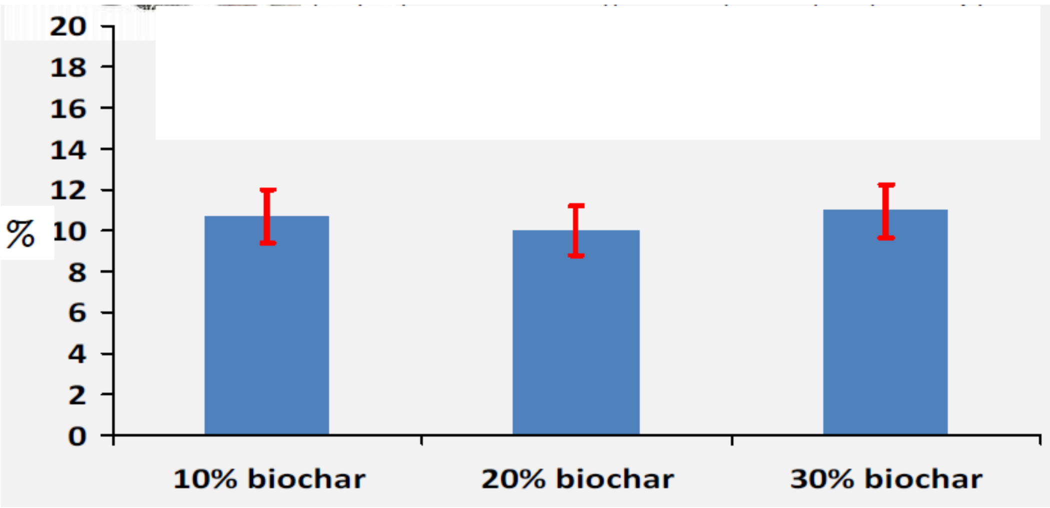
Above: Air capacity, pH, and organic matter content values depending on % biochar
Below: No influence in particle size observed



Plant propagation and rooting

Referring to tests related to propagation of cuttings and rooting, the presence of biochar generally gave a positive result with an increase in the percentage rooting in some plants species and an increase in the percentage root branching in other species.

With these initial experimental mixes preliminary tests on a small scale were conducted to verify the influence of biochar on the storm water retention of green roof growing media.
These tests were conducted with a depth of substrate of 5 cm. A commercial substrate was used as control. Wood pallet biochar was added to the substrate at 10, 20 and 30 % in volume. A rainfall event at 100 mm/h was applied for 30 minute and water retention was determined.
A second rainfall simulation was applied after 2 hours (in saturated conditions). Almost 20% water retention in the control was calculated during the first rainfall simulation. This can be said to be a high value considering a depth of only 5 cm. The samples containing biochar showed increase water retention. During the second rain simulation, when the growing media was saturated, water retention had also increased.



Above: The graph shows the percentage increase in water retention compared to the control depending on the percentage increase in biochar.

Results obtained from the laboratory tests conducted confirm that biochar can be considered an important innovation for green roof growing media. For the LifeMedGreenRoof project, attention was focused on biochar obtained from wood gasification, not solely for its properties, but even because of the availability of such biochar in terms of avaiability.
Moreover, phytotoxicity tests on such biochar (see Annex) showed an absence of negative influences on plants growth and development.

As with respect to the other individual components evaluated, no innovation was recorded. MAC's is well knowledgeable and well-informed about contemporary growing media components. Some preliminary test were carried out on expanded clay (attractive for its light weight; a very important property when it comes to reducing loading on buildings) and coir; a material used as peat substitute. Coconut coir has a low density and is slightly more expensive compared to other similar materials.

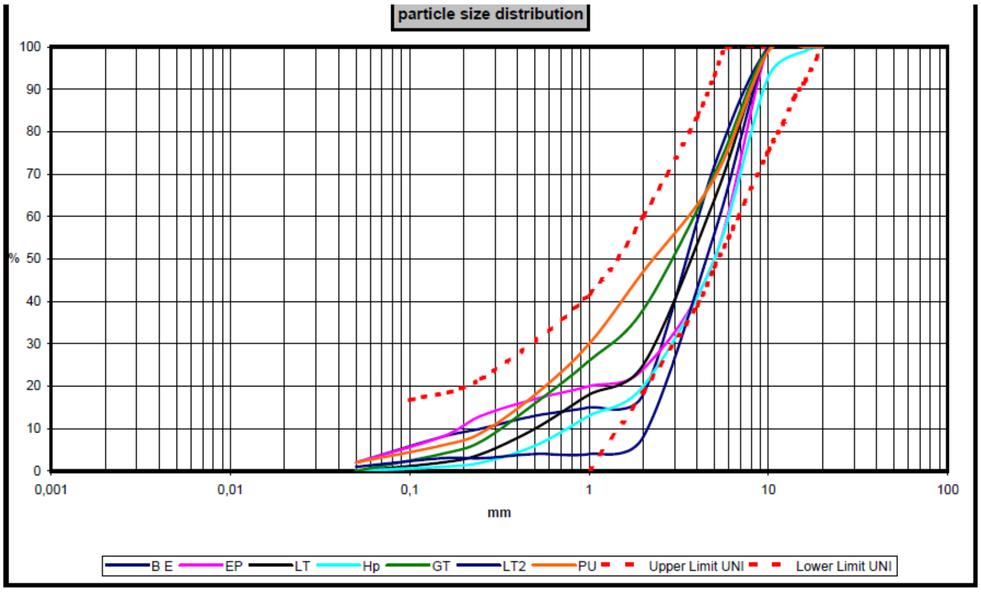
Further research could be conducted to identify material of Maltese provenance. Unfortunately, the components identified in Malta gave immediate unsatisfactory results. Compost showed excessively high salinity levels and during storage biological instability was evident. With regards to the mineral samples tested (coralline limestone spalls, globigerina limestone spalls and crushed concrete), although they had good water drainage properties, they had very high carbonate content. High carbonate levels are incompatible with the use in a green roof (results in Annex).

All the results obtained have allowed us to hypothesize the preparation of new types of growing media, with and without biochar, to be tested in the laboratory in order to verify if their properties were adequate for the planned destination. Satisfactory results were not obtained immediately and some of the first pilot growing media have been abandoned after the first laboratory results (i.e. TA1, TA2, TA3, MAC4, MAC5).

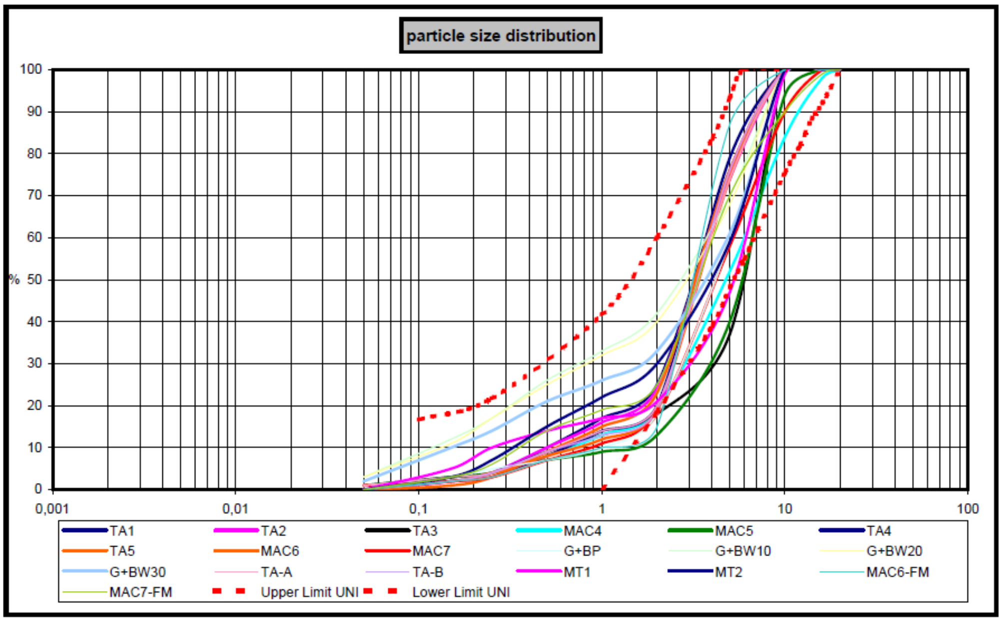
Laboratory characterization tests of commercial and individual components, made it possible to understand the needs of green roof growing media production and to identify the properties to implement, mainly water retention, saturated weight, permeability, and agronomic properties.

Commercial growing media showed different properties, although almost all within the limits present in the Italian UNI Standards for green roof. The major differences related to the water infiltration rate, the water retention capacity, pH, organic matter content, and the availability of water soluble nutrient content.
The following graphs illustrate the main results obtained on commercial and experimental mixes related to particle size.

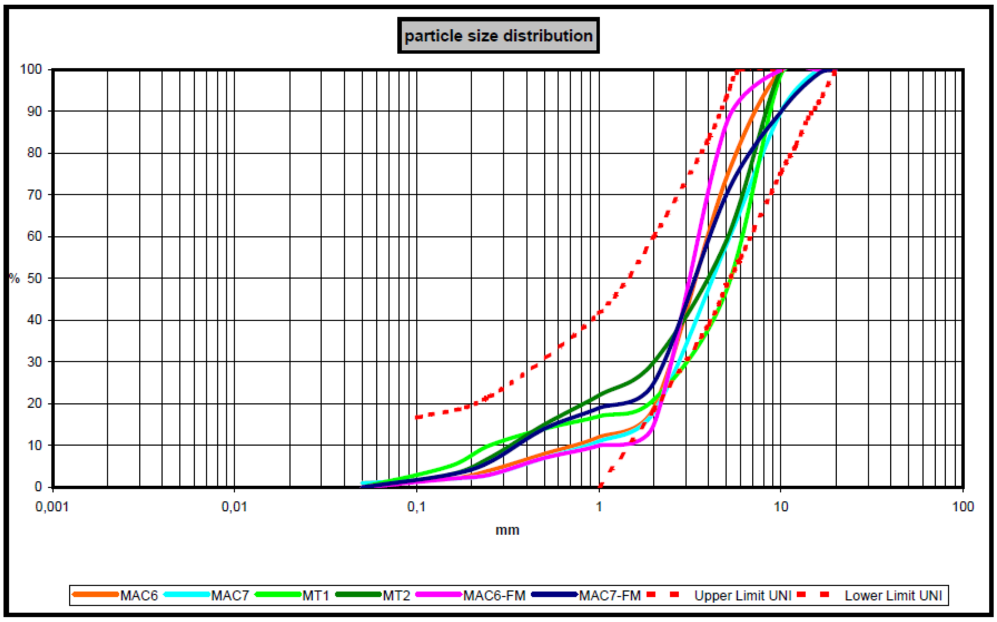
Below: Particle size distribution on commercial growing media compared to the UNI standard. The graph indicates excess coarse particles in one of the samples when compared to the limits set by UNI.



Below: Particle size distribution of the different experimental mixes tested. In this case just two samples are significantly out of the UNI limits (MAC5 and TA3).



Below: Particle size distribution of the experimental growing media subject of further investigation.

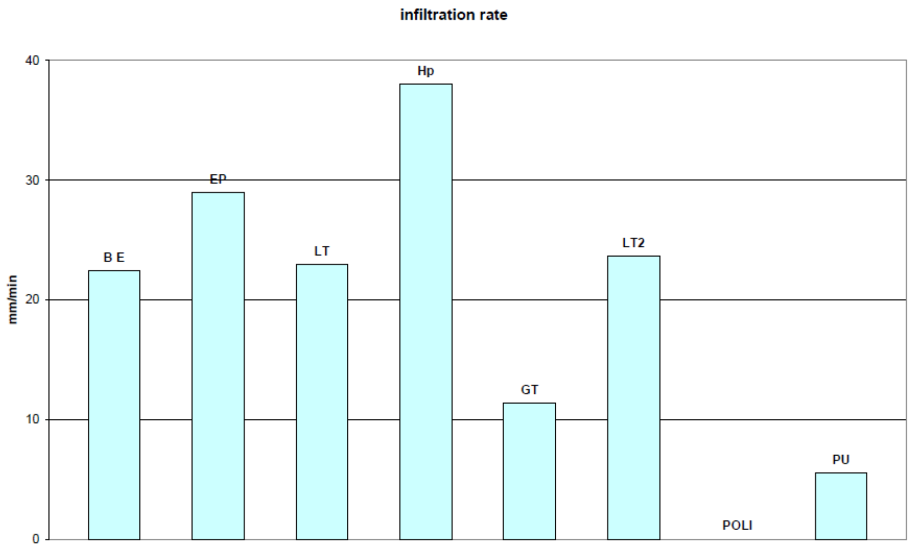


Only MAC6-FM shows a small non-compliance for fraction below 2 mm (low). This result does not preclude the performance of such a mix. Substrates MAC6, MAC7, MAC6-FM, MAC7-FM, and MT2 have biochar included in the mix.

Water infiltration rate

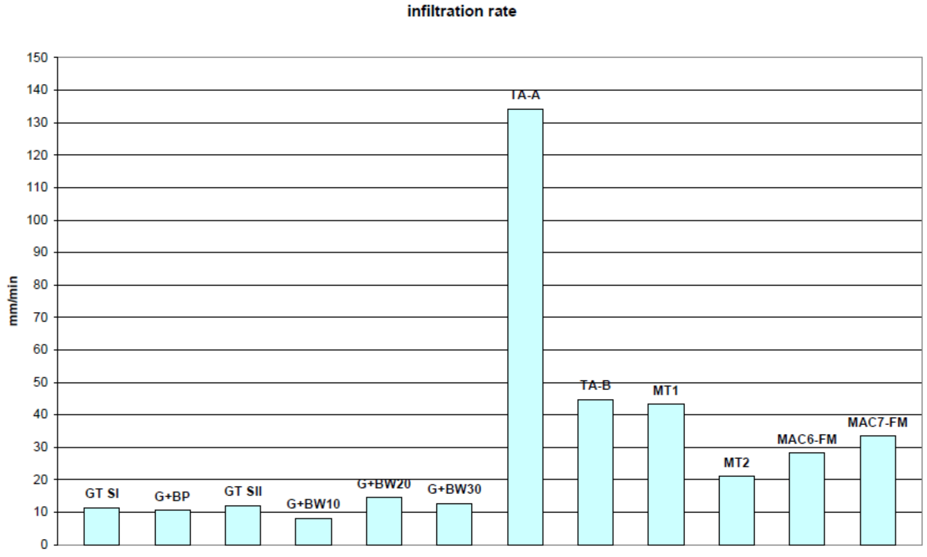
Water infiltration rate is another property which requires verification. Currently, the Italian UNI Standard requires a minimum infiltration rate of 0,6 mm/min for an extensive type growing media, however this figure is set to increase to 5 or 10 mm/min in the new revised edition of the UNI (the POLI sample was not tested for this property due to lack of sample volume).

The graph below shows values for tested commercial mixes. All values are high, (5mm/min to almost 50 mm/min). It is interesting to note that the sample with the lowest infiltration value has the highest percentage of fine particles.



Above: Infiltration rates of various commercial mixes.

Infiltration rate values for the experimental mixes can be observed in the following graph.
Values are generally higher than those recorded for the commercial mix. TA-A shows an infiltration rate which is too high, possible due to increased macro pores.
For MAC6-FM, MAC7-FM, MT1 and MT2 growing media values between 20 and 40 mm/min are considered very positive.

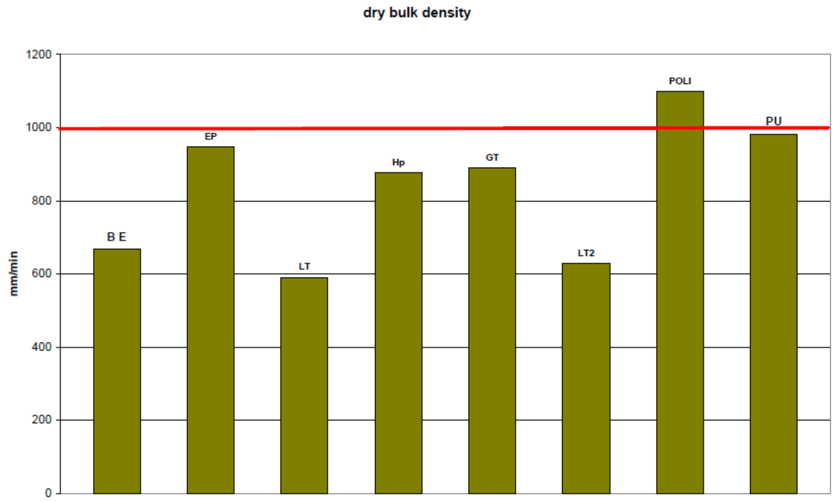


Above: Infiltration rates of experimental mixes.

Dry bulk density

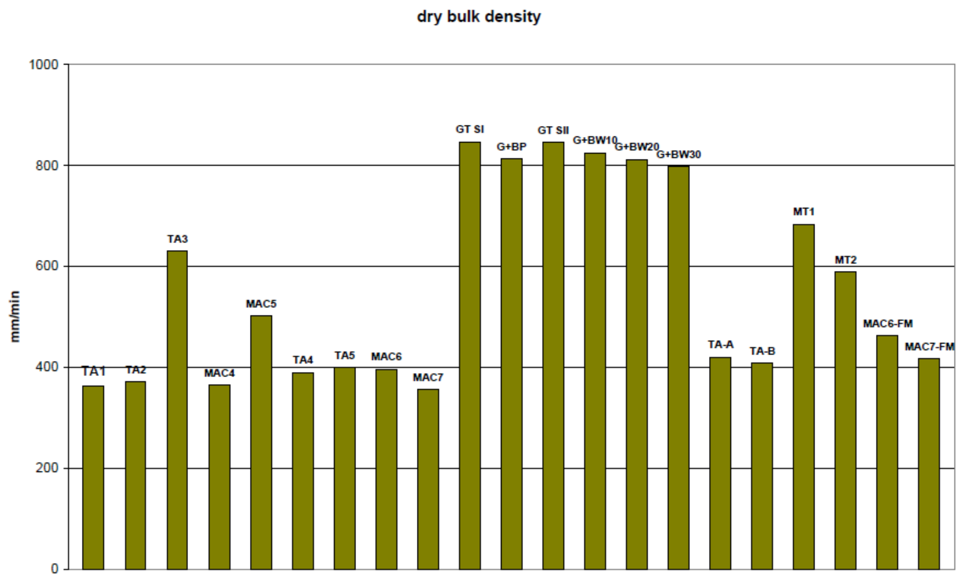
Dry bulk density is an important factor as it is related to porosity and depth of cultivation. It directly influences the weight of substrate. In the Italian UNI Standard the upper limit specified for growing media is 1000 kg/m3.

For the commercial growing media (refer to the graph below), only POLIMI shows a high value which exceeds the limit. For buildings that can withstand heavy weights this factor should not constitute a problem, but high values are generally correlated to low porosity, fine particle size, low infiltration rate, and low air capacity.



Above: Dry bulk density for commercial mixes. Only Poli exceeds the 1000kg/m3 limit as specified by the Italian

In the experimental substrates all values are within UNI limits and some of them are even below the lower limit. It is possible to note the correlation between the low values and the presence of biochar.

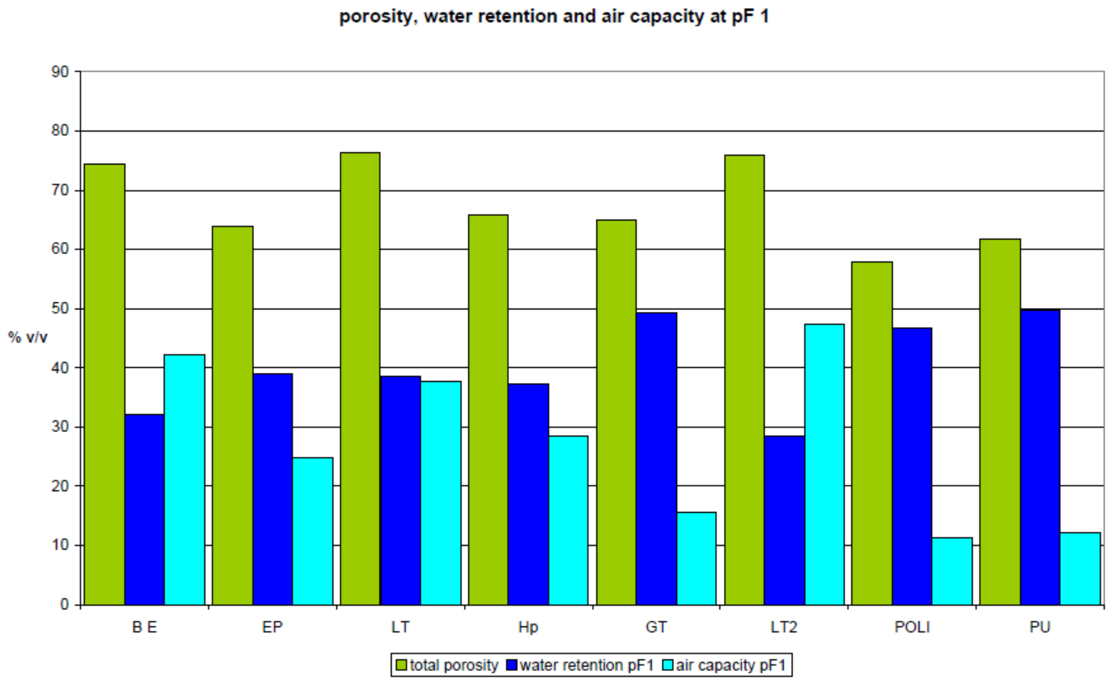


Above: Dry bulk density for experimental mixes. There is a correlation between the use of biochar and low dry bulk

MT1 (no biochar) and MT2 (with biochar) have values between 600 and 700 kg/m3 (positive values, as they are not too light). On the other hand, MAC6-FM and MAC7-FM (both with biochar included) are lighter. It is worth nothing that Italian buildings do not have a high loading capacity (even those destined to have green roofs); for this reason expanded clay has been inserted in the mix.

Water porosity and voids

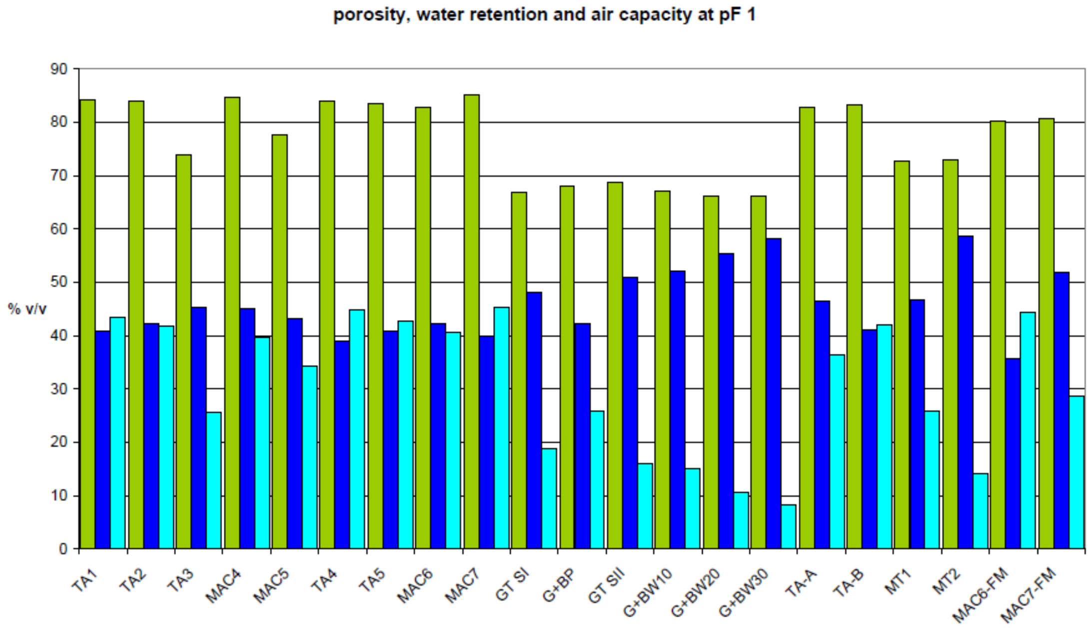
As regards to total porosity and water and air capacity at pF1, the following graph illustrates values for commercial substrates. The total porosity is generally high (>50% v/v) in all the samples. However, differences have been observed between water retention and air capacity. In most cases water retention is greater than air capacity.



Above: Porosity, water retention and air capacity of commercial mixes at pF1..

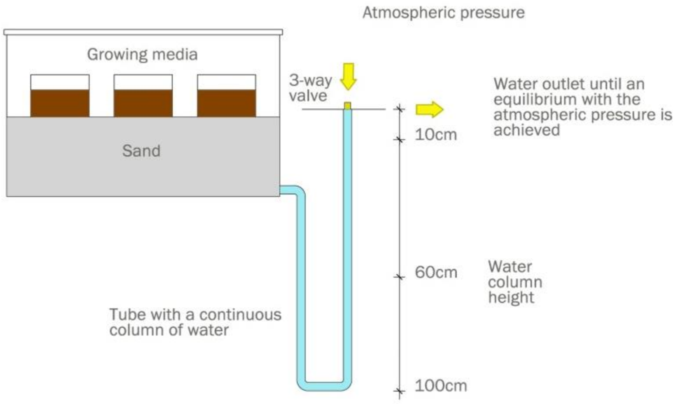
Water retention at pF1 is the maximum amount of water retained by the substrate. Not all the water retained is available to the plants. High values are generally preferred; however a minimum value of air capacity is preferred. This should not be less than 10% v/v due to root respiration activity. These properties

are correlated to particle size and to the water retention capacity of the single components. Generally speaking, low air capacity reflects low infiltration rate.
In the experimental mixed the main purpose was to obtain high value of total porosity and water retention, together with air capacity >15%: in MAC6-FM, MAC7-FM, MT1 and MT2 all these objectives have been reached.



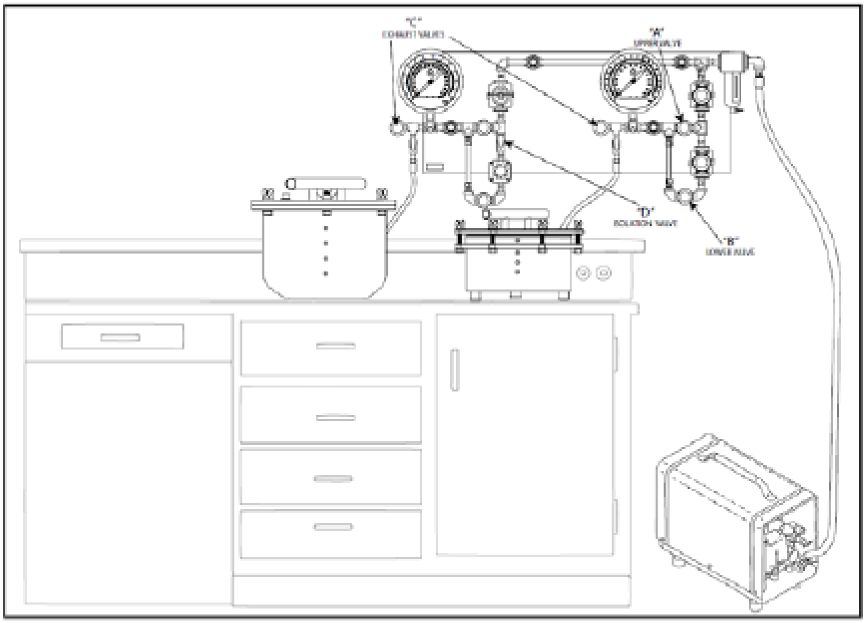
Above: Porosity, water retention and air capacity values for experimental mixes of mixes at pF1.

Another significant property considered in the current Italian UNI Standard is the amount of water available for plants. In order to determine this property, the water content at pF4,2 (wilting point) is established. The difference between the amount of water at maximum retention (pF1) and the amount of water at the wilting point is the water available to the plants. Water retention at low pressure (pF1) is determined by a sand box. (See image hereunder). To determine water content at pF1 a pressure of -1 kPa (-10 cm of water suction) is applied.



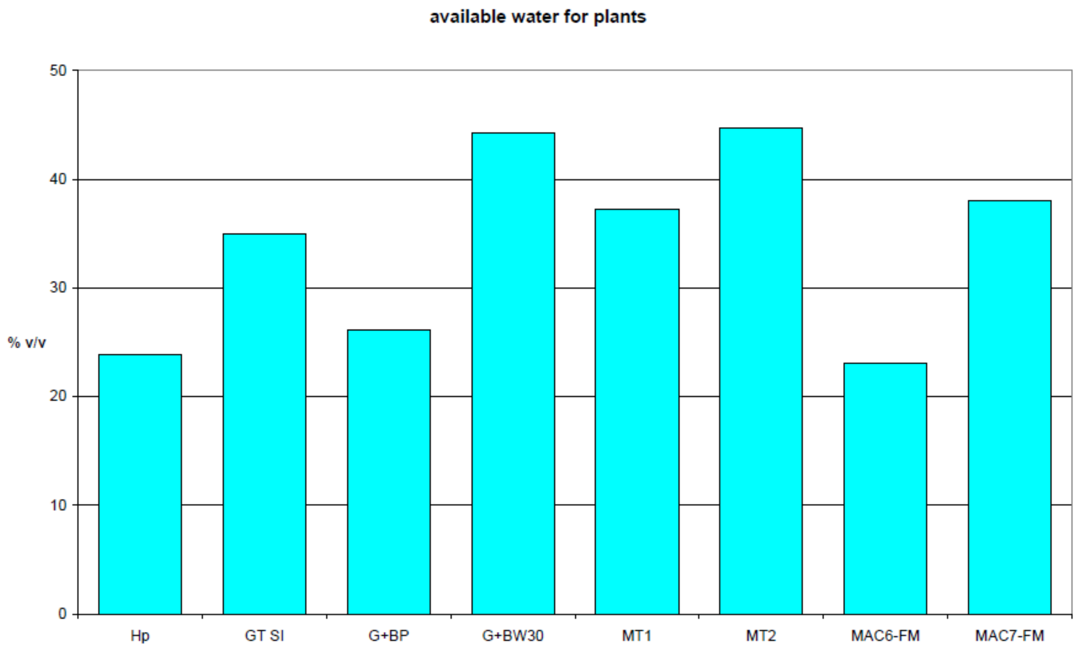
Above: Sand box for water content determination between pF0 and pF2.0

For water content at pF4,2 ceramic plates in an extractor are used. Saturated samples are placed on the plate in the extractor and a pressure of 1,500 kPa (15 bar) is applied.



Above: Extractors for water content determination between pF2.0 and pF4.2

The above procedures to determine the water available for plants were carried out on some of the experimental mixes. Results of the tests are illustrated here under.

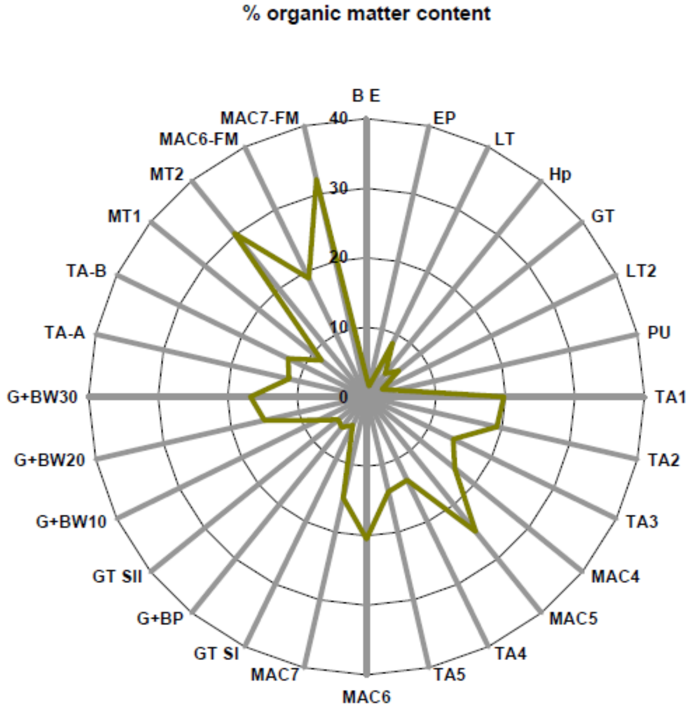


Above: Test results for water availability in commercial and experimental mixes.

The first two values to the left represent the results for commercial samples, while the rest represent results for experimental mixes. Poplar biochar (G+BP) resulted in reduced total available water, while wood biochar (G+BW30) has increased levels of available water (compared to GT SI, same samples without biochar). Wood pellet biochar increases levels of available water (see MT2 with biochar compared with MT1 without biochar). Results for MT1, MT2 and MAC7-FM are considered as very positive.

Organic matter

Organic matter content values are visible in the following figure.

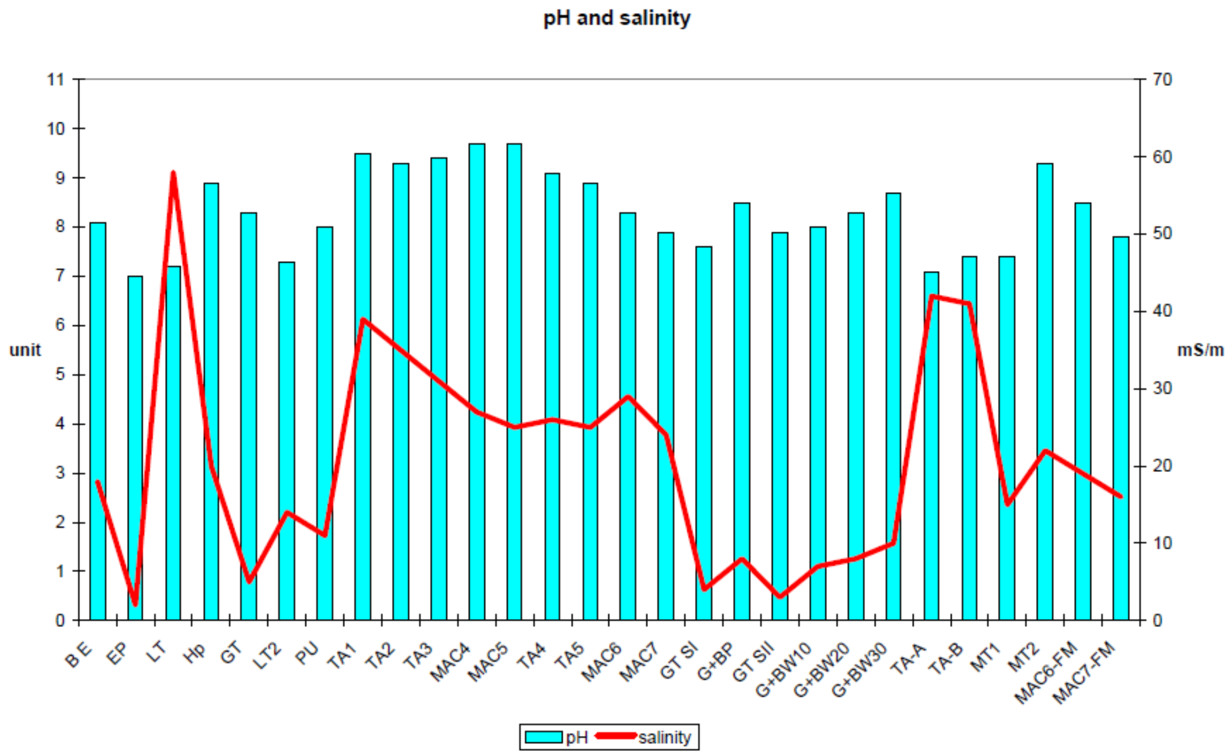


Above: % organic matter content

For extensive green roof growing media, the Italian UNI Standard recommends a maximum content of 8% organic matter. Too much organic matter may lead to the structural instability of the growing media. Samples with biochar show very high values (beyond the UNI limits), however this relates to the analytical methods as organic matter is determined with loss of ignition at 450°C. This method of quantifying organic matter gives an inaccurate result as mentioned earlier on. With such method the biochar carbon behaves as organic matter although it is not. So the reported values for samples with biochar are not true values and do not reflect organic matter content. These data need to be correctly correlated to biochar content (a reduction in the organic matter value of between 40-50% can be considered). Sample MT1 (without biochar) shows a value in accordance with UNI Standards. The issue of the presence of biochar and organic matter content needs serious discussion and evaluation. This should be taken into consideration when drafting the Maltese Standard.

With regards to chemical parameters, generally in commercial extensive growing media pH values are around 8.0-8.5 and salinity is low (less than 50 mS/m). Laboratory test confirm these data except for the LT mix which is more comparable to an intensive green roof mix, as shown in the following graph.

When considering the pH and salinity of the experimental mixes the situation was different due to differing quantities and types of biochar used. The increase in pH of the experimental growing media with biochar should not be considered as problematic due to the issue mentioned before. Results for MT1, MT2 and MAC7-FM can be considered as good.



Above: pH and salinity results

Laboratory activity allowed the achievement of the initially foreseen results; the identification of 2 growing media for the Maltese demonstration site (one with biochar) and 2 new possible growing media (both with biochar) for the Italian demonstration site (there is a possibility that MAC7-FM will be used as a new solution). The 2 growing media for Malta have been used in the Maltese site trials and the monitoring visit in October permitted the verification of a good response of vegetation to both mixes. The substrate without biochar allowed for a better vegetative response, however it was suggested by the MAC representative that irrigation should be different between the two substrates, less water for the growing media with biochar. This solution has given very good immediate response.

In the first Italian site trials, some pilot growing media were already used (essentially a commercial growing media with integrated biochar). New different site trials on water efficiency and re-cultivation of plants are underway; in these last trials all four new substrates are used.

Laboratory activity is on-going till mid-2015.

A prototype of a rain chamber was built in 2014 and tested during early December 2014. It is now ready to be used for the selected substrates to test the run-off coefficient as simulated high intensity rainfall. Such tests will be conducted within the first quarter of 2015.

Annexes

Biochar test results – December 2014

properties/parameters		units	method	biochar from gasification (silage corn)	biochar from gasification (palm kernel shell)	biochar from gasification (conifer wood - Varzi)	biochar from gasification (marc)	biochar from gasification (wheat straw)	biochar from gasification (poplar wood I)	biochar from gasification (olive residues)	biochar from gasification (wodd pellet I)	biochar from gasification (wood)
particle size	< 1mm	% m/m dm	UNI EN 15428:2008	27	18	36	39	75	48	37	14	79
	<2mm	% m/m dm	UNI EN 15428:2008	44	30	64	60	97	91	56	21	93
	<5mm	% m/m dm	UNI EN 15428:2008	77	86	97	100	100	100	100	76	100
	<10mm	% m/m dm	UNI EN 15428:2008	100	100	100	100	100	100	100	99	100
chemical properties	Humidity	% dm	UNI EN 15428:2008	48.7	21.1	6.2	2.3	0.1	23.3	6.8	47.6	2.2
	Ash 550°C	% dm	UNI EN 15428:2008	39.31	9.7	3.77	26.6	24.99	15.8	10.83	9.66	7.05
	Compacted bulk density	g/l	UNI EN 15428:2008	654	585	222	341	118	252	268	540	213
	pH	pH unit	UNI EN 15428:2008	11.6	10.1	10.7	11.8	11.3	10.6	9.9	8.7	12
	pH $_{CaCl2}$	pH unit	rif. UNI EN 13037:2002 + VDLUFA Methodenbuch I A 5.5.1.1	11.6	n.r.	n.r.	11.1	n.r.	n.r.	n.r.	n.r.	n.r.
	Electrical conductivity	mS/m	UNI EN 13038:2012	758	40	30	710	115	121	194	12	281
	Electrical conductivity (1:1,5)	mS/cm	Sonneveld et al. Comm. Soil Sci. Plant Anal. 5:183-202 1974 + 25:3199-3208 1994									
	Nitrate Nitrogen (water soluble)	mg/l fm	UNI EN 13652:2001	<5,65	<5	<5	<5	<5	<5	<5	n.r.	<5
	Ammonium Nitrogen (water soluble)	mg/l fm	UNI EN 13652:2001	72.52	47.6	29.82	48.16	29.4	27.02	27.3	n.r.	18.9
	Phosphorous (water soluble)	mg/l fm	UNI EN 13652:2001	36.2	9.63	<0,4	51.99	9.24	107.06	50.45	n.r.	1.66
	Potassium (water soluble)	mg/l fm	UNI EN 13652:2001	11,500.00	485	307.5	10,250.00	1,475.00	2,050.00	3,250.00	n.r.	122.00
	Calcium (water soluble)	mg/l fm	UNI EN 13652:2001	0.8	27.5	49.5	62.5	3	30	30	n.r.	1275
	Magnesium (water soluble)	mg/l fm	UNI EN 13652:2001	0.15	5.5	6	1.5	2	10.5	4	n.r.	0.25
	Sodium (water soluble)	mg/l fm	UNI EN 13652:2001	85	10.5	22.5	32.5	57.5	22.5	47.5	n.r.	1.2
	Total Carbon	% dm	UNI EN 13654-2:2001	46	67.5	81.3	63.1	61.3	68.1	68.7	91.1	89.8
	Calcium carbonate	% dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met V.1	6.5	3.1	1.5	8.9	1.6	6.8	1.7	0.7	1.2
	Total Nitrogen	% dm	UNI EN 13654-2:2001	1.01	0.72	0.49	1.84	0.84	1.6	0.97	0.48	0.56
	Total Phosphorous	% dm	UNI EN 13650:2002 + Hoffmann - Landw. Forsch. 19,94-107:1966	0.92	0.07	0.04	0.28	0.14	0.23	0.14	0.02	0.08
	Total Potassium	% dm	UNI EN 13650:2002 + ISO 11047:1998	6.9	0.48	0.4	7	2.75	1.75	2.6	0.14	0.44
bioassays	Germination index (lepidium)	%	UNI 10780 App. K:1998 (diluiz. 30%)	70	96	147	55	99	97	95	93	103
	Phytotoxicity test (lettuce)	rating	Reg. Lombardia - BU 13/05/2003 - 1° SS - DGR 16/04/2003 n. 7/12764 - All. B	suitable	suitable	suitable	n.r.	suitable	suitable			
	Germination inhibition (spring barley - 10% biochar)	%	UNI EN 16086-1:2012	-15	0	0	0	3.33	3.33	0		
	Growth inhibition (spring barley - 10% biochar)	%	UNI EN 16086-1:2012	-5.73	-56.49	-23.91	-17.23	-40.1	-44.27	-35.65		

	Germination inhibition (spring barley - 25% biochar)	%	UNI EN 16086-1:2012								-7.55	-42.11
	Growth inhibition (spring barley - 25% biochar)	%	UNI EN 16086-1:2012								-53.24	-7.19
contaminants	PAHs (total)	mg/kg dm	EPA 8310	< IL	< IL	< IL	< IL	< IL	< IL	< IL	0.52	0.47
	Hydrocarbons (C>12)	mg/kg dm	UNI EN 14039:2005	63	55	52	48	50	45	63	112	382
	Lead (Pb)	mg/kg dm	UNI EN 13650:2002 + ISO 11047:1998								<5	
	Cadmium (Cd)	mg/kg dm	UNI EN 13650:2002 + ISO 11047:1998								<1	
	Nickel (Ni)	mg/kg dm	UNI EN 13650:2002 + ISO 11885:2007								<5	
	Zinc (Zn)	mg/kg dm	UNI EN 13650:2002 + ISO 11047:1998								21	
	Copper (CU)	mg/kg dm	UNI EN 13650:2002 + ISO 11047:1998								<1	
	Mercury (Hg)	mg/kg dm	UNI EN 13650:2002 + ISO 11885:2007								<0,2	
	Chromium VI (Cr VI)	mg/kg dm	UNI 10780:1998 App. B 4.7								<0,2	

properties/parameters		units	method	biochar from gasification (silage corn)	biochar from gasification (palm kernel shell)	biochar from gasification (conifer wood - Varzi)	biochar from gasification (marc)	biochar from gasification (wheat straw)	biochar from gasification (poplar wood I)	biochar from gasification (olive residues)	biochar from gasification (wodd pellet I)	biochar from gasification (wood)
particle size	< 1mm	% m/m dm	UNI EN 15428:2008	25	56	33	7				33	12
	<2mm	% m/m dm	UNI EN 15428:2008	35	77	45	12				75	28
	<5mm	% m/m dm	UNI EN 15428:2008	77	96	98	25				99	71
	<10mm	% m/m dm	UNI EN 15428:2008	100	100	100	100				100	100
chemical properties	Humidity	% dm	UNI EN 15428:2008	44.8	50.5	45.6	7.3				32.8	55
	Ash 550°C	% dm	UNI EN 15428:2008	9.53	15.8	9.53	5.68	4.4	4.56	19.92	6.12	18.31
	Compacted bulk density	g/l	UNI EN 15428:2008	588	421	604	117				425	210
	pH	pH unit	UNI EN 15428:2008	9.4	9.6	9.5	10	9	8.4	10.1	10	9.9
	pH $_{CaCl_2}$	pH unit	rif. UNI EN 13037:2002 + VDLUFA Methodenbuch I A 5.5.1.1	n.r.	n.r.	n.r.						
	Electrical conductivity	mS/m	UNI EN 13038:2012	12	39	25	20	50	61	118	116	86
	Electrical conductivity (1:1,5)	mS/cm	Sonneveld et al. Comm. Soil Sci. Plant Anal. 5:183-202 1974 + 25:3199-3208 1994					1.51	1.84	3.54		
	Nitrate Nitrogen (water soluble)	mg/l fm	UNI EN 13652:2001	13.62	<5	<5	18.48				15.26	20.02
	Ammonium Nitrogen (water soluble)	mg/l fm	UNI EN 13652:2001	<5	35.9	22.4	6.77				6.77	6.77
	Phosphorous (water soluble)	mg/l fm	UNI EN 13652:2001	2.4	99.7	8.31	4.43				7.75	9.97
	Potassium (water soluble)	mg/l fm	UNI EN 13652:2001	125	523	292.5	2.85				6.35	18.5
	Calcium (water soluble)	mg/l fm	UNI EN 13652:2001	19.5	18.9	16	9.5				2.45	27.5
	Magnesium (water soluble)	mg/l fm	UNI EN 13652:2001	11	7.2	11	260				2,100.00	1,300.00
	Sodium (water soluble)	mg/l fm	UNI EN 13652:2001	6	52.1	16	1.65				17	4.5
	Total Carbon	% dm	UNI EN 13654-2:2001	84.6	68.1	75.4	81.7	74.8	65.6	69.3	75.6	66.3
	Calcium carbonate	% dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met V.1	5.7	6.7	3.7	1.9	0.7	0	7.1	1.8	9.5
	Total Nitrogen	% dm	UNI EN 13654-2:2001	0.33	1.6	0.53	0.63		2.08	1.93	2.34	2
	Total Phosphorous	% dm	UNI EN 13650:2002 + Hoffmann - Landw. Forsch. 19,94-107:1966	0.09	0.41	0.1	0.08				0.14	0.36
	Total Potassium	% dm	UNI EN 13650:2002 + ISO 11047:1998	0.27	0.95	0.33	0.93				1.4	2.7
bioassays	Germination index (lepidium)	%	UNI 10780 App. K:1998 (diluiz. 30%)	119	n.r.	88						
	Phytotoxicity test (lettuce)	rating	Reg. Lombardia - BU 13/05/2003 - 1° SS - DGR 16/04/2003 n. 7/12764 - All. B		suitable							
	Germination inhibition (spring barley - 10% biochar)	%	UNI EN 16086-1:2012									
	Growth inhibition (spring barley - 10% biochar)	%	UNI EN 16086-1:2012									
	Germination inhibition (spring barley - 25% biochar)	%	UNI EN 16086-1:2012	-53			3.51				3.51	5.26

	Growth inhibition (spring barley - 25% biochar)	%	UNI EN 16086-1:2012	-22			-7.98				-11.37	-13.33
contaminants	PAHs (total)	mg/kg dm	EPA 8310	0.52	<IL							
	Hydrocarbons (C>12)	mg/kg dm	UNI EN 14039:2005	112			413				988	106
	Lead (Pb)	mg/kg dm	UNI EN 13650:2002 + ISO 11047:1998				4				7	20
	Cadmium (Cd)	mg/kg dm	UNI EN 13650:2002 + ISO 11047:1998									
	Nickel (Ni)	mg/kg dm	UNI EN 13650:2002 + ISO 11885:2007									
	Zinc (Zn)	mg/kg dm	UNI EN 13650:2002 + ISO 11047:1998				650				23	62
	Copper (CU)	mg/kg dm	UNI EN 13650:2002 + ISO 11047:1998				130				39	192
	Mercury (Hg)	mg/kg dm	UNI EN 13650:2002 + ISO 11885:2007									
	Chromium VI (Cr VI)	mg/kg dm	UNI 10780:1998 App. B 4.7									

Growing media and components results till December 2014

properties/parameters		unit	method	extensive Beton Eisack - commercial	extensive Europomice - commercial	intensive Laterlite - commercial	extensive Harpo - commercial	extensive Geotec - commercial	extensive Laterlite - commercial	extensive Milano - commercial	Paesaggi Umbri - commercial
particle size	<0,05mm	% m/m dm	UNI EN 15428:2008	2	2	0	0	0	1		2
	<0,15mm	% m/m dm	UNI EN 15428:2008	8	8	2	1	4	3		6
	<0,25mm	% m/m dm	UNI EN 15428:2008	10	13	4	2	7	3		9
	<0,50mm	% m/m dm	UNI EN 15428:2008	13	17	10	6	16	4		18
	<1mm	% m/m dm	UNI EN 15428:2008	15	20	18	13	26	4		30
	<2mm	% m/m dm	UNI EN 15428:2008	18	24	25	20	38	8		47
	<5mm	% m/m dm	UNI EN 15428:2008	72	50	64	50	70	56		69
	<10mm	% m/m dm	UNI EN 15428:2008	100	100	100	93	100	100		99
	<16mm	% m/m dm	UNI EN 15428:2008	100	100	100	99	100	100		100
	<20mm	% m/m dm	UNI EN 15428:2008	100	100	100	100	100	100		100
watwer retention	infiltration rate	mm/min	DIN 18035-4:1991-07	22.42	28.99	22.95	38	11.35	23.66		5.55
	dry bulk density	kg/m^3	UNI EN 13041:2007	667	947	590	877	889	629	1,099	983
	particle density	kg/m^3	UNI EN 13041:2007	2,599	2,621	2,497	2,572	2,542	2,604	2,612	2,573
	porosity	% v/v	UNI EN 13041:2007	74.35	63.85	76.37	65.89	65.04	75.86	57.94	61.79
	water retention pF1	% v/v	UNI EN 13041:2007	32.16	38.93	38.65	37.37	49.38	28.41	46.7	49.69
	air capacity pF1	% v/v	UNI EN 13041:2007	42.18	24.91	37.72	28.51	15.66	47.45	11.24	12.1
	water retention pF1,7	% v/v	UNI EN 13041:2007	25.62	29.33					18.85	
	air capacity pF1,7	% v/v	UNI EN 13041:2007	48.72	34.52					39.09	
	water retention pF2	% v/v	UNI EN 13041:2007	22.43	25.09	33.34	27.28	32.75	16.32	14.51	
	air capacity pF2	% v/v	UNI EN 13041:2007	51.92	38.76	43.04	38.6	32.29	59.54	43.43	
	water retention pF2,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	air capacity pF2,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	water retention pF3,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	air capacity pF3,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	water retention pF4,2	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5				13.46				
	air capacity pF4,2	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5				52.43				
chemical properties	organic matter	% s.s.	UNI EN 13039:2012	2.77	1.58	8.61	4.26	5.98	2.48		4.24
	cation exchange capacity	meq/100g dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met XIII.2	nr	10	9.5	18.4	10			8.1
	compacted bulk density	g/l	UNI EN 13040:2008	744	934	683	974	913	564	1,067	955
	pH	pH unit	UNI EN 13037:2012	8.1	7	7.2	8.9	8.3	7.3	8.2	8
	electrical conductivity	mS/m	UNI EN 13038:2012	18	2	58	20	5	14	3	11
	Ammonium Nitrogen (water soluble)	mg/l (water extract)	UNI EN 13652:2001	2.97	2.72	9.18	3.7	0.73	7.28		5.43
	Nitrate Nitrogen (water soluble)	mg/l (water extract)	UNI EN 13652:2001	7.45	2.48	32.97	4.06	1.35	4.29		1.81
	mineral Nitrogen (water soluble)	mg/l (water extract)	UNI EN 13652:2001	10.42	5.2	42.15	7.76	2.08	11.57		7.24
	Phosphorous (water soluble)	mg/l (water extract)	UNI EN 13652:2001	3.04	1.78	46.68	2.03	0.76	5.58		1.56
	Calcium (water soluble)	mg/l (water extract)	UNI EN 13652:2001	14.5	0.3	51.5	8	4.2	4.3		0.2
	Magnesium (water soluble)	mg/l (water extract)	UNI EN 13652:2001	2.1	0.06	10.5	1.7	1	1.5		0.1
	Potassium (water soluble)	mg/l (water extract)	UNI EN 13652:2001	14	2.5	88.5	23.5	6.5	13.1		6.5
	Sodium (water soluble)	mg/l (water extract)	UNI EN 13652:2001	13	3	30	14	4.9	9.5		2.2
	cation exchange capacity (sum)	meq/100 g dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met XIII.4 + XIII.3	15.4	10				9.7		
	Calcium carbonate ($CaCO_3$)	ppm dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met V.1								
	total organic Carbon	% dm	DM 21/12/00 Suppl. n. 6 GU 21 26/01/2001								

properties/parameters		unit	method	extensive TA 1 - experimental	extensive TA 2 - experimental	extensive TA 3 - experimental	extensive MAC 4 - experimental	extensive MAC 5 - experimental	extensive TA 4 - experimental	extensive TA 5 - experimental	extensive MAC 6 - experimental
particle size	<0,05mm	% m/m dm	UNI EN 15428:2008	1	0	1	1	1	0	0	1
	<0,15mm	% m/m dm	UNI EN 15428:2008	2	2	3	2	3	2	1	2
	<0,25mm	% m/m dm	UNI EN 15428:2008	4	4	4	4	4	3	3	4
	<0,50mm	% m/m dm	UNI EN 15428:2008	10	10	9	8	7	8	9	8
	<1mm	% m/m dm	UNI EN 15428:2008	17	16	13	13	9	14	15	12
	<2mm	% m/m dm	UNI EN 15428:2008	25	24	18	19	13	20	23	19
	<5mm	% m/m dm	UNI EN 15428:2008	76	74	37	52	40	79	76	74
	<10mm	% m/m dm	UNI EN 15428:2008	100	100	100	84	94	100	100	100
	<16mm	% m/m dm	UNI EN 15428:2008	100	100	100	98	100	100	100	100
	<20mm	% m/m dm	UNI EN 15428:2008	100	100	100	100	100	100	100	100
watwer retention	infiltration rate	mm/min	DIN 18035-4:1991-07								
	dry bulk density	kg/m^3	UNI EN 13041:2007	364	371	630	365	502	390	399	396
	particle density	kg/m^3	UNI EN 13041:2007	2,324	2,332	2,412	2,374	2,251	2,421	2,410	2,314
	porosity	% v/v	UNI EN 13041:2007	84.35	84.07	73.9	84.63	77.69	83.91	83.47	82.87
	water retention pF1	% v/v	UNI EN 13041:2007	40.92	42.2	45.32	44.99	43.32	39.11	40.8	42.18
	air capacity pF1	% v/v	UNI EN 13041:2007	43.42	41.87	25.58	39.64	34.37	44.8	42.67	40.69
	water retention pF1,7	% v/v	UNI EN 13041:2007	31.4	32.11						
	air capacity pF1,7	% v/v	UNI EN 13041:2007								
	water retention pF2	% v/v	UNI EN 13041:2007			32.98	34.69	33.08			
	air capacity pF2	% v/v	UNI EN 13041:2007	52.95	51.96	40.92	49.94	44.61			
	water retention pF2,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	air capacity pF2,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	water retention pF3,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	air capacity pF3,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	water retention pF4,2	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	air capacity pF4,2	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
chemical properties	organic matter	% s.s.	UNI EN 13039:2012	19.75	19.25	13.88	16.35	24.96	13.34	14.02	20.47
	cation exchange capacity	meq/100g dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met XIII.2								
	compacted bulk density	g/l	UNI EN 13040:2008	565	583	793	599	697	556	570	520
	pH	pH unit	UNI EN 13037:2012	9.5	9.3	9.4	9.7	9.7	9.1	8.9	8.3
	electrical conductivity	mS/m	UNI EN 13038:2012	39	35	31	27	25	26	25	29
	Ammonium Nitrogen (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	Nitrate Nitrogen (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	mineral Nitrogen (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	Phosphorous (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	Calcium (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	Magnesium (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	Potassium (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	Sodium (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	cation exchange capacity (sum)	meq/100 g dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met XIII.4 + XIII.3								
	Calcium carbonate ($CaCO_3$)	ppm dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met V.1								
	total organic Carbon	% dm	DM 21/12/00 Suppl. n. 6 GU 21 26/01/2001								

properties/parameters		unit	method	extensive MAC 7 - experimental	commerical standard extensive G I - experimental	commercial estensive + poplar biochar 10% - experimental	commerical standard extensive G II - experimental	commerical standard extensive G II + wood pellet biochar 10% - experimental	commerical standard extensive G II + wood pellet biochar 20% - experimental	commerical standard extensive G II + wood pellet biochar 30% - experimental	extensive TA - A - experimental
particle size	<0,05mm	% m/m dm	UNI EN 15428:2008	1	2	1	3	3	3	2	1
	<0,15mm	% m/m dm	UNI EN 15428:2008	2	12	3	10	12	11	10	3
	<0,25mm	% m/m dm	UNI EN 15428:2008	3	16	5	15	17	17	14	4
	<0,50mm	% m/m dm	UNI EN 15428:2008	7	21	7	23	26	25	21	9
	<1mm	% m/m dm	UNI EN 15428:2008	11	27	10	29	33	32	26	14
	<2mm	% m/m dm	UNI EN 15428:2008	18	36	18	36	42	40	33	20
	<5mm	% m/m dm	UNI EN 15428:2008	58	69	59	65	70	68	61	74
	<10mm	% m/m dm	UNI EN 15428:2008	90	100	100	100	100	100	99	100
	<16mm	% m/m dm	UNI EN 15428:2008	100	100	100	100	100	100	100	100
	<20mm	% m/m dm	UNI EN 15428:2008	100	100	100	100	100	100	100	100
watwer retention	infiltration rate	mm/min	DIN 18035-4:1991-07		11.43	10.6	12.1	8.19	14.48	12.69	134.27
	dry bulk density	kg/m^3	UNI EN 13041:2007	356	847	813	846	825	812	798	420
	particle density	kg/m^3	UNI EN 13041:2007	2,396	2,567	2,548	2,555	2,513	2,394	2,369	2,451
	porosity	% v/v	UNI EN 13041:2007	85.16	66.98	68.1	68.88	67.18	66.1	66.3	82.84
	water retention pF1	% v/v	UNI EN 13041:2007	39.88	48.12	42.25	50.99	52.21	55.43	58.14	46.54
	air capacity pF1	% v/v	UNI EN 13041:2007	45.28	18.86	25.85	15.89	14.96	10.66	8.16	36.3
	water retention pF1,7	% v/v	UNI EN 13041:2007		37.72	31.37					36.73
	air capacity pF1,7	% v/v	UNI EN 13041:2007		34.26	36.73					46.11
	water retention pF2	% v/v	UNI EN 13041:2007		26.9	27.05	27.05	29.28	30.83	32.95	35
	air capacity pF2	% v/v	UNI EN 13041:2007		40.08	41.05	39.83	37.9	35.26	33.35	47.84
	water retention pF2,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	air capacity pF2,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	water retention pF3,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5		25.57	26.11	26.87	26.03	27.31	27.38	
	air capacity pF3,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5		41.41	41.99	40.01	41.15	38.79	38.92	
	water retention pF4,2	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5		13.17	16.16				13.86	
	air capacity pF4,2	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5		53.81	51.94				52.44	
chemical properties	organic matter	% s.s.	UNI EN 13039:2012	14.93	4.55	5.67	5.22	7.67	15.08	16.7	11.46
	cation exchange capacity	meq/100g dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met XIII.2		8.4	10.6	6.6	6.8	3.8	2.6	59.5
	compacted bulk density	g/l	UNI EN 13040:2008	475	811	761	832	818	775	726	538
	pH	pH unit	UNI EN 13037:2012	7.9	7.6	8.5	7.9	8	8.3	8.7	7.1
	electrical conductivity	mS/m	UNI EN 13038:2012	24	4	8	3	7	8	10	42
	Ammonium Nitrogen (water soluble)	mg/l (water extract)	UNI EN 13652:2001		3.81	7.84	4.23	1.37	2.58	2.52	8.93
	Nitrate Nitrogen (water soluble)	mg/l (water extract)	UNI EN 13652:2001		<1,13	<1,13	1.35	<1,13	<1,13	<1,13	34.55
	mineral Nitrogen (water soluble)	mg/l (water extract)	UNI EN 13652:2001		3.81	7.84	5.58	1.37	2.58	2.52	43.48
	Phosphorous (water soluble)	mg/l (water extract)	UNI EN 13652:2001		2.05	0.34	8.82	3.33	5.66	1.83	15.22
	Calcium (water soluble)	mg/l (water extract)	UNI EN 13652:2001		1.06	2.39	7.5	7.1	10	5.6	21.5
	Magnesium (water soluble)	mg/l (water extract)	UNI EN 13652:2001		0.6	1.8	2.3	1.6	2.1	1.1	5
	Potassium (water soluble)	mg/l (water extract)	UNI EN 13652:2001		3.4	9.1	10.3	8.4	12.5	15	52
	Sodium (water soluble)	mg/l (water extract)	UNI EN 13652:2001		3.8	6.4	5.8	6.3	8	7.1	6.5
	cation exchange capacity (sum)	meq/100 g dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met XIII.4 + XIII.3				11.5	12.8	13	16.4	
	Calcium carbonate ($CaCO_3$)	ppm dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met V.1								
	total organic Carbon	% dm	DM 21/12/00 Suppl. n. 6 GU 21 26/01/2001								

properties/parameters		unit	method	extensive TA - B - experimental	Malta 1 10/14 - experimental	Malta 2 10/14 - experimental	MAC 6 10/14 - experimental	MAC 7 10/14 - experimental	expanded crush clay G - component	fine coir G - component	crush coir G - component
particle size	<0,05mm	% m/m dm	UNI EN 15428:2008	0	0	0	0	0			
	<0,15mm	% m/m dm	UNI EN 15428:2008	2	5	3	2	3			
	<0,25mm	% m/m dm	UNI EN 15428:2008	4	10	7	3	6			
	<0,50mm	% m/m dm	UNI EN 15428:2008	9	14	15	7	14			
	<1mm	% m/m dm	UNI EN 15428:2008	13	17	22	10	19			
	<2mm	% m/m dm	UNI EN 15428:2008	19	21	30	15	25			
	<5mm	% m/m dm	UNI EN 15428:2008	76	47	59	87	70			
	<10mm	% m/m dm	UNI EN 15428:2008	100	99	100	100	90			
	<16mm	% m/m dm	UNI EN 15428:2008	100	100	100	100	99			
	<20mm	% m/m dm	UNI EN 15428:2008	100	100	100	100	100			
watwer retention	infiltration rate	mm/min	DIN 18035-4:1991-07	44.7	43.18	21.1	28.18	33.39			
	dry bulk density	kg/m^3	UNI EN 13041:2007	408	684	589	462	417	349		
	particle density	kg/m^3	UNI EN 13041:2007	2,433	2,502	2,182	2,336	2,158	2,574		
	porosity	% v/v	UNI EN 13041:2007	83.24	72.68	72.99	80.23	80.68	86.43		
	water retention pF1	% v/v	UNI EN 13041:2007	41.15	46.74	58.76	35.82	52	34.77		
	air capacity pF1	% v/v	UNI EN 13041:2007	42.08	25.93	14.23	44.41	28.68	51.67		
	water retention pF1,7	% v/v	UNI EN 13041:2007	33.26							
	air capacity pF1,7	% v/v	UNI EN 13041:2007	49.98							
	water retention pF2	% v/v	UNI EN 13041:2007	31.22					24.98		
	air capacity pF2	% v/v	UNI EN 13041:2007	52.02					61.45		
	water retention pF2,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5		13.31	17.54	13.55	14.65			
	air capacity pF2,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5		59.37	55.45	66.68	66.03			
	water retention pF3,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	air capacity pF3,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	water retention pF4,2	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5		9.52	14.03	12.69	14			
	air capacity pF4,2	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5		63.16	58.96	67.54	66.68			
chemical properties	organic matter	% s.s.	UNI EN 13039:2012	12.54	8.35	30.28	18.95	32.11			
	cation exchange capacity	meq/100g dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met XIII.2	65.3	31.9	22.5	32	66.5			
	compacted bulk density	g/l	UNI EN 13040:2008	526	786	734	587	557	528	374	229
	pH	pH unit	UNI EN 13037:2012	7.4	7.4	9.3	8.5	7.8	7	7.4	7.7
	electrical conductivity	mS/m	UNI EN 13038:2012	41	15	22	19	16	12	20	7
	Ammonium Nitrogen (water soluble)	mg/l (water extract)	UNI EN 13652:2001	11.31	6.55	5.04	5.38	3.7			
	Nitrate Nitrogen (water soluble)	mg/l (water extract)	UNI EN 13652:2001	31.16	3.16	1.81	2.03	1.58			
	mineral Nitrogen (water soluble)	mg/l (water extract)	UNI EN 13652:2001	42.47	9.71	6.85	7.41	5.28			
	Phosphorous (water soluble)	mg/l (water extract)	UNI EN 13652:2001	15.73	10.39	7.79	5.97	8.31			
	Calcium (water soluble)	mg/l (water extract)	UNI EN 13652:2001	19.5	7.3	6.8	6.8	4			
	Magnesium (water soluble)	mg/l (water extract)	UNI EN 13652:2001	5	2	1.7	2.4	1.1			
	Potassium (water soluble)	mg/l (water extract)	UNI EN 13652:2001	60	25	47.5	32	33			
	Sodium (water soluble)	mg/l (water extract)	UNI EN 13652:2001	6	10.5	12.3	6.4	4.7			
	cation exchange capacity (sum)	meq/100 g dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met XIII.4 + XIII.3								
	Calcium carbonate ($CaCO_3$)	ppm dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met V.1								
	total organic Carbon	% dm	DM 21/12/00 Suppl. n. 6 GU 21 26/01/2001	7.1							

properties/parameters		unit	method	compost - Wasteserv Malta - component	sand - sabbia di coraline limestone - component	Globigerina - Biocalcarnite - component	coraline limestone 1/2 - 3/4 pollici - component	4-10 mm concrete low grade - calcestruzzo - component	4-10 mm concrete high grade - calcestruzzo - component	10-20 mm concrete low grade - calcestruzzo - component	10-20 mm concrete high grade - calcestruzzo - component
particle size	<0,05mm	% m/m dm	UNI EN 15428:2008								
	<0,15mm	% m/m dm	UNI EN 15428:2008								
	<0,25mm	% m/m dm	UNI EN 15428:2008								
	<0,50mm	% m/m dm	UNI EN 15428:2008								
	<1mm	% m/m dm	UNI EN 15428:2008								
	<2mm	% m/m dm	UNI EN 15428:2008								
	<5mm	% m/m dm	UNI EN 15428:2008								
	<10mm	% m/m dm	UNI EN 15428:2008								
	<16mm	% m/m dm	UNI EN 15428:2008								
	<20mm	% m/m dm	UNI EN 15428:2008								
watwer retention	infiltration rate	mm/min	DIN 18035-4:1991-07								
	dry bulk density	kg/m^3	UNI EN 13041:2007		1623	1166	1462	1109	1148	1,152	
	particle density	kg/m^3	UNI EN 13041:2007		2,639	2,644	2,646	2,613	2,612	2,614	
	porosity	% v/v	UNI EN 13041:2007		38.49	55.89	44.75	57.57	56.05	55.92	
	water retention pF1	% v/v	UNI EN 13041:2007		38.2	20.61	5.67	13.21	13.59	11.67	
	air capacity pF1	% v/v	UNI EN 13041:2007		0.29	35.29	39.08	44.37	42.47	44.25	
	water retention pF1,7	% v/v	UNI EN 13041:2007		20.19	19.1	4.6	12.54	12.74	11.19	
	air capacity pF1,7	% v/v	UNI EN 13041:2007		18.3	36.79	40.15	45.03	43.31	44.73	
	water retention pF2	% v/v	UNI EN 13041:2007		17.02	18.49	4.14	12.24	12.38	11.01	
	air capacity pF2	% v/v	UNI EN 13041:2007		21.47	37.41	40.61	45.34	43.67	44.91	
	water retention pF2,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	air capacity pF2,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	water retention pF3,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	air capacity pF3,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	water retention pF4,2	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	air capacity pF4,2	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
chemical properties	organic matter	% s.s.	UNI EN 13039:2012								
	cation exchange capacity	meq/100g dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met XIII.2								
	compacted bulk density	g/l	UNI EN 13040:2008	559	426	1119	1213	1057	1003	1,052	1,023
	pH	pH unit	UNI EN 13037:2012	8.2	9.9	9.8	10	12.2	12.2	11.8	11.6
	electrical conductivity	mS/m	UNI EN 13038:2012	273	6	10	5	326	364	248	192
	Ammonium Nitrogen (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	Nitrate Nitrogen (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	mineral Nitrogen (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	Phosphorous (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	Calcium (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	Magnesium (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	Potassium (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	Sodium (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	cation exchange capacity (sum)	meq/100 g dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met XIII.4 + XIII.3								
	Calcium carbonate ($CaCO_3$)	ppm dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met V.1		826	892	743	793	620	826	818
	total organic Carbon	% dm	DM 21/12/00 Suppl. n. 6 GU 21 26/01/2001								

properties/parameters		unit	method	coraline limestone 20 mm - component	coraline limestone 3/8 pollici - component						
particle size	<0,05mm	% m/m dm	UNI EN 15428:2008								
	<0,15mm	% m/m dm	UNI EN 15428:2008								
	<0,25mm	% m/m dm	UNI EN 15428:2008								
	<0,50mm	% m/m dm	UNI EN 15428:2008								
	<1mm	% m/m dm	UNI EN 15428:2008								
	<2mm	% m/m dm	UNI EN 15428:2008								
	<5mm	% m/m dm	UNI EN 15428:2008								
	<10mm	% m/m dm	UNI EN 15428:2008								
	<16mm	% m/m dm	UNI EN 15428:2008								
	<20mm	% m/m dm	UNI EN 15428:2008								
watwer retention	infiltration rate	mm/min	DIN 18035-4:1991-07								
	dry bulk density	kg/m^3	UNI EN 13041:2007	1334	1264						
	particle density	kg/m^3	UNI EN 13041:2007	2,648	2,647						
	porosity	% v/v	UNI EN 13041:2007	49.61	52.24						
	water retention pF1	% v/v	UNI EN 13041:2007	8.22	9.41						
	air capacity pF1	% v/v	UNI EN 13041:2007	41.39	42.82						
	water retention pF1,7	% v/v	UNI EN 13041:2007	7.15	7.98						
	air capacity pF1,7	% v/v	UNI EN 13041:2007	42.46	44.26						
	water retention pF2	% v/v	UNI EN 13041:2007	6.66	7.32						
	air capacity pF2	% v/v	UNI EN 13041:2007	42.95	44.92						
	water retention pF2,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	air capacity pF2,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	water retention pF3,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	air capacity pF3,5	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	water retention pF4,2	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
	air capacity pF4,2	% v/v	DM 1/08/97 SO n. 173 GU 204 2/09/1997 Met.5								
chemical properties	organic matter	% s.s.	UNI EN 13039:2012								
	cation exchange capacity	meq/100g dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met XIII.2								
	compacted bulk density	g/l	UNI EN 13040:2008	1135	1122						
	pH	pH unit	UNI EN 13037:2012	9.8	9.7						
	electrical conductivity	mS/m	UNI EN 13038:2012	5	5						
	Ammonium Nitrogen (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	Nitrate Nitrogen (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	mineral Nitrogen (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	Phosphorous (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	Calcium (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	Magnesium (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	Potassium (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	Sodium (water soluble)	mg/l (water extract)	UNI EN 13652:2001								
	cation exchange capacity (sum)	meq/100 g dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met XIII.4 + XIII.3								
	Calcium carbonate ($CaCO_3$)	ppm dm	DM 13/09/1999 SO n. 185 GU 248 21/10/1999 Met V.1	950	1074						
	total organic Carbon	% dm	DM 21/12/00 Suppl. n. 6 GU 21 26/01/2001								