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Use of organic by-products as growing media in soilless cultivation

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Abstract

Nowadays, the most used constituent for growing media in soilless cultivation is still peat. However, limitations related to their extraction cost, availability on the market from one year to the next and a possible environmental impact, pushed the research to focusing on possible alternative materials. By-products from production/transformation processes could represent a source of materials for growing media, with the general advantage of a circular economy. Different by-products: coir, compost, grape marc, hemp residues and wood fibers were considered. First part of research was focused on the evaluation of main physical, chemical and biological properties of coir, green compost, hemp residues and grape marc. Then materials were tested in a series of comparative cultivation trial (i.e. basil transplant cultivation). Coir showed interesting results, some properties (i.e. water retention and capillary rise), proved to be good in particular with high percentages of coir pith (70% or more). Coir properly supported plants growth, providing same or better results when compared to peat. Some limitation were found for hemp residues (scarce hydraulic properties) and grape marc (high electric conductivity). The grape marc suitability as substrate increased washing marc to reducing salts concentration and mixing with materials with better physical characteristics (peat and coir). Research also evaluated the totally or partially peat replacement with wood fibers and different types of compost. Wood fibers and compost in peat-based substrates modified the physical properties of the growing media such as water retention and capillary rise, suggesting the need of an increase of irrigation frequency when using alternative substrate for ornamental production irrigated with ebb and flow system. According to the presented results, also fertilization and water management are pivotal for successful soilless cultivation.

1 INTRODUCTION

1.1 Soilless culture and growing media in agriculture

Unlike what we usually think, plants soilless cultivation is not a practice born in modern times, but also experienced in different ways in the past. As shown in several paintings (Naville, 1913) already in the Ancient Egypt, 4000 years ago, cultivation of plants in containers was used to transfer trees from their native places to be grown in the royal palaces. In 79 A.D. Plinio il Vecchio describes the technical cultivation of some rose variety, to obtain flowering out of season in green house built using mica (Puccini, 1971).In the seventeenth century, plants were moved around especially from Far and Middle East to Europe, and grown in orangeries "*a dedicated room or building on the grounds of fashionable residences from the 17th to the 19th centuries where orange and other fruit trees were protected during the winter, similar to a greenhouse or conservatory*" (Markham, 1631). In the orangeries, plants were cultivated with the purpose to collect rare fruit and vegetable or specimens with a high aesthetic value. Orangery was the first example of farming system based on container where as substrate was used soil (Raviv and Lieth, 2008). Nursery production increase their importance in agricultural production, only after the Second World Was, thanks to the level of specialization and the increase of agriculture investment. The first description about growing media considered it as a mix of soil (in particular mixtures of sandy, clay and organic matter) with other material such as peat and sawdust (Matkin and Chandler, 1957). During 60's and 70's years a great impulse to soilless cultivation (with industrial purposes) was given by the studies on plant nutrition, .Around 1970, studies on rooting media lead to improving the knowledge about plant nutrition, and management of water and oxygen, highlighted how they could increase yields through the soilless cultivation (Cooper, 1975; Verwer, 1976)., and a further step was represented by the study about disease control and plants protection, combining the new discoveries with container production.. Then, the study on the use of growing media continued, focusing more and more on the use of other materials than soil, such as peat (the main substrate component) and progressively also other type of materials, also developing cultivation systems based on water without employing any substrate (Hydroponics). The modern definition of growing media is "material other than soil in situ used for plants growth" (European Committee of Standardization, 1999). Today, the largest industries of soilless production are closely connected to the greenhouse production of ornamental and vegetables, outdoor container nursery production and urban horticulture, where all containerized plants are grown without any field soil. Soilless cultivation permits to have a better control on pathogens and diseases and a more sustainable management of water and nutrients. At the same time, the root volume is restricted inside the container and requires a different management compared to plants grown on open fields (Dunik et al., 1990; Bar-Tal, 1999).

Our society is characterized by an increasing demographic growth and improved standards of life for both developed and developing countries. This scenario increases the demand for food, including out-of-season produce and the global consumption will continue to rise for the foreseeable future (Godfray et al., 2010). The results of this trends will be an additional increment of the use of protected crops and green house production (Raviv and Leth, 2008), totally ground on the use of growing media. Therefore, the knowledge about substrates and their ability to support the growth of healthy plants with high commercial value is very important. Since a close relationship substrate/plant implies that the quality of a substrate is evaluated on the base of different species cultivated, irrigation system and type of container, so that a type of substrate can be for one purpose but not for another (AIPSA, 2013).

1.2 Substrate/plant relationship in soilless cultivation system

The main function of growing media is providing simultaneously sufficient levels of oxygen and water to the plants (Raviv et al., 2004), which continuously absorb water, transport through the growing medium into the roots and plant xylem towards the plant leaves where transpired to the atmosphere. The continuous uptake of water is essential for the growth and survival of the plants, because they lose quite a large amount of water throughout the day, and mainly during the period of high evaporative demand. Uptake of water occurs along gradients of decreasing potential from the growing medium to the roots; flows along the potential gradient from the rhizosphere, where high (slightly negative) total water potential exists, through the plant vascular system to the leaves and to the atmosphere where the water potential is lower (higher negative) (Raviv et al., 2004). The total water potential (Ψ_t) is divided into different component:

$$\Psi_t^{\text{medium}} = \Psi_g + \Psi_o + \Psi_m$$

Ψ_g represent gravitational potential gradient, negligible for most substrate (Raviv et al., 2004). Ψ_o is the osmotic potential proportional to the dissolved particles and solute concentration. Ψ_m is the matric potential and combine the adhesion force between medium solid surface and cohesion force among water molecules. A water stress in plants occurs when water loss by the canopy is greater that water uptake by roots. Its effect depends to the duration, period and adaptation mechanism. Water stress affects the photosynthesis and the plant growth, reducing plant turgidity, expansive growth and sugar storage, and in the horticultural context, usually this represent an undesirable yield loss. In soilless production, roots are confined into a specific well-defined root zone. The effect of a restricted root volume is a high sensitivity to water stress and nutritional deficiencies, especially in substrate with scarce water buffer capacity (fraction of water retained by substrate, difficult to absorb, but which the plant can be use in case of water stress). This implies that great importance have the characteristic of media, such as the effective pore space (the volumetric amount of water that saturates a give volume of substrate) and the easily available water for plants. Regarding the oxygen availability, a well-aerated media is important to the performance of horticultural crop (Paul and Lee, 1976; Veen, 1989; Soffer et al., 1991): an oxygen deficiency has an immediate effect on root formation (Gislerod, 1983), growth (Soffer and Burger, 1988), metabolic activity and water/nutrient uptake (Morard et al., 2000; Sojka and Stolzy, 1980; Sojka and Stolzy, 1988). The microorganism activity and the root growth increases the root transpiration and then oxygen demand, but at same time the higher demand of water (especially cause to the higher temperature in the greenhouse compared to the open fields, which increase water loss due to evapotranspiration makes harder the air availability into the medium. Air volume is defined as the volume of medium at container capacity (medium saturated with water after free drainage) occupied by the air; there is not an optimal value of air porosity, but it may depend on the considered crop (i.e. Bunt, 1988; Paul and Lee, 1976) and the used irrigation system. In Table 1. are reported some indicative values of air and water volume for several different container crop systems, express as percentage of volume at pF (water retention at tension of 1 kPa; Frangi, 2009).

Table 1. Indicative physical characteristic of ideal growing media in different soilless ornamental cultivation (Frangi, 2009)

Cultivation system	Air volume pF 1 (%V/V)	Water volume pF 1 (%V/V)	Easily Available Water (%V/V)
Sowing (tray container)	15-20	70-80	30-40
Cuttings rooting	30-60	40-60	20-30
Shor cycle cultivation	15-20	70-80	30-40
Overhead irrig. System	15-30	70-80	20-40
Subsurface irrig. System	20-50	55-80	25-35
Small pot (<1l)	30-40	55-70	20-35
Medium-big pot (>1l)	30-40	50-65	25-45

pF 1 express the percentage of volume of water retained (and consequently air volume) at pressure at 1kPa (is available to the plants).

1.3 Physical and chemical characteristics of growing media

Substrate is a porous media composed by one or more different type of material, that contribute to influence the bulk density, defined as the dry mass per unit of volume. Each component is characterized by particles with different shape, and size. Usually, components that significantly show high variability in particle size contribute to create a high Bulk density in the mix (Pokorny et al., 1986). Bulk density influences the choice of media on the base of different type of cultivation (i.e. tree outdoor production requires substrate with high bulk density to prevent container instability in windy condition), handling and transportation (transportation of media with low BD are easier and cheaper than those with high bulk density media).

Particle distribution determines substrate texture, while the attitude of particle to aggregates into larger unit is called structure. Both of these properties determines the total porosity of the media and the distribution of macro- and micro-pores. Unlike for soil, the particle aggregation attitude is less, and porosity is more influenced by shape and size of the particles (Crippa, 2008). Macro- and micro-pores influence the ability of a media to retain air (macro-pores) and water (micro-pore). A practical way to have an idea of the attitude of media to retain water and air is the *Coarseness Index* (percentage of particles > 1mm): an increase of CI leads to a decrease of water holding capacity, easily available water and water conductivity (Crippa, 2008). Macro- and micro-pores represent the total porosity, (difference between volume of medium and volume of solid matter) expressed as volume percentage. In the growing media macro-pores have a diameter of 300 µm and are fundamental for O_2 and CO_2 exchange, pore with diameter between 300 and 60 µm retain easily available water, while at 30-60 µm are retain reservoir water and, pore with a diameter of 0.2-0.2 µm retain not available water for plants (Verdonck and Gabrels, 1992; Michiela et al., 1993).

The water retention or water holding capacity is a function of total pore space, but also of suction force that retain water (generally expressed in cm of water pressure or KPa) (Blok et al., 2008), that represent the force that plants roots must exercise to absorb water from the medium. For substrate generally are consider the water retained in the rage between 0 and 10 kPa, useful because represents the main parameter for the management of soilless culture (AIPSA, 2013), as summarized in the Table 2.

Table 2. Water retention characteristic point (AIPSA, 2013).

Tension applied	Parameter (%V/V)	Definition
pF 1	Water retention at 1kPa	water holding capacity
pF 1	Air volume at 1kPa	Air capacity (Air volume content)
pF 1.7	Water retention at 5kPa	Reservoir water and not usable water
pF 2	Water retention) at 10kPa	Not usable water
pF 1-1.7	Water retention) between 1-5kPa	Easily Available Water
pF 1.7 – 2	Water retention between 5-10kPa	Buffer capacity
pF 1-2	Water retention between 1-10kPa	Total available water

Water retention is expressed as percentage V/V it is inversely proportional to the air content and is possible to calculate it by difference between total porosity and water retention. More suction is applied, the drier the material gets and the higher the air content will be (Klute, 1986). The result are indicative of the ease or the uptake of water and nutrition by plants as well as the wetness in various growing system (Blok et al., 2008).

The relationship water/substrate are also influenced by capillarity that affects the flux of water in the substrate inside the pot. After an irrigation event, substrate contains the maximum amount of water that can hold and at the bottom of the pot, there is a completely saturated area equal to capillary rise (AIPSA, 2013). In the coarse substrates, saturation zone is quite thin (poor capillary properties), while in the fine substrate, the saturation zone can reach levels of considerable thickness.

About mainly chemical properties (pH and EC), pH indicates the substrate acidity or basicity degree, measured by the concentration of hydrogen ions (H^+) present in the water solution spread in the substrate. The concentration is expressed in logarithmic form, between a range of value of 0 and 14. The pH values in the substrates are influenced by the nature of the material (i.e. acids in the peats, basic for compost) and can change depending on the used fertilizers or corrective adding. pH influences the availability of nutrients, such as manganese, copper, zinc and boron; according to Handreck and Black (2005) the availability of iron falls down to a pH above 6.5. At the same time, at pH values below 5, iron and manganese solubility may increase up to reach toxic values. The initial pH value can be modified during the cultivation according to the characteristics of the irrigation water, elements solubilization and roots absorption.

Electric conductivity gives an estimation of the salts concentration in water solution that directly affects osmotic potential (Ψ_o) that affects the availability of water to plants.

The effect of an excessive salts concentration increase the osmotic potential causing a reduction of water absorption and a consequently physiological withering, which may result in a lower plant growth of the plant and reduction of yield.

Different materials have different characteristics that influence the final characteristic of substrate (mix or made by one component). Subsequently the main components that are nowadays used in the substrates production are described: peat, and some organic alternative materials, to introduce finally the purpose of this work.

1.4 Peat

Peat is formed by the slow decomposition of mosses, such as sphagnum moss, and sedges in wet acid ecosystems where such biomass accumulates because the condition of low pH and low oxygen content are not conducive to microbial activity. Peat has a minimum organic matter content equal to 30% (Bunt., 1988; Joosten and Clarke, 2002) and climate plays a key role because it affects wealth and type of species present in the peat bogs, as well as speed of decomposition of plant residuals (Cattivello., 1990). In a water saturated environments such as bogs, carbon cycle is not closed with the same speed that characterize other ecosystems and the lack of oxygen produce the inhibition (or slowdown) of organic matter degradation and mineralization, with a positive carbon balance which results an increase and accumulation of partially decomposed organic matter until the formation of peat (Kadlec and Knight, 1996).

On the base of different ecosystem that characterize peat bog and type of process that organic substance undergoes, is possible to distinguish:

- Wetland Area that are frequently flooding or saturated by water which favor the formation of a vegetation fit to live in condition of water saturation
- Peatland: Areas with a layer of peat accumulated over the time. Vegetation may be present od the top of peat accumulation
- Mire: Areas in which peat is in continuous formation

Peatland covers almost 4 million of km^2 (Lappalainen, 1996), and occurs over a wide range of climates but major proportion are in the higher middle latitude (50-60° N). in Canada (1 139 26 Km^2) , Russia (1 310 206 Km^2) and Finland (79 429 Km^2) and Sweden (65 623 Km^2).(source: CSPMA) Establishing if the peat formation process is in progress is not easy, however on the basis of classification is clear that wetland is a “container” inside which there are peatlands, which contains mire (Joonsten and Clarke, 2002).

There is not one classification for peat, the International Peat Society has proposed a classification system based on its botanical composition, decomposition degree and nutrient status (Kivinen, 1980) as summarized in Table 3.

Table 3. peat classification system based on botanical composition, degree of decomposition and nutrient status (Kivinen, 1980)

Botanical composition	1. Moss peat (sphagnum and other mosses) 2. Sedge peat (sedges, grasses, herbs) 3. wood peat (trees residues and woody shrubs)
Degree of decomposition	1. weakly decomposition (H1 - H3) 2. medium decomposition (H4 - H6) 3. strongly decomposition (H7 - H10)
Trophic status	1. oligotrophic (low nutrient) 2. mesotrophic 3. eutrophic (high in nutrient)

Peat is used for several purpose such as energy, industry and horticulture; becoming the major component of growing media throughout Europe and North America because is ready availability and gained a reputation from growing media producers and growers alike for its combination of unique properties useful for plant cultivation (Schmilewski, 2014). The properties of peat depend on the nature of the plants remains and their degree of decomposition. Usually peat has low bulk density (light material), high total porosity, and provides good aeration and adequate reservoir of water, proving also to have relatively physically stable when used as growing media (Maher et al., 2008). About chemical properties pH is low, make it easy to attain the desired levels through the addition of lime and fertilizer. In the Table 4 are summarized different type of peat and they influence on main substrate characteristics (AIPSA, 2013).

Table 4. Influence of different type of peat on the substrate characteristic (AIPSA, 2013)

type	Air volume	Water ret.	shrinkage	stability	weight	Buffer cap.
Sphagnum peat	= / +	+	= / +	= / +	=	+
reed-sedge peat	+	-/=	-	-/=	+	-
white peat	+	+	-	-	-	-
Transitional peat	= / +	=	+	+	=	=
black peat	-	-	-/=	=	+	+
milled peat	=	+	=	=	=	=
sod peat	+	-/=	+	+	= / +	=
frozen black peat	-	-/=	-	=	+	+
coarse peat	+	-	+	+	=	-
medium peat	=	=	= / +	= / +	= / +	=
fine peat	-	+	-/=/+	= / +	+	+

Increases + unchanged = decreases -

Peat was the main substrate component in the last forty years, however since the late 1970s there has been a worldwide search for new peat substitutes (Raviv et al., 1986; Robertson, 1993; Abad et al., 2001). Some important factors related to peat production, move researcher and substrate producers to focus on alternative materials. One reason is the high price of high quality horticultural peat (Abad et al., 2001), it was highlighted an increase of energy cost fir the all stages of production and transportation in northern Europe producers and in different companies of the continent (Marzialetti et al., 2005). Also, irregular years in terms of weather hinder collection, storage and handling of peat are causing unpredictable shortage of this material (Sannazzaro, 2008). Another question concerns the possible environmental impact connected to the use of peat that reflects in numerous documents. From an environmental standpoint, peat is considered a slow-renewable resource playing a role in atmospheric CO_2 sequestration (Joosten 2009; Billet et al., 2011), peat bogs also play a major role in the quality of ground-water in some part of the world (Syrovetnik et al., 2007), and peat bogs serve as a special habitat for many endemic species of plants and animals, these natural communities are rapidly changing due to anthropogenic intervention (Rakowska and Sitkowska., 2010). As result peat extraction is restricted in some countries, and it is anticipated that this trend will strengthen in the future (Carlile, 2008). Some specific action are in place to reduce or replace the use of peat in horticulture, the German Federal State of Lower Saxony have the ambition to end peat extraction in Lower Saxony is based (Niedersächsisches Ministerium für Umwelt, Energy und Klimaschutz, 2013); in 2011 the UK Government issued the “White Paper” (HM Government, 2011) in which the phase-out of peat in the hobby market by 2020 and in commercial horticulture by 2030 is envisaged; in Switzerland, where peat extraction has not been allowed since 1987, peat-based growing media are still in use for plant production, however, the Swiss government is considering a full phasing-out of peat based media (Anon, 2012). In Austria, growing media can be awarded a national ecolabel if the requirements given in the governmental document for peat free growing media are fulfilled (BMLFUW, 2011). In accordance with the quality criteria laid down by the EU Commission, growing media may not be awarded the EU ecolabel if they contain peat (EU Commission, 2006).

1.5 Use of by-products as alternative growing media components

A source of alternative materials to use as growing media could be represented by organic by-products, secondary product derived from manufacturing process. By product generally can be described as the output from a joint production that not realize value compared to the main products, and if not marketable are considered waste.

Recycling is a process that convert waste material into reusable material to prevent waste of potential useful materials, reduce the consumption of fresh raw materials and reduce energy and pollution connected to the "conventional" management of waste. Possible advantage derived to use by-products for container plants cultivation could be represented by a consequently value-added for materials considered waste and again became useful (Hauke et al., 1996; Burés, 1997), and a possible reduction of price of production and transport. Recycle and reclaim solid wastes, organic residues generated by agriculture, farming, forestry, industries and city center have been already successful used as container media for plant production (Verdonck, 1988; Abad et al., 1997; Ingelmo et al., 1998; Papafotious 2004; Zhang, 2012). Mainly possible alternative material to make growing media are represented by:

- Coir
- Compost
- Wood fiber

1.5.1 Coir

Coir is the name of fibrous material that comes from the processing of coconut fruit (*Cocos nucifera* L.) (Abad et al., 2002). The husk of the coconut contains approximately 75 per cent fiber and 25 per cent fine material called 'coir pith' (Mhaer et al., 2008). From the coconut processing are obtained longer fibers, used for the production of mats and ropes; while finer fraction, composed by different degrees of shorter fibers, pith and finer fraction similar to dust (dust pith) represent base material for substrate mix (Cattivello, 2009). The coconut palm is widespread in tropical humid area, characterized by an average annual temperature of 29 °C and moderate temperature change. The fruit is a drupe whose seed is rich of fat used for get cocoa butter involved in cosmetic and food industries. Important producers are India, the Philippines, Mexico and Ivory Coast (Evans et al., 1996), the main producer is Sri Lanka.

Short fibers and fine particles have always been considered a waste (Meerow 1997), the alternative to landfilling and the use for pots plants cultivation was already known since the late 40s (Hume, 1949). Initially the employing for the soilless production was located in the production area (Reynolds, 1974; Chweya et al., 1978), and the diffusion as possible peat alternative has occurred around the 90s (Handreck, 1993; Meerow, 1994; Noguera et al., 1997; Stamps and Evans 1997; Offord et al., 1998).

Processing of coconut residue consist of maceration and mesocarp grinding to separate logger fiber (for industrial processing) to the waste: coir fiber and coir pith, and store and stabilization for a period not less than six months or alternatively compost it for that a period to get a stable physical product. When sodium, chloride and potassium levels are high, these elements have be leached with water containing a cation, usually calcium nitrate (containing exchangeable cation). The area of production and the way to process (i.e. use of salt or fresh water for washing) can determine difference of physical characteristics (i.e. particle size distribution) and chemical properties (i.e. pH, electric conductivity and Na level) between materials produced (Evans et al., 1996). Coir used as substrate, generally showed a high water retention a good air volume and physical stability (Least, 1999), with wide variation in values of air filled porosity and easily available water (Maher, 2008). In particular, Coir fiber shows a low bulk density and high porosity, almost entirely, fill by air, coir pith is characterized by higher bulk density and high porosity filled by water in the fraction more fine (Cattivello, 2009). The easily available water and reserve water increase at decreasing of particle size, with the highest value in the fraction finely grind (0-6 mm). About chemical properties is found a great variation in pH and electric conductivity. In Table 5. are shown some value range found using water extract method (different ration coir and water).

Table 5. Different level of pH and EC in coir (Meher et al., 2008)

pH	EC (mScm^{-1})	Reference
4.9-6.4	0.17-2.32	Noguera et al. (2003)
5.6-6.9	0.13-1.26	Evans et al. (1996)
4.8-6.8	0.32-0.97	Meerow (1994)
5.5-5.7	0.80-1.90	Handreck (1993)
5.0-5.7	0.12-1.51	Prasad (1997)
4.9-6.6	0.32-0.41	Smith (1995)
6.0-6.7	0.2-0.4	Kipp (2000)

Value of Noguera et al. (2003), Evans et al. (1996), Meerow (1994) are made with saturated media extract, Smith (1995) om 1:5 water extract, Handreck (1993), Prasad (1997) and Kipp (2000) on 1:1.5 water extract

Regarding the application as growing media, good results were obtained with substrates where peat has been partly replaced by coir for ornamental plants cultivation (Meerow, 1994; Amoroso and Frangi, 2004; Lanzi 2005). In sweet pepper cultivation (Baixauili et al., 2011), a substrate 100% coir pith and mix of coir pith and coir chips showed same results as peat. It was also highlighted an improvement of water efficiency combining substrate coir based and reduction irrigation frequency (Baixauli et al., 2011) which could result in a reduction of water consumption during cultivation (Morgani et al., 2005). The use of coir fiber compared to peat seems to promote a fast seed germination and an higher uniformity of seedlings (Cresswell, 1992) and interesting results have also been seen in specific applications and orchids germination in vitro (Aggarwal and Nirmala, 2012). Also regarding the effect of coir on plants, various researches have recorded a better rooting ability using substrate containing coir fiber or coir pith in ornamental species (Meerow, 1994), that in vegetable species (Possanzini, 2005), caused for some authors (Suzuki et al., 1998) by the presence of substances having a rhizogenic effect (i.e. hydroxybenzoic acid); that could have favorable implications in rooting of the plants after transplantation.

1.5.2 Compost

Compost is the common name to indicate organic matter that has been decomposed by a long, thermophilic, aerobic decomposition and recycled as fertilizer, soil amendment and substrate component. Compost can be produced from a wide variety of organic matters and on the base of different material used is possible classify compost such as green compost or mixed compost:

- Green compost is made by green waste such as pruning residues, grass and leaves coming from garden and landscaping management and other type of green waste (i.e. bark)
- Mixed compost is made by different source of material such as animal manure, food processing wastes, household organic waste.

Composting process is a biological decomposition of organic material under control conditions into a stable humus-like product (Golueke, 1972). The process is aerobic and part of it is carried out to thermophilic condition. Thorough the composting are reduced phytotoxicity, pathogens and weed seeds stabilizing the material. Composting process is promoted by bacteria and fungi requiring oxygen and an adequate moisture level to proceed up to the maturation stage. Research about the use of compost as growing media starts in the early 70’s (e.g. Cappaert et al., 1974) to continue diffusely over the time (Burger et al, 1997; Atiyeh, 2000; Garcia-Gomez et al., 2001; Moore, 2005; Raviv 2005; Grigatti et al., 2007; Bachman and Metzger, 2007; Ali et al., 2007; Prasad and Carlie, 2009; Jayasinghe et al., 2009; Aviani et al., 2010; Raviv 2011). During these years, the research has allowed to improve the composting process, providing results, sometime different, about its properties as growing media and its application in soilless plants production. However, compost compared to peat and other material such coir is characterized to be a locally resource in practically in every habituated on the globe (Raviv, 2013). The application in horticultural production have in many case the advantages of a nutritional contribution (Raviv, 2005; Barker and Bryson, 2006; Bardhan et al., 2008), with a slow-release fertilizer effect which could offset a temporal or local nutrional deficits (Grigatti et al., 2007). Another advantage is represented by the suppressive capacity of compost against a variety of soil-borne diseases (Hoitink et al., 1977; Termorshuizen et al., 2006; Noble, 2011), partially thanks to the microbial community that develops in the composted mass (Hadar and Mandelbaum, 1986; Scheuerell and Mahafee 2005). However, because of the wide difference of primary raw materials, compost suffers of a lack of uniformity (Agnew and Leonard 2003; Lopez et al., 2010) and occasionally an excessive salt content and high pH was underlined (Mazuela et al., 2005) and sometime inferior physical properties compared to peat or coir (Lopez et al., 2010; Medina et al, 2010). Compost maturity is an important characteristic in relation to its use as growing medium component (Maher, 2008) if not the mature compos appears to be toxic (Aviani et al., 2010; Buono et al., 2011). Table 6. are shown some physical and chemical properties of compost. (Centemero, 2009). Compared to peat compost generally showed higher pH and electric conductivity, less water retention and higher bulk density.

Table 6. Physical and chemical compost properties compared to peat (Centemero, 2009)

Property	**Sphagnum peat**	**Ideal substrate**	**Green compost**	**Mixed compost**
Bulk density (gcm^{-1})	0.6 – 0.1	0.15 – 0.50	0.35	0.4
Total porosity (% V/V	>96	>85	80 – 85	80 – 85
Air volume (%V/V)	5 – 50	20 – 30	25 – 30	25 – 30
Water retention (% V/V)	24 – 40	24 – 40	12 – 15	14 – 16
pH	2.5 – 3.5	4.5 – 6	7.5 – 8.0	7.8 – 8.3
EC (dSm^{-1})	0.2 – 0.4	< 1	1	2.5
CSC cmol L^{-1}	14.8	10 - 100	23.7	17.4

1.5.3 Wood fiber

Wood fiber is a renewable resource product from fresh or waste-wood (e.g. pellets) usually using spuce (*Picea* spp.) that represent 90-95% of some commercial products (Gumy, 2001) or pine trees. Wood fiber for horticulture contain a little percentage of bark, that represent a separate category also involved in greenhouse production (wood for production of fibers are generally debarked). The production of stabilized wood fiber are made with an initial grinding at temperature between 110 and 160 °C (Cattivello, 2009). Than in some case, materials are colored and treated with nitrogenous compound. About is characteristics as growing media wood fiber has high level of total porosity and in most cases a very high level of air-filled porosity and a rather level of easily available water (Maher et al., 2008). Wood fiber shown similar bulk density and total pore space of peat substrates, but lower water retention and higher drainage ability (Gruda and Schnitzler, 2003). About its application no significant different were found using a substrate composed by wood fiber compared to a substrate of withe peat for tomato transplant production (Gruda and Schnitzler, 2001; Gruda and Schitzler, 2003). Use of in ornamental productions, suggest the possibility to use wood fiber as partial peat substitutes peat (Frangi and Sordo, 2003; Amoroso and Frangi, 2004); showed growth results comparable to those obtained using peat. However was also highlighted that the the low percentage of reserve water and limited water retention requiring an irrigation frequency increased compared to peat (Roeber and Leinfelder, 1997). About its chemical characteristics has been highlighted a nitrogen immobilization (Prasad, 1997; Gruda et al., 2000) induced to the microbial activity cause a high C/N ratio. N-immobilization can be a cause of nutritional imbalance of plants grown in organic substrate containing wood fiber. Therefore, fertilization management must be consider this aspect during the cultivation, or is possible use fiber impregnated with slow release nitrogen source. The use of wood fiber treated with nitrogen seems performed better or without difference compared to peat.

1.6 Production of substrates in Europe

Substrate production include professional and hobby market. In the professional market substrate, represent a production factor within a system that involves nurserymen, technician, horticulturalist and gardeners. The professional market is represented mainly by pots ornamental plants, flowers and vegetables production and later by other sectors such as the production of fruit plants or plants for landscape. The second market is relative to customers that use substrates for recreational purposes related to plants care at home (i.e. private garden, urban farming). According to the mainly study about growing media industry in Europe (Schmilewski, 2009) the average of growing media product by 13 European country was estimate around 34,632.300 m^3,overall percentage of 77.4% was covered by peat. (Figure 1.)

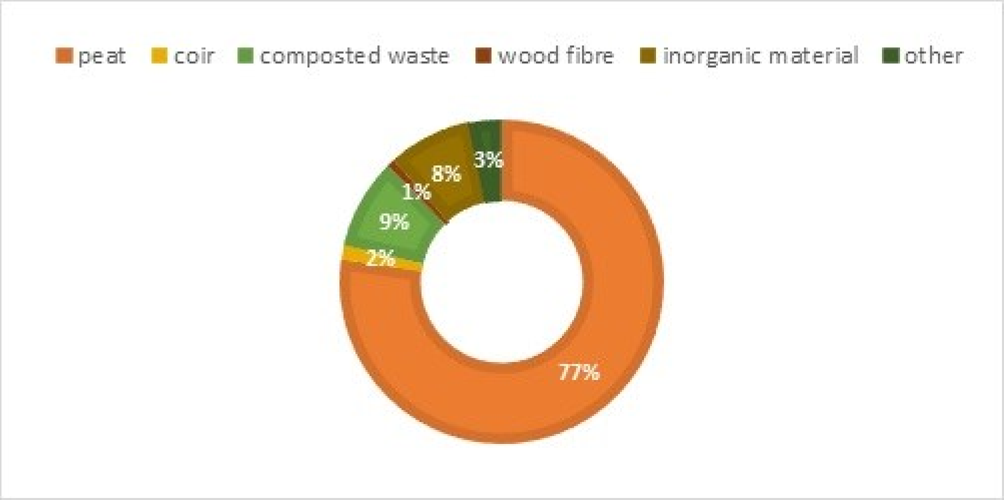

Figure 1. Percentage of different material used for the production of growing media in the major producer country in the EU. Percentage are referred to an estimate production of 34,632,300 m^3 of growing media in 13 EU contry. For composted material are considered composted biodegradable waste and also composted bark and composted woodwaste. Inorganic material group mineral and shyntetic material. (elaboration of the basis of Schmilewski, 2009).

Traditional peat extracting countries as Denmark, Finland, Germany, Ireland, Sweeden and UK have a strong focus on peat use in growing media production, but also large part of peat is exportend to countries lacking of indigenous peat resources like Netherlands, Italy and Belgium. Germany is the country with the largest use of peat, folloved by Italy, Netherlands, and United Kindom (Table 7.).

Table 7. Amout of peat (m^3 in 000's acc.) used in the major producer countries in EU . (Schmilewski, 2009)

Country	Bog (*Sphagnum*) peat				Fen peat	
	H1-H5		H6-H10		H1-H10	
	Pro.	Hob.	Pro.	Hob.	Pro.	Hob.
Austria	30	70	2	18	0	0
Belgium	400	200	350	450	0	0
Denmark	300	330	0	0	0	0
Finland	600	150	20	120	0	0
France	510	620	0	0	68	206
Germany	1740	1150	2700	2880	0	0
Ireland	56	0	222	694	0	0
Italy	1911	819	1053	117	0	0
Netherlands	1545	295	795	205	0	0
Poland	500	300	300	400	300	300
Spain	350	146	0	0	0	0
Sweden	210	600	55	150	15	0
UK	695	383	463	893	0	120

Pro. = professiona market; Hob.= hobby market

About alternative materials, was highlighted that composted bark and wood fiber are importan constituent in France, Spain and UK, used traditionally and with the objective to reduce the peat import, more expensive than indigenous material. Coir, wich represents a small percentage of the alternative peat material (2%) are widely used in Netherland and Italy. The amout of composted material represent the 9% of the total considered materials (the highest percentage among the varius alternative material) used expecially by France, Germany, United Kindom, Italy and Spain, but almost only for the production of substrate for hobby market (Table 8.).

Table 8. Amout of alternative organic material (m^3 in 000's acc.) used in the major producer countries in EU (Schmilewski, 2009)

Country	Bark		Coir		Wood-fibers		Wood		Composted	
	Pro.	Hob.	Pro.	Hob.	Pro.	Hob.	Pro.	Hob.	Pro.	Hob.
Austria	0	0	1	0	5	20	0	0	18	72
Belgium	5	15	15	5	0	0	0	0	35	50
Denmark	4	0	5	0	0	0	0	0	0	10
Finland	0	15	0.5	0	0	0	0	4	0	51
France	187	277	11	11	332	113	0	0	261	750
Germany	5	5	20	5	55	35	10	5	120	175
Ireland	0	0	0.2	6	0	0	0	0	1	85
Italy	10	40	150	0	0	0	0	0	20	247
Netherlands	140	40	190	35	15	0	0	2	48	50
Poland	50	50	0	0	0	0	0	0	0	0
Spain	0	0	0	0	0	0	0	0	50	500
Sweden	0	0	0	0	0	0	0	0	10	45
UK	0	0	17	7	20	4	0	0	136	417

(Pro. = professiona market; Hob.= hobby market). Composted are referred to sum of composted bark, composted biodegradable waste, composted woodwaste and other composted matherials.

Peat-free substrates represent a low percentage (6.1%) of substrate produced (Schmilewski, 2009), mainly used in hobby marked than in professional marked (Figure 2).

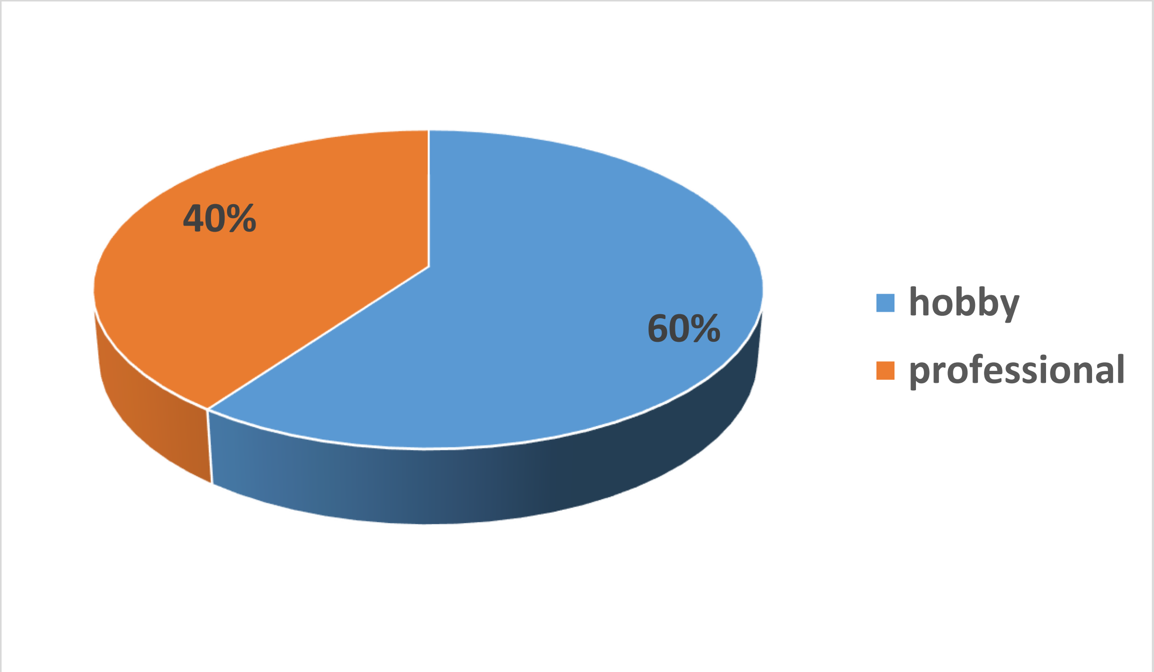

Figure 2. Percentage of peat-free growing media produced in the major EU coutries divided by market sector. Data are reffered to organic and inorganic substrate (elaboration of the basis of Schmilewski, 2009).

1.7 Research goals

The present research was developped within a scenario where peat represents the main material for the growing media production, but as shown some weakness point related to not constant supply, increase of production and transport cost and a possible environment impact. In this contest there are already available possible alternative materials, resulting from organic waste processing (compost) and the re-use of by-products (coconut and wood fibers). This materials are still underused, especially in the professional markets.

Starting from this point, the objectives of this research are:

- Characterize the main physical, chemical and biological properties of some possible alternative materials represented by-products generated by agricultural and urban activity., comparing between them results and hypothesizing limits and applicability in the nursery production.
- Use of agricultural and urban by-products as possible growing media in partial or total peat replacement. This part particularly focused on the possibility to use coir, material that showed intresting results in scientific literature, but still not widely used. The research was conducted through cultivation tests (in particular transplant vegetable cultivation), comparing the growths obtained on different alternatve substrates.
- Assessing the possibility to increase the use of compost and wood fibers in ornamental pot plants cultivation, evaluating the results of growth and the results obtained in the laboratory with particular focus to the physical characteristics of the used alternative substrates.

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2 PHYSICAL, CHEMICAL AND BIOLOGICAL PROPERTIES OF SOME ALTERNATIVE GROWING MEDIA

2.1 Introduction

The production of pot plants is characterized by the use of growing media, materials other than soil, usually composed by different constituents. Peat is the main constituent, gaining a good reputation among growing media producers and growers for the combination of unique properties useful for plant cultivation (Schmilewiski, 2014). Nevertheless, the high price of good quality horticultural peat, especially in countries without peat moss resources, and the questionable availability of peat in the near future due to environmental constraints (Abad et al., 2000) are driving the research to investigate new alternative media. Recycled and reclaimed solid by-products and various organic residues generated by agriculture, industries and city could become a new material source for substrate production with the advantage of low prices. Some basic physical, chemical and biological characteristics provide important information to validate organic by-products as suitable for horticulture production, if these are in compliance with growing media requirements. Important properties, relate to physical characteristics for a growing media are the ability to simultaneously provide roots with sufficient levels of oxygen and water (Raviv, et al., 2004). Physical properties affect the irrigation control in terms of time and quantity of water application (Raviv et al., 2004). According to the water condition and different plants characteristics, a different ability to retain water can lead to a different irrigation management and a different ability to adsorb water by capillarity may make suitable or not a substrate to a specific irrigation system (i.e. sub-irrigation). At the same time, having a substrate with a higher rate of aeration is important parameter in ensuring successful production, especially in case with lower evapotranspiration level and higher rate of water availability (Nemati et al, 2013). An oxygen deficiency affect the root formation (Gislerod, 1983); growth (Soffer and Burger, 1988) and water uptake (Morad et al., 2000). About the chemical properties are usally considered suitable for container plants growth pH values between 5.5 and 6.5, and low salts content to avoid effects on water uptake.. Positive or negative effects of the substrate may be due to physical and chemical properties but also to the biological characteristics related to the presence of microbial activity and the absence of toxic compounds (Zaccheo, 2008) The aim of this research was to compare some possible alternative organic materials derived from agriculture and city by-products, using a series of rapid tests and to evaluate their possible suitability as growing media or media components.

2.2 Materials and methods

Four different by-products originated by agriculture and urban activity (Table 1.) were collected, described and used for a series of laboratory test characterization. All Materials, possible media component candidate, represent an organic vegetable by-products, derived from different production process, more or less complex based on their industrial development and primary destination of the main product.

Table 1. Analyzed by products and their different sources

Source	Main product	By-product
Coconuts palm fruit	Vegetable fat and coconut milk	Mesocarp fibrous residues
Cultivated Hemp	Oil, flour and fiber	Trunk and leaves residues
Grape	Wine	Stalk, seed and skin residues
Urban gardens and parks	service	Green waste like pruning, leaves and grass

Materials were initially collected, fractionated, according to their different characteristics and described. Than a series of analysis were performed to have a general description of main physical, chemical and biological properties assuming their use as growing media. The analysis were made in the ecophysiology laboratory of Marche Polytechnic University of Ancona and the origin of the materials was also indicated: “local” from Marche Region (Italy) or specifying the geographical area of production.

2.2.1 Materials description

Residues of fruit (drupe) of Coconut palm (*Cocos nucifera* L.), used in the present work are represented by the fibrous material called coir that constitutes fruit mesocarp. The husk of coconut contain a part of fiber (coir fiber) and a part of fine material called coir pith.

Long fibers are usually used for the production of ropes and mats, whereas short fibers and fine fractions are suitable for horticulture use. Sri Lanka and India represent the main producers of coconuts, but coconut palms are present in other eleven countries, at least. For many tropical and subtropical populations coconuts represent part of the daily diet, but is commonly known for fat production used in human food and cosmetic production.

In this work, an industrially manufactured material from Mozambico and India was used. Such material was washed in a solution containing calcium nitrate (exchangeable cations) to reduce the level of sodium, chloride and potassium, and then it was dried and compacted in blocks of 5 kg. For the characterization was considered coir fiber fraction with particle size > 5mm and coir pith fraction with particle size < 5mm. Three different combinations (Figure 1.) of fiber and pith (mixed by volume) were analyzed:

- Coir fine (Cp) represented by a 100% of coir pith
- Coir medium (Cm) represented by a combination of 30% of coir fiber and 70% of coir pith
- Coir gross (Cg) represented by 60% of coir fiber and 40% of coir pith

Before the analyses start different compacted blocks were remanufactured submerging in tap water (pH: 7.0, EC: 0.58 $mScm^{-1}$) for 24 hours and then dried again.

Figure 1. Different coir mixes used for characterization: 100% coir pith (A), 30% coir fiber + 70% coir pith (B) and 60% coir fiber + 40% coir pith (C)

Hemp, is the common name of the industrial variety of cannabis (*Cannabis sativa* L.) a multipurpose crop delivering fibers, seeds and oil. The origin of this species is the Himalayas and was introduced in Europe in the second millennium B.C. Hemp seeds, have a high nutritional value and oil is highly appreciated for the organoleptic acid profile. Both seeds and oil (extract from seeds) are used for human food and animal feed. Hemp is also famous for the production of fibers, used in the production of ropes and clothes and commonly recycled as house wall insulation. When hemp is cultivated only for seeds and oil production, by-products are represented by all the portions of the plant that are not harvested (i.e. stem and leaves). Hemp residues used in this work, were collected from a local farmer and consisted by dry stalks and raw coarse fiber covering the stalks. The material was originally collected in a 15 kg bale, which was divided, into two fractions (Figure 2.):

- Fine fraction (Hf) was obtained chopping an half of the bale with a 6 mm mesh size mill. The result was a composition of a tiny hemp shiv from stalks and a material similar to dust from fiber.

- Gross fraction (Hg) was obtained reducing the size the other half of the bale using a machine for wood grinding. After an accurate grinding, the coarse fraction was composed by a mix of stalk shiv with different size and medium and long fiber.

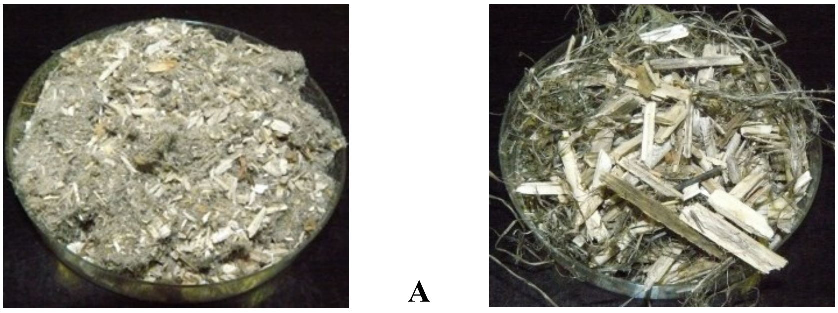

Figure 2. Different hemp fraction used for the characterization. Fine fraction (A) chopped with a 6 mm mesh size mill. Gross fraction (B) with particle size > 6mm

Solid residues of grape (*Vitis vinifera* L.) after pressing for wine production are called grape marc or pomace. Grapevine production is spread in more than 40 countries all over the world but half of the cultivated area in Europe. The material used in the present work was collected from a local farmer and was composed by grape skin, residue of pulp, seed and stalk. These residues are rich of polyphenols, tannic and sugar compounds and are usually used in the production red wines to increase the color or in the brandy production and and also in biogas factory. However, when marc are not used for other purpose, represent a by-products to be disposed of. Because the high humidity (81%) of fresh material, the mix of skin, seed and stalk was initially dried in the oven at 105 °C for 48 hours to reduce humidity and increase the conservation. Afterwards, dried marc was grinded with a 6 mm sieve size mill to obtain a mass with more uniform particles. Compared to the other two previously described materials, only one single of material (Gm) was obtained for marc presenting a final appearance of a dry granular dark mass (Figure 3.).

Figure 3. Grape marc fraction used for the characterization. Raw material was dried and grind with 6 mm sieve size mill

Green compost is the result of a bio-oxidation and humification process of organic green waste such as leaves, tree pruning material, grass and plants residues. Modern composting is a multi-step monitored process with measured inputs of water, air, carbon and nitrogen under controlled temperature conditions. Usually decomposition process is helped by shredding the starting organic matter, adding water and ensuring proper aeration by regularly turning the mass. Aerobic bacteria and fungi are the principal organisms responsible for the composting process. Based on a biological transformation, compost production shows an initial mesophilic phase, in which decomposition is carried out under moderate temperature, than decomposition temperature increases and bacteria work under high temperatures, finally during the maturation phase, temperature decreases again. Green compost used for characterization in the present work was produced by a HERA Company of Ozzano (Emilia Romagna) using a collection of grass clipping and pruning materials from public and private garden management. Raw green wastes were grinded to increase the degradable surface by micro-organism. The composting process has taken place at a controlled temperature included between 55 and 73 °C, constant humidity included between 45 and 55% and oxygen level higher than 6% for a period of about 24 weeks. In the final stage composted material was sieved with a 6-to-8 mm sieve. Green compost (Gc) used in the present work was a dark-brown mature material with 6 mm particles size (Figure 4.).

Figure 4. Green compost used for the characterization. Composted material was sieved with 6 mm sieve

2.2.2 Materials characterization

Materials were collected and stored in a well-ventilated room to obtain a relative humidity around 10%. The bulk density (BD) was measured according to the method for biomass, UNI EN 15103:2010. A cylinder 4 l volume (V) with ratio height/diameter of 1.5, was filled with the tested materials without compression. The full cylinder was weighted (W) and the bulk density (ρ) calculated as follow:

$$\rho = W/V \qquad (1)$$

bulk density was expressed as Kg m^{-3} using an average value of four measurements.

The main hydraulic characteristics of the tested materials were also evaluated: water retention and capillary rise (Cattivello et al., 2009). Samples for such characterizations were added with water in order to obtaining 55% humidity of the materials.
The water holding capacity (WHC) was determined by pouring water of a fixed volume of each material (Figure 5.) and measuring the water drained (amount of water not retained). A volume of 0.3 l of different media were used to fill plastic pots (top diameter of 10 cm) and placed above 1000 ml Becker to collect the leachate. 50 ml of water was poured on samples and the volume of drained water was measured after 30 minute of drainage (considering drainage concluded), The operation was repeated three times, pouring a total amount of water of 200 ml. The percentage of water retained was calculated using the amount of poured and drained according to the following formula:

$$WHC=(100-((D_W/T_W)\times 100)) \qquad (2)$$

D_W: Total amount of water drained after 4 times
T_W: Total amount of water (200 ml) poured

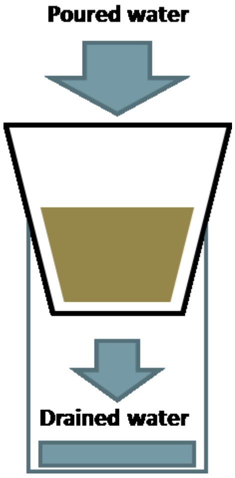

Figure 5. Measurement mode of water holding capacity. Determined pouring water of a certain volume of material and measuring the water drained.

Water retained by capillarity rise (WHCc) was estimated according to the increase of weight of each tested material subjected to wetting from below. For the measure, 0.35 l of each media (humidity of 55%) was used to fill plastic pots (height 11 cm, top diameter 13 cm, bottom diameter

9 cm) without using pressure. The filled pots were weighted and placed in a box with a layer of 2.5 cm of water. Eight pots were placed together in the box to obtain a uniform increase of water level and permit the water capillary rise through the material. After 30 minutes pots were removed from the box and placed to drain. At the end of drainage phase, pots were weighted again and capillary rise was expressed as percentage of weight increase, according to the following formula:

$$WHCc= ((F_w - P_w)/(I_w - P_w))x100 \qquad (3)$$

F_w: Final weight of the substrate and pot after wetting and drainage
P_w: Pots weight
I_w: Initial weight of substrate and pot before wetting.

After the measurement of water holding capacity, samples were dried in the oven at 105 °C for 48 hours, weighted and used to determinate the particle size classes. (distribution of fraction of a material with particles with a diameter larger than a given lower limit and smaller than a given upper limit), Different samples were put on a set of sieves with decreasing mesh size (15 mm, 10 mm, 5 mm, 2 mm, 1 mm, 0.5 mm and 0.2 mm.), and sifted for 6 minutes. Then the particles collected from each sieve were weighted and the class fractions were expressed as percentage (w w^{-1}).

The last physical characterization was the air filled porosity (AFD) measured using the Wolverhampton method (Bragg and Chambers, 1888). This method, developed by ADAS (Agricultural Development and Advisory Service) at the Wolverhampton Centre U.K., is a volumetric method that involves an initial material wetting from below to obtain a completely saturation. The principle presumes that, in a completely saturated media, the porosity (macro- and micro- pores) is filled by water that after drainage is lost from the macro-porosity, and replaced with air, therefore the volume of drained water is equal to the air amount in the media. For the measurement, standard plastic pots (height 11 cm, top diameter 13 cm, bottom diameter 9 cm) whose internal volume has been determinate (1.1 l) were fitted with a plastic collar (Figure 6.). Pots were filled with the materials within 2 cm of the collar lip and placed in a container filled with water and gradually wet from below, ensuring that the water level was sufficiently high to cover all media (Figure 7.).

Figure 6. Pot and collar used to air filled porosity (AFD) measurement

Figure 7. For the measure of AFP Pots were filled with materials within 2 cm of the collar lip and placed in a container filled with water and gradually wetted from the bottom, ensuring that the water level was sufficiently high to cover all media

Water was added slowly to avoid floating effect. After initial wetting, the pots were removed from the container and allowed to drain for 10 minutes. A volume loss under natural drainage is normal, so the operations of wetting and drainage was repeated for 3 time to stabilize the material to a final volume. After the third cycle, the collar was removed and the excess of material sliced away, providing a precise media volume of 1.1 liters. The pots were placed again in the container and saturated from below, adjusting water level according to material surface. When media was completely wet, with water visible be seen on the surface (Figure 8.), the pots were slide off onto a rubber sealing pad and water level adjusted again. The rubber were pressed at the pot base providing a water tight seal, and then transferred on a Becker for a completely drainage (30 minutes).

Figure 8. Complete saturation has been obtained bringing water to the level of the substrate, checking that water was visible on the material surface.

Finally, the volume of drained water was measured, and AFD expressed in percentage of volume according to the following formula:

$$AFD = D_w \times 100 / V \quad (3)$$

D_w: Water drained after 30 minute in liters
V: substrate volume (1.1 l)

The main chemical characteristics, pH and electric conductivity (EC), were analyzed using an extract prepared by extraction of a suspension of 1 volume of material and 5 volume of water (water extract 1:5 V/V). The extract was prepared by filtering a suspension of 60 ml of material and 300 ml of demineralized water mixed for 1 hour. The final measurement was obtained as average of three replicates.

The same extract was used to perform a bioassay. It was carried out to check a possible inhibition effect on the plant growth using the germination and sprout growth (germination index) of cress (*Lepidium sativum* L.) seeds in contact with a water extract of different materials (Zucconi et al., 1982). Cress seeds were placed in petri dishes 9.5 cm of diameter (5 seeds per dish) on filtering paper wetted with the water extracts (1.5 ml) and incubated for 48 hours at 27 °C in the dark, to permit the germination. Ten replicates were arranged for each by-products and compared with demineralized water (control). After the incubation, the number of germinated seeds and root length were recorded to calculate the germination index (GI):

$$GI = ((G \times R)/(G_t \times R_t)) \times 100 \quad (4)$$

G: number of germinated seeds in different treatments
R: root length in cm of germinated seeds in different treatments
Gt: number of germinated seeds using demineralized water
Rt: number of root length in cm were recorded to calculate the germination

Moreover, a series of chemical analysis were performed to complete material characterization in the biomass lab of Marche Polytechnic University Using 1 g of different material, according to the method UNI EN 14775 were determinate the ash content. According to the method UNI EN 15290 were determinate the total content of C,H and N with Analyzer Perkins Elmer 2400. Finally the heavy metal content (As, Cd, Cr, Cu, Hg, Mn, Ni, Pb, Zn) was determinate using an emission spectrophotometer Perkin Elmer, according to UNI EN 15290.

2.3 Results and discussion

Particle (Figure 9.) was expressed as percentage of material weight in the different particle classes referred to the total weight of the sample. Results underlined differences between materials, connected to the shape and size of the particles. Materials containing 60% fiber (Cg) or coarse fraction of hemp stalk (Hg) showed a high percentage of particles >15 mm, composed of mesocarp long fiber or woody stalk chips. Conversely 100% coir pith (Cp), green compost (Gc) and grape marc (Gm) contained 0% of particles within a range of 15-10 mm. In particular, green compost and 100% coir pith showed the highest distribution of particles in a rage of 2 and 0.2 mm, whereas grape marc was characterized by the highest percentage of particles within 2 mm of diameter.

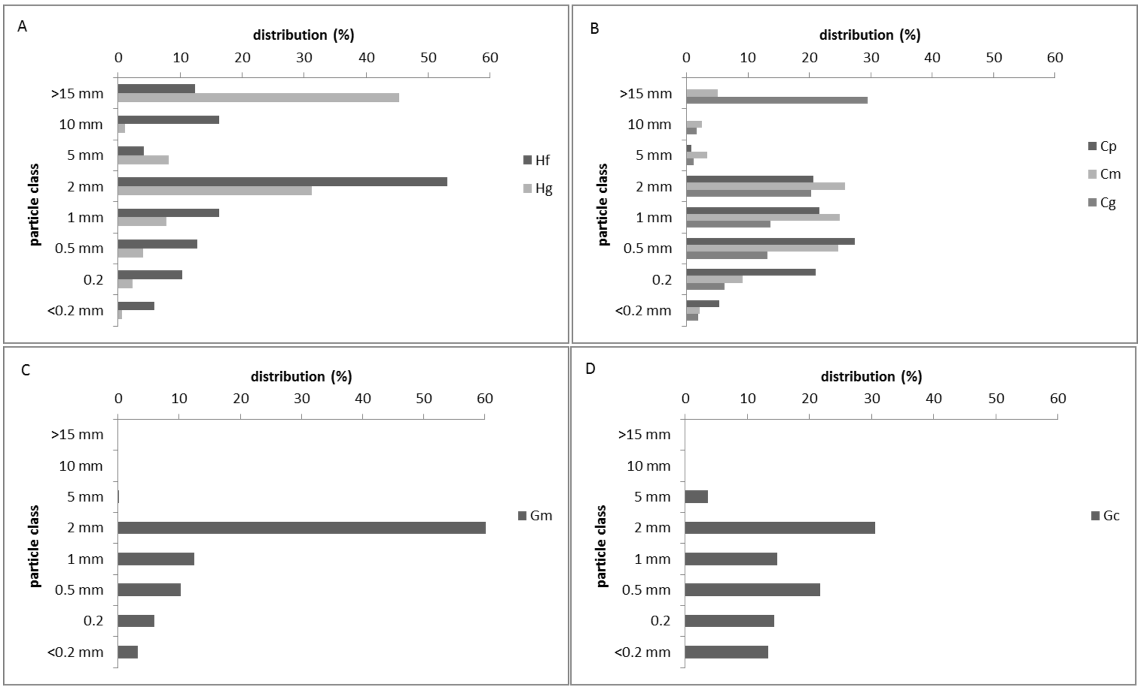

Figure 9. Particle size distribution of the tested materials expressed as percentage of weight class on total sample weight (ww^{-1}). A: Hg (hemp>6 mm), Hf (hemp = 6 mm); B: Cp (100% pith), Cm (70% pith + 30% fiber), Cg (40% pith + 60% fiber); C: Gm (grape marc); D: Gc (green compost).

A practical consideration about particle size distribution is connected to the possibility to mix different materials. Materials show a different particle shape, with a specific spatial distribution, so that a different influence on the porosity. When different particle sizes are mixed together may be less than the final volume of their sum, as the smaller particles are interposed to the bigger one.

Bulk density (Table 2.), was higher in green compost and grape marc compared to the other materials. In practical terms, bulk density is important for trade and handling: coir mix and hemp showed lowest value, especially in presence of high percentage of fibrous particles, which consequently resulted less dense and lighter. The lightness of the material used as substrate has some positive aspect, i.e. easiness of movements and manipulation, and lower cost of plants transport. However, a drawback is the less stability of pots especially with long-cycle cultivation and high size plants.

Table 2. Different Bulk Density (BD) of the tested materials, measured according to method UNI EN 15103:2010

Material	BD (Kg m^{-3})
Hemp gross	38
Hemp fine	136
Coir fine	132
Coir medium	123
Coir gross	48
Grape marc	472
Green compost	329

Concerning the hydraulic properties, the water drained (ml) after four irrigation events varied and consequently the water holding capacity, expressed as percentage of retained water, and changed (Table 3.). Fine coir (100% coir pith) showed the highest water holding capacity (91.9%), draining only 16.3 ml of the total amount of poured water (200 ml).Coir mixes retained water decreased with increasing percentage of coir fiber, with a value of 25.3% for coir gross (60% of fiber). Fiber particle seem to have a low ability to retain water, as suggested also by gross hemp that showed the lowest value of 14% of water retained. Even coarse materials, like Grape marc, did not show a good attitude to water retention (29.8%). As showed in Figure 10. method provides an evaluation on the base of water retention capacity. According to Cattivello et al. (2009), a water holding capacity equal or higher than 70% is excellent (as showed by coir pith), whereas values lower than 40% is considered insufficient (as showed by hemp gross, coir gross and grape marc).

Table 3. Average drained water and Water Holding Capacity (WHC) measured pouring 200 ml of water on a certain volume of material (0.3 l).

Material	Drained water (ml)	WHC (%)
Hemp fine	172.0	14.0
Hemp gross	91.0	54.5
Coir fine	16.3	91.9
Coir medium	87.5	56.3
Coir gross	149.5	25.3
Grape marc	140.5	29.8
Green compost	92.0	54.0

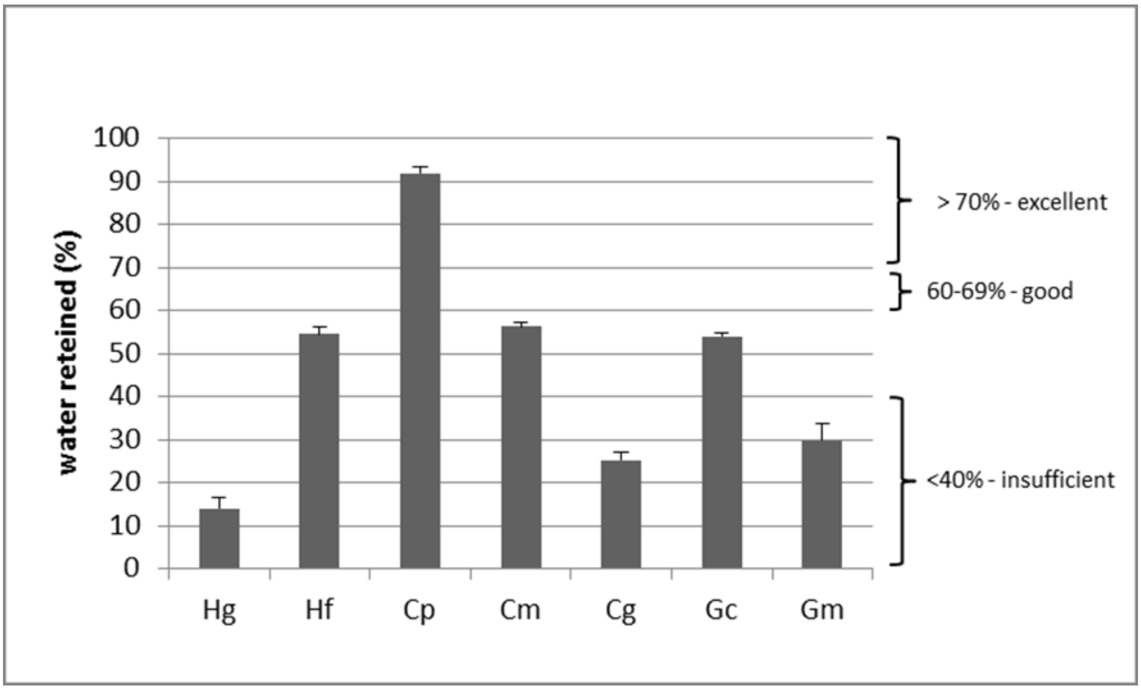

Figure 10. Water Holding Capacity (WHC) of tested materials, expressed as % of retained water. Hg (hemp > 6 mm), Hf (hemp = 6 mm), Cp (100%pith), Cm (70% pith + 30% fiber), Cg (40% pith + 60% fiber), Gc (green compost), Gm (grape marc). Bars indicate the standard error. For a peat-based substrate, WHC>70% is considered excellent, between 60-69 good, 50-59 discrete, 40-49 sufficient, <40% insufficient (Cattivello et al., 2009).

The second hydraulic property evaluated was the water retained by capillary rise that shows the ability of a material to take up water against gravity. The property is particular important for cultivation system based on subsurface irrigation method, and can decrease further when materials dry, increasing the uneven distribution of water. Capillary rise was evaluated as percentage increase of weight (Table 4). As found for water retention also for capillary rise, the highest increase of weight was showed by coir fine (100% coir pith), decreasing progressively by increasing the percentage of coir fiber. Also for hemp fraction capillary rise decreased in fibrous fraction and the lowest values were recorded for marc, which seemed to have poor capillary properties. Also for this parameter a classification (Cattivello, 2009) referred on peat substrate was used. Substrates which showed weight increase more than 350% are consider excellent, at contrary, increase below 200% indicates materials with insufficient capillary properties.

Table 4. Capillary rise. evaluated as percentage of substrate weight increase in weight of the substrate after having absorbing water for 30 minutes Classification are referred to peat-based substrate.

Capillary rise	Weight increase (%)	Material
Excellent	≥350	Coir fine, coir medium
Good	300-349	
Discrete	250-299	Hemp fine, compost
Sufficient	200-249	Hemp gross, coir gross
Insufficient	<200	Grape marc

Considering the Air Filled Porosity (Figure 11.) a different behavior was recorded. An increase of air porosity is generally connected to a reduction of water retention, as showed in fibrous or coarse materials. Hemp Gross (particle > 6mm) showed the highest AFD compared to the other materials. Even the mix containing 60% of coir fiber (coir gross) showed high AFD values when compared to the other coconut mixes, where the values of AFD decreased by increasing the percentage of coir pith. The coir fine (100% coir pith) had the lowest values. Green compost showed the lowest values of AFD, similar to 100% coir pith. Fine hemp chopped and grape marc showed similar AFD values, in a range included between 20%-30%.

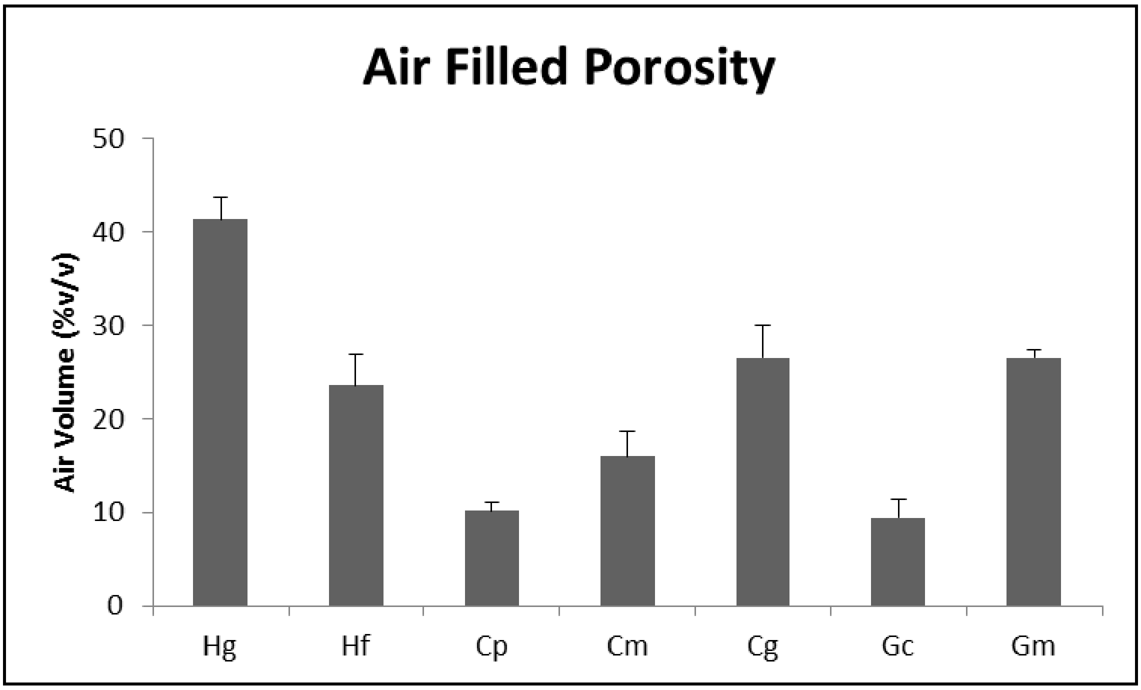

Figure 11. Air Filled Porosity (AFD) of tested material measured with Wolverhampton method (Bragg and Chambers, 1888) expressed as % of air volume. Hg (hemp > 6 mm), Hf (hemp = 6 mm), Cp (100% pith), Cm (70% pith + 30% fiber), Cg (40% pith + 60% fiber), Gc (green compost), Gm (grape marc). Bars indicate the standard error.

Focusing on the chemical properties (Table 5.), a range of pH between 5.5 and 6.5 can be considered suitable for a growing media. Only coconut by-products and grape marc showed a sub-acid pH around 6; pH of the hemp and green compost resulted neutral and basic, respectively. EC was low for all the tested materials, except for compost (1.52 mS cm^{-1}) and grape marc, which showed an extremely high value (3.43 $mScm^{-1}$).

Table 5. pH and electric conductivity (EC) of tested materials. Measured using a water extract ratio material water: 1:5 (V/V).

Material	pH	EC (mS cm^{-1})
Hemp fine	7.28	0.18
Hemp gross	7.69	0.06
Coir fine	6.30	0.52
Coir medium	6.21	0.77
Coir gross	6.41	0.26
Grape marc	6.56	3.43
Green compost	9.05	1.52

The potential inhibition of plant growth, evaluated through the bioassay, showed a low reduction of germination index (GI) in hemp (73%) and a high reduction in green compost (37%) and grape marc (47%), with a reduction to about 50% compared to demineralized water (control). Only coconut by-products did not show potential toxic properties (Figure 12). Grape marc showed extremely high EC and compost showed high values compared to the others. The reduction of GI, as well as a possible toxic effect, may be influenced by EC values.

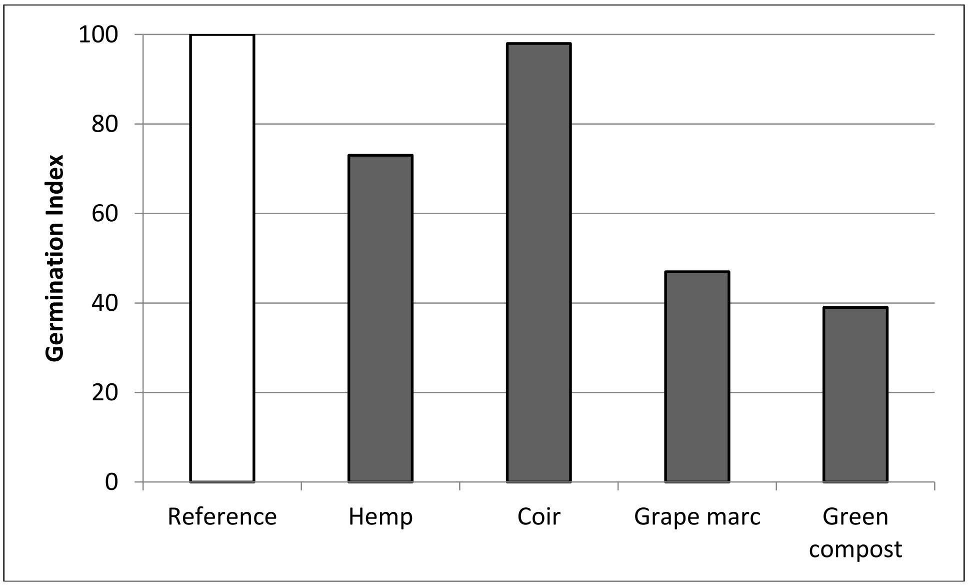

Figure 12. Bioassay results expressed as germination index (IG) of cress after 48 hours of contact in a water extract (1:5 V/V) of the different tested materials.

The results of the bioassay tests provide an idea of a possible negative effect for plants produced by a growing media. It may be due to contaminants or organic or inorganic compounds or to the high soluble salts concentration. The interpretation of results, however, should consider that for the bioassay was used a species with high sensitivity to compounds, and that the sensitivity to a toxic component could be a temporary condition, in which plants can, in some case, adapt. In Table 6. are shown the values of ash content, the percentage of total Carbon, Hydrogen and Nitrogen and heavy metals content expressed as mg/Kg divided by materials typology.

Table 6. Ash content; total C,H and N content and heavy metal content measured for different material category according to UNI EN 15290.

Parameter	unit	Hemp	Coir	Grape marc	Green compost
Ash	%	7,5	9,6	9,9	41,9
C	%	47,4	48,3	53,3	34,1
H	%	4,7	4,4	6,0	3,2
N	%	0,5	0,5	2,1	2,3
As	mg/Kg	< 1,0	< 0,1	< 1,0	< 1,0
Cd	mg/Kg	< 0,5	0,3	< 0,5	1,1
Cr	mg/Kg	21,6	2,8	< 1,0	37,1
Cu	mg/Kg	6,6	10,3	44,8	73,1
Hg	mg/Kg	0,1	< 0,1	< 0,1	< 0,1
Mn	mg/Kg	48,7	92,0	19,7	338,2
Ni	mg/Kg	12,7	2,5	< 1,0	22,9
Pb	mg/Kg	5,1	1,0	1,0	34,9
Zn	mg/Kg	47	4	12	191

Ash content was very high for green compost compared to the other materials, while looking at percentage of carbon and nitrogen together. Considering % of C and N for hemp and coir. for both C/N ratio is high (hemp: 94.8, coir: 96.6) compared to grape marc and green compost (25.3 and 14.8, respectively), suggesting a possible greater resistance to microbial degradation but also a special attention in the nitrogen management during fertilizzation in order to avoid phenomena of N depletion from microrganisms. Compost showed an high presence of heavy metals, while for grape marc was recorded a higher Cu level compared to the other analyzed metals. This is probably due to the vineyard management using copper-based fungicides.

2.4 Conclusions

Four organic by-products from agricultural and urban activity were tested in order to verify their possible suitability as materials for growing media production. The materials showed different physical characteristics related to their particle size, which influence the ability to retain water and provide air.

Coarse, fibrous materials seem to create a drawback caused by their insufficient water retention ability and poor capillary property. Low hydraulic property may limit their application forcing to increase irrigation frequency with overhead system or reduce the use in cultivation system based on subsurface irrigation system, needing to be mixed with fine materials. At the same time they could ensure an easy drainage when involved in mix.

A good physical properties were showed by fine coir fraction (100% coir pith), as highlighted by the highest retained water. Also green compost, a balanced mix of coir pith (70%) and coir fiber (30%) and fine hemp residues, showed to be materials with a discrete ability of water retention. These materials seem to have no physical limitations suggesting a possible use like pure material or main component in the mix to increase capillary properties.

According to chemical characteristics, only coconut wastes showed to have pH within an optimum range. For the other materials, pH correction, mixing with a percentage of acid peat is probably necessary. For grape marc, a serious drawback for the use as substrate constituents is represented by the high EC values. The same materials also showed a possible inhibition of plants growth, thus requiring pre-treatments, like reduction of salts concentration with several washings, and mixing with other low EC materials.

The use of organic by-products is possible to create substrates, but in some cases there are some limitations requiring a less applied percentage or a pre-treatment procedure. Coconut by-products showed good chemical properties and absence of phytotoxicity, and a high possibility to improve the physical characteristics, mixing different percentage of pith with fiber. These characteristics confirmed that coconut by-products are an interesting alternative substrate with a good potential to partially or totally replace peat in growing media.

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3 USE OF ORGANIC BY-PRODUCTS AS GROWING MEDIA IN SOILLESS CULTIVATION

Among the possible peat alternative material, coir is an interesting material in the panorama of the substrates, still underused. Coir is the name given to the fibrous material that constitutes the thick mesocarp (middle layer) of the coconut fruit (*Cocos nucifera* L.). The long fibers of coir are extracted from the coconut husk and used in manufacturing industrial products (Balick and Beck, 1990). Traditionally, the short fibers and dust left behind were accumulated as a waste product for which no industrial use had been discovered (Meerow, 1994). Coir pith has several qualities that suggest to recommend it as a peat substitute (Cresswell, 1992) since it shows high water-holding capacity (equal to sphagnum peat), slow decomposition and acceptable pH, cation exchange capacity (CEC) and electrical conductivity (EC). Furthermore, coir, as previously mentioned, is a by-product of coconuts manufacturing; by-products could represent a source of alternative materials to use as growing media. Through the recycling, it is possible to convert by-products into reusable material, reducing waste production and use of primary resources (such as peat). Compost is another example of recycling material;, the common name indicates organic matter (usually coming from green waste or household waste) that has been decomposed by a long, thermophilic, aerobic decomposition and recycled as fertilizer, soil amendment and also substrate component (Carlie, 2008; Prasad and Carlie, 2009; Mota et al., 2009; Jayasinghe et al., 2009; Jayasinghe et al., 2010; Aviani et al., 2010; Raviv 2011). Composting process has been also applied to by-product such as grape marc, then used as growing media for container plants cultivation (Baran et al., 2000; Bustamante et al., 2008;Carmona et al., 2012), but low information is available about the use of non-composted marc and the possible application as growing media.

Assuming that by-products originated from several process such as agriculture and urban activity, can be potentially re-used in soilless cultivation, the purpose of this research was to assess comparative growth using different organic by-products as growing media, partially or totally replacing peat, to evaluate which materials are better suited than others for this purpose.

The first part of the study was focused on the use of coir, which according to previous researches, seems to have high potential as growing media. In the second part, the attention was extended also to the possible use of other materials, such as compost, grape marc and hemp fiber.

3.1 Use of coconut residues

The possibility to replace peat with coir-based substrates was evaluated in two different soilless cultivation system:

- Vegetable transplants (short cycle)
- Ornamental bush cultivation (long cycle)

Alternative materials were represented by an industrially coir mix of 70% coir pith (particle size < 5 mm) and 30% coir fiber (particle size > 5 mm) mixed by volume (V/V).

Chemical properties, pH and electric conductivity (EC), were determined using a water extract (1: 5, v:v^{-1}).Water extract was obtained filtering a solution of 60 ml of material and 300 ml of demineralized water mixed for one hour. Water holding capacity was evaluated and expressed as the percentage of water retained by a certain volume of substrate at a known moisture level (Cattivello et al., 2009). The substrate (0.3 l at humidity 55%) was used to fill plastic pots (diameter 10 cm) placed on a beaker. Water (50 ml) was poured on the substrate, and drained water was collected in the beaker under the pot. After drainage, the operation was repeated again, until a total of 200 ml poured of water was used. Then the amount of drained water (non retained water) was measured and the percentage of retained water expressed as:

$$(100-((\text{ml drained water } /200 \text{ ml}) * 100))$$

3.1.1 Experiment 1 – Materials and methods

The influence of two different growing media (coir mix and sphagnum peat) was tested in a cultivation trial, using two horticultural species: lettuce (*Lactuca sativa* L.) and basil (*Ocimum basilicum* L.). The duration of test was 36 days and plants were grown in104 holes tray plant containers (hole diameter: 3.5 cm; volume 0.03 l). The container holes were filled with substrates for ¾ of their volume and seeding operation was performed (23.09.2014) by hand, using a pair of tweezers and depositing three seeds in each hole. The seeds were covered with the respective substrate, filling the remaining hole volume and substrates were wet to ensure an adequate moisture for germination. After one week from the beginning of germination, germinated seeds were thinned to leave only one seedling for each hole. Experiment was carried out in the D3A experimental greenhouse of Marche Polytechnic University, with a completely randomized block design: 4 blocks and 12 replicates for each block. During the cultivation, irrigation was managed using microspray system, providing 1.2 liters of daily water and distributed into 4 irrigation events. More over, 2 l of additional water was sprayed daily to maintain constant moisture level of growing media. Plants were fertilized with 0.21 g/plant of a controlled-release complex fertilizer (Osmocote Bloom 2-3M 12% N, 7% P2O5 and 18% K2O, MgO 1.5%, 0.01% B, 0.045% Cu, 0.35% Fe, 0.05% Mn, 0.017% Mo, 0.013% Zn). After 36 days from sowing, the influence of the substrate on the growth was evaluated on 16 plants per each species with a series of measurements: length of the stem and roots, basal stem diameter, fresh and dry weights of above-ground portion (stem and leaves) and roots. The dry weight was obtained by drying samples in the oven at 70 °C for 72 hours. Data were subjected to statistical analysis of variance and separation of means by Tukey test, using the JMP software (version 8, SAS Institute Inc., Cary, NC, USA, 2009).

3.1.2 Experiment 1 – Results and discussion

Substrates used for the vegetable transplant trial showed different characteristics (Table 1.). pH was acid for peat and sub-acid for coir, and the electric conductivity resulted higher in coir than peat. Water retention showed low differences between the two tested substrates, resulting slightly higher for peat than for coir.

Table 1. Properties of sphagnum peat and coir used for vegetable transplant trial. Chemical properties are referred a water extract of growing media (1:5 V/V). Water retention was express as water retained by a known volume of substrate.

Substrate	pH	Electric conductivity mScm^{-1}	Water retention %
Peat	4.4	0.41	65.5%
Coir	6.2	0.77	56.2%

Results of plants growth (above-ground portion and roots portion) influenced by the different growing media are shown below (Table 2. for basil and Table 3. for lettuce). No significant differences were found in basil fresh and dry weight (leaves and stem), but coir substrate seemed to increase roots growth. Roots fresh weight in coir was significantly higher (0.54 g) when compared to those grown in peat-based substrate (0.30 g). The same behavior was registered for the dry weight. Also for lettuce, after 36 days of cultivation, no significant differences were found in the above-ground portion. Roots fresh weight in coir (0.66 g) was double than in peat (0.33 g) and significantly higher values were registered also for roots dry weight. Roots of lettuce grown in the coir substrate were significantly longer (9.15 cm) than those grown in peat (7.78 cm). Basal stem diameter of lettuce plants grown in the coir substrate showed the highest value (2.75 mm), significantly different compared to lettuce basal stem diameter in peat (1.85 mm).

Table 2. Growth values of basil after 36 days of cultivation using two different growing media. Different letters indicate significant difference (Tukey test p<0.05)

	Shoot			Root		
Substrate	**Fr.weight (g)**	**Dr weight (g)**	**Diameter (mm)**	**Fr. weight (g)**	**Dr weight (g)**	**Length (cm)**
Peat	1.47 ns	0.07 ns	1.68 ns	0.30 b	0.01 b	7.49 ns
Coir	1.35 ns	0.07 ns	1.62 ns	0.54 a	0.03a	6.21 ns

Fr.weight and Dr. weight indicates fresh and dry weight express in g

Table 3. Growth values of lettuce after 36 days of cultivation using two different growing media. Different letters indicate significant difference (Tukey test p<0.05)

	Shoot			Root		
Substrate	**Fr.weight (g)**	**Dr weight (g)**	**Diameter (mm)**	**Fr. weight (g)**	**Dr weight (g)**	**Length (cm)**
Peat	**2.11 ns**	**0.08 ns**	**1.85 b**	**0.33 b**	**0.03 b**	**7.78 b**
Coir	2.53 ns	0.11 ns	2.75 a	0.66 a	0.06 a	9.15 a

Fr.weight and Dr. weight indicates fresh and dry weight express in g

3.1.3 Experiment 2 – Materials and methods

The effect of partial and total replacement of peat by coir was evaluated in a long-cycle cultivation of an ornamental Mediterranean species: laurel (*Laurus nobilis* L.). Trial was carried out for about 17 months, from transplant (June 2013) to the end of nursery cultivation (October 2014). The combination of different materials was used for tested growing media: coir mix, peat and pumice. Materials were mixed by volume, adding 40% of pumice as practice to increase the aeration (Table 4.), the remaining 60% was covered by using peat progressively replaced by coir (T2-T4); in T5 also pumice was replaced by coir, representing 100% coir mix substrate. As control (T1) a mix of 60% of peat and 40% of pumice was used (Figure 1.).

Table 4. Volume percentage of different material that constitute different treatments.

Treatment	% Coir	% Peat	% Pumice
T1*	0	60	40
T2	12	48	40
T3	30	30	40
T4	60	0	40
T5	100	0	0

***T1 is the treatment without coir, used as reference**

Figure1. A mix of 40% of pumice and 60% of peat used as reference (A). Peat in the mix was progressively replaced by coir (B)

The experiment was carried out in a professional private nursery (Figure 2.) located in Ripatransone (Ascoli Piceno – Italy) with a randomized block design (4 blocks and 25 replicates each block for a total of 100 plants per each treatments). Laurel plantlets were cultivated using pots of 5.5 l of volume (size: 20×20 cm, diameter × height); as the local practice, water was provided with sprinkler irrigation system and fertilization with 30g/pot of slow-release fertilizer (Osmocote Exact HI Std 9-11-15) and 0.75 g per pot of chelate Fe (Fe sequestrene NK 138) added to the substrate during transplant operations. Plants were pruned twice: after one and three months from transplanting, to stimulate growth and compact habitus, respectively.

Plants growth was checked during the 17 months cultivation cycle and described with destructive and non destructive measurements of above-ground portion and roots.

Collected data were subjected to analysis of variance (ANOVA) and differences were compared using mean separation by Tukey-Kramer HSD test. Statistical analysis was conducted using JMP Software (Release 8; SAS Institute Inc., Cary, NC, USA, 2009).

Figure 2. Experiment was carried out in a professional green house, for about 17 months from plants transplanting in 5.5 l of volume pots to the end of nursery cultivation, obtaining ready to sell plants

3.1.4 Experiment 2 – Results and discussion

Properties of different tested substrates are reported in Table 5. Substrate with 0% coir (Standard: 60% peat+40% pumice) showed a low electric conductivity and acid pH. pH value seemed to increase when coir percentage increased, up to a value of 6.6 in substrate 100% coir. Electric conductivity showed low differences between treatments, with values around 0.31 mScm^{-1}. Low differences were found between tested substrates for the water retention, with higher values in 100% coir compared to the other treatments (Table 5.)

Table 5. Different properties of growing media tested in the laurel cultivation trial . Coir% represent the percentage (by volume) of coir in the substrate, mixed with peat and pumice.

Coir %	pH	Electric conductivity mScm^{-1}	Water retention %
0	4.7	0.27	54.0
12	4.7	0.27	50.5
30	4.9	0.31	52.5
60	6.5	0.38	51.0
100	6.6	0.31	58.7

In Table 6. the results of plant growth after three months from transplant are shown. Few differences were found observing the different parameters. Only the substrate containing 30% of coir showed the highest stem height compared to plants grown on the substrate with low percentage of coir. Also a higher root length was registered compared to the other treatments, without differences compared with 100% coir substrate. Plants growth did not show differences according to the growing substrate after three months from transplanting.

Table 6. Growth of above ground portion and roots of laurel plants, after 3 months of cultivation, using substrate with increasing percentage of coir in replacement of peat. Different letter represent significant difference (Tukey test p<0.05)

	shoot				root		
Coir%	**Height (cm)**	**Fr.weight (g)**	**Dr.weight (g)**	**Diameter (mm)**	**Length (cm)**	**Fr.weight (g)**	**Dr.weight (g)**
0	43.3 ab	11.6 a	3.18 a	5.01 a	31.2 a	4.55 a	0.71 a
12	40.9 b	09.8 a	2.86 a	3.10 a	30.7 b	4.32 a	0.68 a
30	46.6 a	11.8 a	3.37 a	3.41 a	37.2 a	5.22 a	0.88 a
60	46.2 ab	12.2 a	3.39 a	3.53 a	31.2 b	4.27 a	0.78 a
100	43.7 ab	11.3 a	2.94 a	3.33 a	32.8 ab	4.90 a	0.74 a

0 is a substrate without peat composed by 60% peat and 40% pumice (V/V) that represent the standard for the trial.
Fr.weight and Dr.weight express fresh and dry weight of shoot (shoot and leaves) and roots.

In Table 7. the results of laurel growth after 17 months of cultivation are shown (end of the trial). A significant difference was found comparing the fresh weight (stem and leaves) of plants grown in substrate with low percentage of coir (treatment 12%) and laurel grown with 100% coir substrate. No significant differences (fresh and dry weights) were found between plants grown on 100% coir and on standard substrate without coir (60% peat and 40% pumice). Also for the basal stem diameter no significant differences were found between treatments; plants height was significantly higher for 100% coir treatment (122 cm) when compared to substrate without coir (155 cm). For plants grown on substrate containing 12, 30 and 60% of coir, similar results were found, with no significant differences between treatments.

Table 7. Above ground portion of laurel plants growth after 17 month of cultivation, using substrate with increasing percentage of coir in replacement of peat. Different letter represent significant difference (Tukey test p<0.05)

Coir %	**Height (cm)**	**Fresh weight (g)**	**Dry weight (g)**	**Stem diameter (mm)**
0	115.4 b	82.8 ab	32.6 ab	10.2 a
12	117.7 ab	78.7 b	30.1 b	10.0 a
30	121.2 ab	98.9 ab	40.5 a	10.8 a
60	119.0 ab	89.0 ab	39.0 ab	10.7 a
100	122.2 a	100.6 a	40.6 a	11.2 a

0 is a substrate without peat composed by 60% peat and 40% pumice (V/V) that represent the standard for the trial

3.1.5 Conclusions

Considering the results obtained in two different cultivation trials, it is possible to get some indications about the possibility to use coir as growing media in order to replace peat (partially or totally), in two cultivation systems. In both experiments, no significant differences were recorded for the growth of the above-ground portion, between the substrates containing coir and those peat-based. An interesting effect on the roots development was recorded in the 100% coir substrate in both species and transplanting systems. This effect could have good implication, on the transplant of young seedlings in soil or bigger container.

3.2 Reuse of organic by-products

A second set of experiments was carried out to study the response of plants using different by-products as growing media. Considering the good results obtained with the use of coir, this material was used again, with different combinations of coir pith and coir fiber. Four different organic by-products were used as growing media for a basil cultivation trial. Materials originated from agriculture and urban activity.

Residues of fruit of Coconut palm (*Cocos nucifera* L.) are represented by fibrous (coir fiber) and fine (coir pith). Three different mixes (V/V) of fiber and pith were used:

- Coir fine (CoF): 100% coir pith
- Coir medium (CoM): 30% coir fiber and 70% coir pith
- Coir gross (CoG): 60% coir fiber and 40% coir pith with 60%

Residues of hemp are represented by dry stalks and raw coarse fiber covering the stalks. Two fraction were used:

- Fine (HeF) obtained chopping raw material with a 6 mm mesh size mill.
- Gross (HeG) material was coarsely chopped obtaining shiv and fiber >6 mm

Grape marc (Gm), composed by solid residues of grape (*Vitis vinifera* L.) after pressing for wine production: grape skin, residue of pulp, seeds and stalk. Marc was dried in the oven at 105 °C for 48 hours and grinded with a 6 mm sieve size mill.

Green compost (Gc) was the results of a process of bio-oxidation and humification of organic green wastes such as grass clipping and pruning materials. The tested green compost was a fraction sieved at 6 mm.

3.2.1 Experiment 1 – Materials and methods

The influence of different materials as growing media for basil (*Ocimum basilicum* L.) transplant seedling was studied in a greenhouse experiment. The experiment was planned with the aim to assess the plants response to the use of alternative materials as substrate, sole or mixed with 50%

of peat (pH: 4.45, EC: 0.44 mScm^{-1} measured on a water extract 1:5 V/V) (Table 8.), considered as the principal substrate of soilless production.

Table 8. Different by-products used as growing media for transplant basil cultivation trial. Different materials were used sole or mixed with 50% of sphagnum peat.

Material	acronym	% of material
Coir fine	CoF	100 50
Coir medium	CoM	100 50
Coir gross	CoG	100 50
Hemp gross	HeG	100 50
Hemp fine	HeF	100 50
Gape marc	Gm	100 50
Green compost	Gc	100 50

Chemical properties (pH and electric conductivity (EC) of materials and mixes were determined using a water extract (1:5, v:v^{-1}).Water extract was obtained filtering a solution of 60 ml of material and 300 ml of demineralized water mixed for one hour.

Cultivation trial was realized in the experimental greenhouse of Marche Polytechnic University, using tray plant containers (104 holes; volume unit 0.03 l). Treatments were arranged with a completely randomized block design (4 blocks and 12 replicates per each block). Container holes were initially filled with substrates (Figure 3.), and then seeded (21.04.2015) manually using a pair of tweezers, depositing three seeds per each hole. After seeding, seeds were covered with the respective substrate, placed on an aluminum table and substrates were wet with water to ensure an adequate moisture for germination. During the experiment, containers have been raised (Figure 4.) to avoid contact with the bottom of the Table, allowing an air-pruning effect and limit the root growth within the cell volume. After one week from the beginning of germination, germinated seeds in the holes were thinned to have one seedling for each hole. During the cultivation, plants were irrigated using micro-spray system, providing 1.5 liters of water daily divided into 5 irrigation events and 2 l of additional water was sprayed daily to maintain substrate moisture constant. Substrates were fertilized with 0.21 g / plant of a controlled-releasecomplex fertilizer (Osmocote Bloom 2-3M, 12% N, 7% P2O5 and 18% K2O, MgO 1.5%, 0.01% B, 0.045% Cu, 0.35% Fe, 0.05% Mn, 0.017% Mo, 0.013% Zn).

Figure 3. Different by-products were used and mixed with peat to fill tray plants container

Figure 4. During the experiment, containers were raised to avoid contact with the bottom of the Table, allowing an air-pruning effect

At the end of the experiment (30 days from germination), the following growth parameters were measured (16 plants each treatment): above-ground portion (shoot and leaves) and roots fresh and dry weight, shoot and root length, shoot diameter, lea number and area and Chlorophyll content (determined using a SPAD meter). A factorial ANOVA was conducted for the analysis of significant difference between treatments and separation of means was made by Tukey test, using the JMP software (version 8, SAS Institute Inc., Cary, NC, USA, 2009).

3.2.2 Experiment 1 - Results and discussion

In the Table 9. were shown the results of pH and electrical conductivity of different material and mixed with peat (pH: 4.31, EC: 0.44 mScm^{-1}). pH sole material was neutral for hemp and basic for compost. For marc and coir pH was found generally sub acid. For all material (except compost) pH values has been reduced to value around 5 when mixed with peat. About electrical conductivity (EC) of non mixed material, grape marc shower the highest value, much higher compared to other material that showed an EC under 1 mScm^{-1} (except compost which showed a value of 1.38 mScm^{-1}). Also for this parameter, the mix with 50% of peat has reduced the value for all mix.

Table 9. Chemical properties of different material alone (100%) or mixed with sphagnum peat (50%). Properties are referred to a water extract of growing media (1:5 V/V).

Material	acronym	% of material	pH	EC (mScm^{-1})
Coir fine	CoF	100	6.7	0.52
		50	4.7	0.24
Coir medium	CoM	100	6.2	0.77
		50	4.7	0.62
Coir gross	CoG	100	6.6	0.26
		50	4.2	0.19
Hemp gross	HeG	100	7.5	0.13
		50	4.9	0.14
Hemp fine	HeF	100	7.5	0.11
		50	4.9	0.07
Gape marc	Gm	100	6.5	3.33
		50	5.1	1.56
Green compost	Gc	100	9.5	1.38
		50	6.9	0.72

After 30 days from germination for 100% grape marc low germination was detected and the few seedlings died few days after the germination, probably because of the high EC. For this reason, it was possible only to collect data on plants grown on grape marc mixed with peat. Table 10a and 10b. summarize results about the growth of the above-ground portion (stem and leaves). The highest stem length was found for treatment containing coir fine (100% coir pith) and green compost (length average: 7.6 cm), sole or mixed with 50% of sphagnum peat. The results were significantly different compared to the other treatments (Figure 5.). No significant differences were found considering the height of shoot of plants grown in the substrates coir medium (70% pith and 30% fiber), coir gross (40% pith and 60% fiber) sole or mixed with peat and hemp gross (average: 5.2 cm). The lowest values of shoot length were shown by plants grown on fine hemp sole or mixed, sole gross hemp and from grape marc mixed with peat. Higher stem diameter was recorded for basil grown on coir fine (100% pith) and green compost sole or mixed (1.97 mm), compared to the other treatments. The lowest value was observed for fine hemp fraction (1.07 mm). No differences between other treatments were recorded. Similar results were found for fresh weight and dry weight of above-ground portion (stem and leaves), basil grown on coir fine (100% pith) and green compost sole or mixed showed the highest results compared to other treatments. The number of leaves produced decreased for plants grown on fine hemp sole or mixed, grape marc mix and 100% gross hemp (average of leaves produced: 4.4), while no significant differences were found between the other treatments (average of leaves produced: 5.6).

Considering the chlorophyll content, expressed as SPAD unit, high values were found for basil grown on coir substrate (sole and mixed) and in the mix of gross hemp and peat. SPAD values decreased in the other treatments, with significant lower values for plants grown on substrate composed of grape marc and peat. Area of the leaves was higher in plants grown on coir pith and compost sole or mixed, and decreased in the other treatments. In particular small leaves were produced by basil grown on substrates composed of fine hemp sole or mixed, 100% gross hemp and mix of grape marc and sphagnum peat.

Table 10a. Influence of different substrate on the above-ground portion growth of basil seedling.). Different letter represent significant difference (Tukey test $p<0.05$)

Treatment	%	Length (cm)	Diam. (mm)	Fresh weight (g)	Dry weight (g)
CoF	**50**	7.68 a	1.93 ab	2.21 a	0.18 a
	100	7.80 a	2.00 a	2.17 a	0.20 a
CoM	**50**	4.76 bcd	1.44 c	1.09 bcd	0.08 bcde
	100	5.69 b	1.63 bc	1.36 b	0.11 b
CoG	**50**	5.46 b	1.51 c	1.18 bcd	0.09 bc
	100	5.41 b	1.41 cd	1.24 bc	0.10 bc
HeF	**50**	3.36 de	1.36 cd	0.71 cde	0.05 cdef
	100	2.33 e	1.07 d	0.47 e	0.03 f
HeG	**50**	4.96 bc	1.57 c	1.28 b	0.09 bcd
	100	3.74 cde	1.30 cd	0.67 de	0.04 def
Gc	**50**	7.30 a	1.95 ab	2.12 a	0.17 a
	100	7.54 a	1.97 ab	1.99 a	0.13 b
Gm	**50**	3.24 e	1.32 cd	0.72 cde	0.04 ef
	100	.	.	.	.

% express the amount of material present in the substrate

(.) Gmarc 100 showed a scarce germination and seedling died before the end of the trial. No data were recorded for this treatment

Table 10b. Influence of different substrate on the above-ground portion growth of basil seedling.). Different letter represent significant difference (Tukey test $p<0.05$)

Treatment	%	Leaves number	Leaf area (cm^2)	SPAD
CoF	**50**	6.3 a	55.9 a	24.9 a
	100	6.1 a	50.8 a	24.3 ab
CoM	**50**	5.3 abc	29.3 de	24.7 ab
	100	5.6 abc	36.2 bcd	22.4 abc
CoG	**50**	5.2 abcd	29.5 de	24.6 ab
	100	5.2 abcd	33.3 cd	23.5 ab
HeF	**50**	4.6 cde	18.7 ef	22.3 abc
	100	4.1 de	11.4 f	21.4 bc
HeG	**50**	5.2 abcd	34.0 cd	22.7 abc
	100	4.8 bcde	19.1 ef	23.6 ab
Gc	**50**	5.8 ab	49.3 ab	21.8 abc
	100	5.6 abc	46.0 abc	22.1 abc
Gm	**50**	4.0 e	18.3 ef	20.0 c
	100	.		.

% express the amount of material present in the substrate
(.) Gmarc 100 showed a scarce germination and seedling died before the end of the trial. No data were recorded for this treatment

Figure 5. At the end of cultivation, plants grown on coir fine (100% coir pith) (A) and compost (B) showed the highest growth in terms of size and weight. While, lowest growth was showed by plants grown on marc mixed with peat (C) and fine hem (D)

In Table 11. are shown the results of the effect of different substrates on the roots. The highest root length was recorded for the mix of peat and compost (12.5 cm) compared to the other treatments. No differences were found comparing root length of plants grown on 100% green compost, medium coir (70% pith and 30% gross), coir fine (100% coir pith) and gross hemp fraction sole or mixed with peat. The lowest value of root length was found for fine hemp mixed with peat and mix of grape marc and peat. The highest fresh root weight was observed on green compost mixed with peat and fine fraction of coir (100% coir pith), lowest for fine hemp sole and mixed, gross hemp fraction and grape marc mixed with peat. As for the roots dry weight, the highest values were recorded for medium coir fraction, resulting significantly different compared to the others. No significant differences were recorded for treatments containing compost, coir pith, gross fraction of coir and coir medium mixed with peat. The lowest value was recorded for hemp fine fraction.

Table 11. Influence of different substrate on the above-ground portion growth of basil seedling. Substrate were made using material alone (% = 100) or mixed with 50% of peat (% = 50). Different letter represent significant difference (Tukey test p<0.05).

Treatment	%	Length (cm)	Fresh Weight (g)	Dry Weight (g)
CoF	**50**	7.4 bcd	0.8 abc	0.07 ab
	100	8.9 bc	1.2 ab	0.08 ab
CoM	**50**	7.5 bcd	0.6 cde	0.05 ab
	100	9.1 b	0.8 bcd	0.12 a
CoG	**50**	6.5 cd	0.6 cdef	0.06 ab
	100	6.6 cd	0.7 cdef	0.08 ab
HeF	**50**	5.7 d	0.5 cdef	0.02 ab
	100	8.0 bcd	0.2 f	0.01 b
HeG	**50**	8.6 bc	0.6 cdef	0.04 ab
	100	8.7 bc	0.4 def	0.02 ab
Gc	**50**	12.5 a	1.3 a	0.10 ab
	100	10.0 ab	0.8 bcde	0.08 ab
Gm	**50**	5.1 d	0.2 f	0.02 ab
	100	.	.	.

(.) Gmarc 100 showed a scarce germination and seedling died before the end of the trial. No data were recorded for this treatment

After 34 days of cultivation, basil seedling showed a positive response to substrates composed by coir pith and green compost sole or mixed. Good was also the growth of plant on substrate composed by medium coir and gross coir fraction sole or mixed. Therefore the use of coconuts residues (different fraction) and compost seemed to be suitable for basil seedling production, compared to the other possible substrates. The use of gross hemp fraction for seedling production seems to be suitable if it is mixed with peat, indeed the plants growth increased in the gross hemp fraction mix and decreased when hemp was used sole. The plants growth decreased using fine hemp fraction sole or mixed and grape marc, that seems to have a high limit when used in purity. Plants produced using this type of substrate reached a small size and showed a reduction of leaves production and leaf color (for marc), while the possible application in the seedling production seems to be more limiting.

3.2.3 Experiment 2 - Materials and methods

A second experiment was realized to compare the basil growth on different organic growing media obtained using organic by-products. On the base of the previous results, for this experiment fine fraction of hemp and grape marc were not used. The experiment setting, also in this case, involved the use of material sole or mixed with sphagnum peat in the ratio 1:1 (V/V), as summarized in Table 12. As reference was used a substrate 100% sphagnum peat. Different substrates were used to fill plastic cylinder pots (volume: 750 ml, top diameter: 12 cm).

Table 12. Different by-product used as growing media for basil cultivation trial. Different material were used alone (100%) or mixed by volume with 50% of sphagnum peat (50%). As reference was used sphagnum peat.

Material	acronym	% of material
Peat	Peat	100
Coir fine	CoF	100 50
Coir medium	CoM	100 50
Coir gross	CoG	100 50
Hemp gross	HeG	100 50
Green compost	Gc	100 50

Pots were sown with basil seeds (2/4/2015) and wet by hand from the top to ensure adequate moisture for germination; after germination, the number of seedling was reduced to obtain a number of five plants per pot. Each pot was fertilized with 1.05 g of slow-release fertilizer (Osmocote Bloom 2-3M, 12% N, 7% P2O5 and 18% K2O, MgO 1.5%, 0.01% B, 0.045% Cu, 0.35% Fe, 0.05% Mn, 0.017% Mo, 0.013% Zn). During the trial, pots were irrigated with drip irrigation system (flow rate 2l/hour), providing each pot with 30 ml of water. For three weeks after germination each pot was irrigated with the same amount of water, then starting from 24/4/2015 the pots were divided into two groups and irrigated with two different frequencies:

- Daily: 30 ml of water, supplied every day, with one irrigation event (1 minute).
- Alternate: 60 ml of water, supplied on alternate days, with one irrigation event (2 minute).

All irrigation frequencies were combined with all tested substrates in order to verify a possible interaction between substrate and irrigation and the influence on plants growth.

In the last cultivation week, the amount of supplied water was doubled (with the same frequency):

- Daily: 60 ml of water, supplied every day, with one irrigation event (1 minute).
- Alternate: 120 ml of water, supplied on alternate days, with one irrigation event (2 minute).

Starting from the third week of cultivation, sample of water drained from the pots during each week was collected (using 4 pots each treatment) to have a description of the capacity of different mixes to retain water (Figure 6.).

Figure 6. Drained water was collected placing a plastic bag under the pot. For each treatment 4 pots were used, collecting water each week (from the third week of cultivation)

The experiment was realized in a completely randomized block design (2 blocks). In each block were used both irrigation frequencies, and all substrates tested were match to each irrigation frequencies (3 pots per each irrigation frequency per block). After 42 days of cultivation, 8 plants per each treatment were harvested and fresh and dry weights of the above-ground portion (stem and leaves), length of stem and stem basal diameter, leaf area and leaf chlorophyll (SPAD unit) were measured. An evaluation of root growth was also made using a visual evaluation scale. The evaluation considered a scale from 1 (no roots reaching the external surface of the substrate) to 4 (root system forming a compact mesh that colonized the whole substrate) (Figure 7.). Root system evaluations was performed considering two halfs of substrate in the pot: top portion and bottom portion (Figure 8.).

Figure **7. Root evaluation was made using a visual evaluation scale. The evaluation considered a scale from 1 to 4**

Figure 8. Roots evaluations was made considering two half of substrate in the pot: top portion and bottom portion

Data collected were subjected to analysis of variance (ANOVA) and differences were compared using mean separation by Tukey-Kramer HSD test. Statistical analysis was conducted using JMP Software (Release 8; SAS Institute Inc., Cary, NC, USA, 2009).

3.2.4 Experiment 2 – Results and discussion

In the Table 13. the result of the ANOVA test are summarized considering two factors: irrigation (Frequency) and growing media (different by-product sole and mixed). Different water managements influenced only plants height; only different growing media influenced the other considered growth parameters.

Table 13. ANOVA results, * meaning that there was an effect of factor on parameter measured

Measured parameter	substrate	irrigation	Substrate x irrigation
Shoot length	*	*	
Shoot diameter		*	
Fresh weight		*	
Dry weight		*	
Leaf number		*	
Leaf area		*	
Chlorophyll		*	

The use of alternate irrigation reduced the height of the plants. Average height of the plants grown using an alternating irrigation frequency was lower (16.2 cm) than the average height of plants irrigated every day (17.9 cm) (Figure 9).

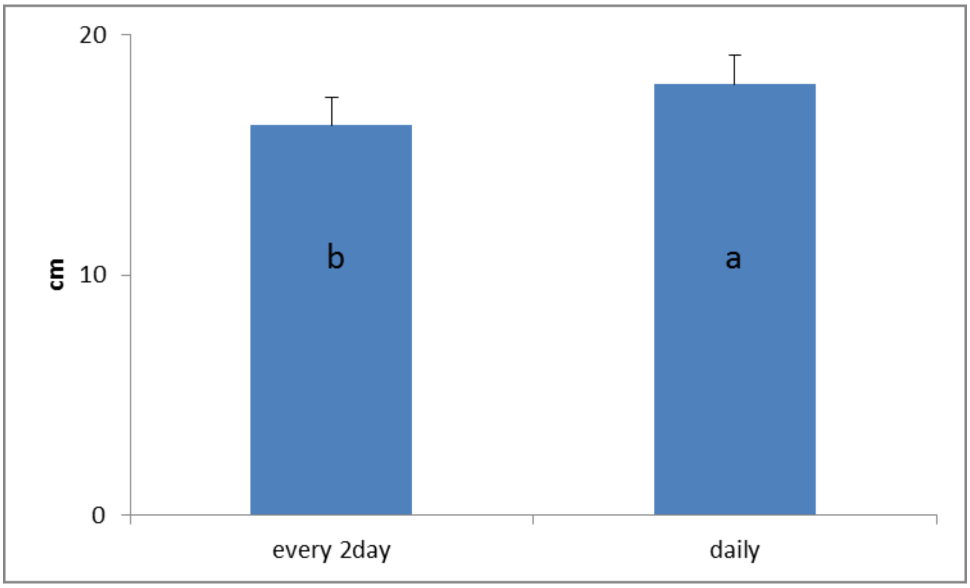

Figure 9. Effect of different water management on plants height. Bars indicate standard error. Different letters indicate significant difference (Tukey test p<0.05)

Table 14.shown the results of different growing media influence on plants grown. Plants grown on mix of compost and sphagnum peat showed the highest shoot length (22.3 cm), compared to the other treatments and significantly higher than plants grown on peat (17.3). No significant differences were recorded for plant height between plants grown on mix of peat and compost and plants grown on fine and medium fraction of coir mixed with peat and 100% compost. The lowest values were found for plants grown on substrate of 100% hemp fiber, much lower than the other treatments (4.8 cm). No significant differences were seen for the plants height between the other treatments and compared to peat. Stem diameter decreased for plants grown on substrate composed by 100% hemp (0.8 mm), that showed the lowest value, significantly different compared to the others. Stem diameter in mix of hem and peat was higher than 100% hemp without significant difference compared to peat. 100% hem showed the lowest value of fresh and dry weight, leaf area and SPAD compared to the other treatment. Considering all fraction of coir (sole or mixed) and compost (sole or mixed) no significant difference was found for fresh weight between them and compared to peat. The same results was found for number of leaves produced, leaf area and SPAD compare coir fraction, green compost and peat.

Table 14. Influence of different substrate made with by product alone (100%) or mixed by volume with sphagnum peat. Different letter represent significant difference (Tukey test $p<0.05$).

Subs.	%	Length (cm)	Diam. (mm)	Fr.weight (g)	Dr.weight (g)	Lf.number	Lf.area (cm^2)	SPAD
Peat		17.3 bcd	2.7 ab	5.0 abc	0.44 abc	11.1 a	127.7 ab	31.3 ab
CoF	**50**	21.0 ab	3.2 a	7.1 a	0.55 ab	13.0 a	157.8 ab	30.7 abc
	100	17.6 bcd	2.7 ab	5.9 ab	0.40 abc	10.7 a	143.6 ab	29.0 abc
CoM	**50**	20.3 abc	3.0 ab	7.0 a	0.60 a	14.3 a	161.8 ab	32.6 a
	100	17.0 cd	3.3 a	5.8 ab	0.40 abc	11.1 a	120.3 ab	27.6 abc
CoG	**50**	17.2 bcd	2.7 ab	4.3 bc	0.32 c	09.2 ab	97.7 b	32.0 ab
	100	16.7 cd	2.6 ab	4.8 abc	0.38 bc	10.8 a	112.7 ab	31.2 ab
HeG	**50**	14.3 d	2.3 b	3.3 c	0.23 cd	10.0 a	109.5 ab	27.1 bc
	100	04.8 e	0.8 c	0.2 d	0.03 d	04.2 b	13.2 c	26.1 c
Gc	**50**	22.3 a	3.3 a	7.3 a	0.59 a	13.1 a	176.0 a	27.4 abc
	100	19.3 abc	2.7 ab	5.1 abc	0.35 bc	09.8 a	103.4 ab	27.3 abc

Fr.weight and Dr.weight express fresh and dry weight of shoot (shoot and leaf) and roots. Lf number express the number of the leaf produced by plants, Lf area express the area of leaf in cm^2

Considering above-ground portion, the highest results in terms of size and plants growth was obtained using coir (in particular 100% coir pith and 70% coir pith + 30% coir fiber) and compost. For coir and for green compost, results suggest the possible use as growing media for a short cycle of cultivation, in substitution to peat. The presence of peat in the mix seems to have an effect when mixed with hemp (Figure 10.). Plants grown on hemp mix with peat, generally showed significantly greater size than plants grown on 100% hemp fiber, which showed the lowest results (Figure 11.).

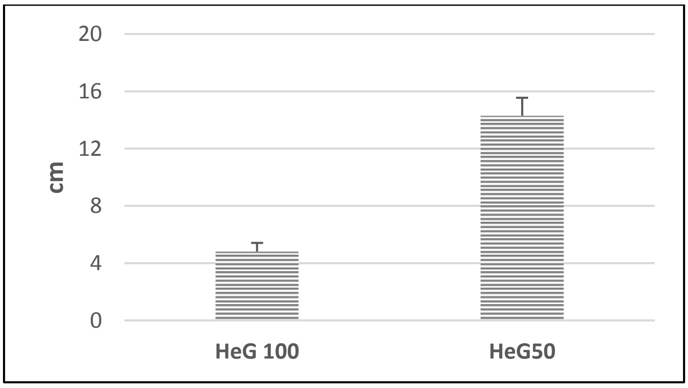

Figure 10. Shoot lenght of basil cultivated on 100% hemp gross (HeG 100) and in a mix of hemp gross and peat (HeG 50). Bars indicate standard error

Figure 11. Plants growth on hemp mixed with peat has generally shown greater size than plants grown on 100% hemp fiber.

Roots growth evaluation is show in Table 15. Scarce root production was recorded for treatment 100% hemp fiber that also showed the lowest above-ground portion growth. The roots proliferation seemed to increase when hemp fiber was mixed with peat. This is probably connected to the lower ability showed by hemp fiber to retain water, which increased mixing with a material with higher retaining property. The relationship water/material may also probably explain a different distribution of roots observed for some materials. For 100% of gross fraction of coir (40% pith and 60% fiber) root growth was concentrated in the lower half of pots (3.1) and very scarce in the top half (1.9). In a pot filled with a mix mainly composed by fibrous particle, fine particle like coir pith, with marked water retention properties, would concentrate on the bottom, driving roots to develop in this direction. In 100% coir fine (100% coir pith) root growth was abundant and concentrated on the top half of pots. In coir fine and coir gross mixed with peat and in 100% coir medium and compost, roots distribution seemed more homogeneous comparing top and bottom portion of pot.

Table 15. Roots distribution in the substrate considering the top half of pot (top) and bottom half of pot (bottom) in different substrate evaluate on a scale from 1 to 4. Different letter represent significant difference (Tukey test $p<0.05$).

Treatment	% of by-product	Top	Bottom
Peat	100	2.5 abcd	1.0 c
CoF	100	3.6 a	1.4 bc
	50	3.5 a	3.1 a
CoM	100	2.9 abc	2.3 abc
	50	3.4 ab	3.5 a
CoG	100	1.9 cd	3.1 a
	50	2.7 abc	2.6 ab
HeG	100	1.2 d	1.5 bc
	50	2.1 bcd	2.3 abc
Gc	100	3.2 abc	2.7 ab
	50	3.4 ab	3.4 a

Evaluation of root growth were made, using a visual evaluation scale with values from 1 to 4: 1 representing roots which did not reach the surface of the surface of the substrate and value 4 representing a root system forming a compact mesh that colonized the whole substrate

An interaction between substrate and different irrigation frequency was found (Figure 12. and Figure 13.).

100% hemp fiber shown to have low ability to retain water that significant increase when it is mixed with peat (50%). Same behavior was showed by gross coir (40% coir pith + 60% coir fiber), but difference between 100% gross coir and gross coir mixed with peat result no significant (for both type of irrigation frequency). Coir (coir fine and coir medium) showed low value of water drained and with daily frequency of irrigation, coir fine (100% coir pith) and coir medium (0% coir pith and 30% coir fiber) showed to have no difference (100% and 50%).

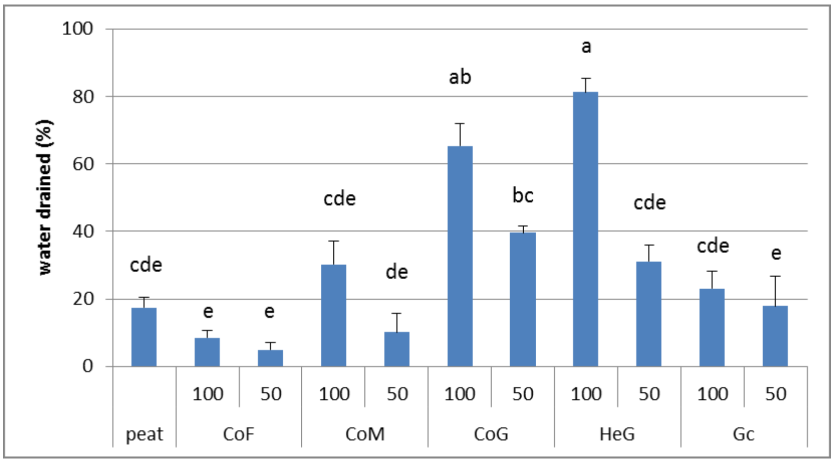

Figure 12. Percentage of water drained in the last three weeks of cultivation trial in different substrates irrigate with alternate irrigation frequency. Bars indicate the standard error, different letters indicate a significant difference between treatments (Tukey-Krament HDS test, $p<0.05$).

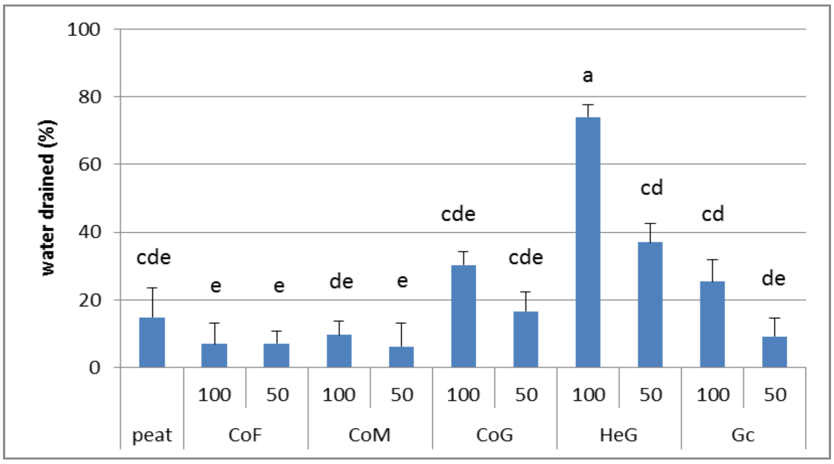

Figure 13. Percentage of water drained in the last three weeks of cultivation trial in different substrates irrigate with daily irrigation frequency. Bars indicate the standard error, different letters indicate a significant difference between treatments (Tukey-Krament HDS test, $p<0.05$).

3.2.5 Experiment 3 - Materials and methods

The aim of the experiments was to study the effect of treated and non treated grape marc on plants growth and the suitability of grape marc as growing media for transplant seedling. A volume of 0.3 l of dried grape marc was used to fill plastic pots and treated with a series of washing, using tap water (EC 0.58 $mScm^{-1}$). Grape marc was placed under continuous flux of water for two minutes, then saturated and placed on a beaker to drain. After 30 minutes (at the end of drainage), the operation was repeated again, for a total of eight washings. After each washing/drainage cycle, drained water was collected to analyses electric conductivity.

A second laboratory test was performed to evaluate a possible effect of treated (washed) and non treated grape marc on plants. A bioassay was carried out using a water extract obtained with 1 volume of marc and 5 volume of demineralized water (1:5 V/V) put in contact for one hour in agitation. Inhibition effect was evaluated through the number of germinated seeds and roots growth (germination index) of cress seeds (*Lepidium sativum* L.) in contact with an extract of treated and non treated marc (Zucconi et al., 1982). Cress seeds were placed in petri dishes 9.5 cm of diameter (5 seeds per dish) on filtering paper wetted with water extracts (1.5 ml) and incubated for 48 hours at 27 °C in the dark. Ten replicates per treatment were arranged and the control was represented by demineralized water. After the incubation, the number of germinated seeds and roots length were recorded to calculate the germination index:

$$G.I. = ((\text{n. of germinate x root length})/(\text{ n. of germinated}_{\text{control}} \text{ x root lenght}_{\text{control}})) \text{ x } 100.$$

The second part of the experiment involved a basil seedling cultivation trial. Treated and non treated grape marc were used as growing media, sole or mixed with 50% of sphagnum peat or 50%

coir pith (ratio 1:1 V/V), as summarized in Table 16. (grape marc alone or mixed with peat) and Table 17. (grape marc alone or mixed with coir).

Table 16. Material combinations used for basil seedling cultivation trial. Treated (G_t) and non treated (G_n) grape marc were used alone and mixed with peat (1:1 V/V)

Material	G_t	G_n	G_t+P	G_n+P	P
Treated grape marc (%)	100	0	50	0	0
No treated grape marc (%)	0	100	0	50	0
Peat (%)	0	0	50	50	100

Table 17. Material combinations used for basil seedling cultivation trial. Treated (G_t) and non treated (G_n) grape marc were used alone and mixed with coir (1:1 V/V)

Material	G_t	G_n	G_t+C	G_n+C	C
Treated grape marc (%)	100	0	50	0	0
No treated grape marc (%)	0	100	0	50	0
Coir (%)	0	0	50	50	100

Cultivation trial was carried out in the experimental greenhouse of Marche Polytechnic University, using tray plants container (104 holes; volume unit 0.03 l). Treatment were arranged in a completely randomized block design (4 blocks and 12 replicates per block). Container holes were initially filled with substrates and seeded (21.04.2015) manually using a pair of tweezers, depositing three seeds per each hole. After seeding, seeds were covered with the respective substrate, placed on an aluminum table and wet with water to ensure an adequate moisture for germination. Containers were raised to avoid contact with the bottom of the table, allowing an air-pruning effect (the root grows within the cell volume). After one week from the beginning of germination, seedling in the holes were thinned to obtain one seedling for each hole. During the cultivation, plants were irrigated using micro spray irrigation system, providing 1.5 liters of water daily divided into 5 irrigation events and spraying 2 l of additional water, to maintain constant the moisture of the substrate, and fertilized with 0.21 g / plant complex fertilizer (Osmocote bloom 2-3M) controlled release (12% N, 7% P_2O_5 and 18% K_2O, MgO 1.5%, 0.01% B, 0.045% Cu, 0.35% Fe, 0.05% Mn, 0.017% Mo, 0.013% Zn).

At the end of experiment (after 30 days from germination) 16 plants for each treatment were harvested. Above-ground portion (shoot and leaves) and roots fresh and dry weight, shoot and root length, shoot diameter, leaf area were measured. Chlorophyll content was determinated using SPAD meter. Collected data were subjected to analysis of variance (ANOVA) and differences were compared using mean separation by Tukey-Kramer HSD test. Statistical analysis was conducted using JMP Software (Release 8; SAS Institute Inc., Cary, NC, USA, 2009).

3.2.6 Experiment 3 – Results and discussion

By washing, electrical conductivity of marc leachate has been gradually reduced (Figure 14.), from 1.8 $mScm^{-1}$ to 0.59 $mScm^{-1}$. After the first three washings, EC decreased rapidly, then the values maintained very similar, around 0.62 $mScm^{-1}$.

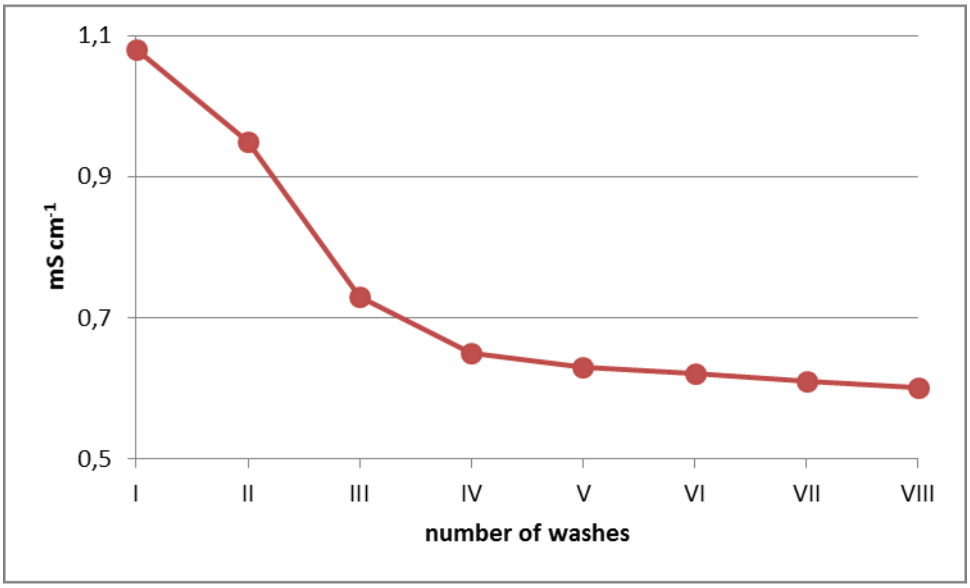

Figure 14. Electric conductivity variation of grape marc during washing. Values are referred to the water collect after 2 minute of wash.

An increase of cress germination index (Table 18.) resulted for seeds in contact with treated marc extract (IG: 76.7), compared to seeds put in contact with non-treated marc (IG: 41.8). Differences in germination index may be due to an increase of root elongation in treated marc extract compared to non-treated marc; the number of germinated seeds was similar for both treatments and compared to control. The roots length increased from an average of 11 mm (non-treated) to an average of 18 mm (treated), showing a significant difference. Washing operations reduced electric conductivity and improved the response to the bioassay. However, an effect of marc seemed to persist on plants and the roots length measured for treated marc was significantly lower than the control.

Table 18. Results of bioassay. Number of germinated seeds, roots length and germination index od cress. Number of germinated seeds was analyzed with chi2 test. Roots length was analyzed with Tukey test (p<0.05). Different letters indicate significant differences.

	n. of germinated	Root length (mm)	Germination index
Control	47 ns	23 a	100
Treated marc	41 ns	18 b	76.7
No Treated marc	46 ns	11 c	41.8

As shown in Table 19. washing operations reduced the EC of marc from 3.33 mScm^{-1} to 0.12 mScm^{-1}. Also mixing marc with other materials reduced the EC value to 1.56 mScm^{-1} in the mix with peat and 1.52 in the mix whit coir, that also influenced the pH, higher for coir than peat.

Table 19. Chemical properties of treated (G_t) and no treated (G_n) marc sole or mixed (1:1 V/V) with sphagnum peat (P) or coir (C) evaluated using a water extract 1:5 (V/V)

	G_t	G_n	G_t+P	G_t+C	G_n+P	G_n+C	P	C
pH	6.44	6.55	5.42	6.48	5.09	6.69	4.31	6.75
EC	0.12	3.33	0.49	0.63	1.56	1.52	0.44	0.52

This experiment confirmed the unsuitability of non-treated marc that showed low % of germination and germinated seediling died before the end of the test. Basil germination on mix of non treated marc and peat and coir did not show drawbacks, seeds germinated without problem and more than 70% of seedling completed the cultivation cycle. Looking at the percentage of seedling that died before the end of the trial (Table 20.), this is higher for 100% treated marc and mix containing non treated marc compared to coir and peat and treated marc mix.

Table 20. Percentage of died plants on treated (G_t) and no treated (G_n) marc sole or mixed (1:1 V/V) with sphagnum peat (P) or coir (C) after 30 days of cultivation. For each substrates 48 plants were grown.

	G_t	G_n	G_t+P	G_t+C	G_n+P	G_n+C	P	C
Dead plants (%)	18.8	0	6.3	8.3	6.3	20.8	4.2	4.2

Table 21. shows the results of basil growth on substrate of sole marc or mix with peat. Basil stem length, after 30 days of cultivation was higher for plants grown on treated marc mixed with peat (11.3 cm) and in peat (10.7 cm), without significant difference between them, compared to height of basil cultivated using the non-treated marc mixed with peat (8.96 cm) and 100% treated marc that showed the lowest significant values (7.10 cm). Shoot diameter was high for plants grown on treated marc and peat mix, without significant differences compared to plants grown on 100% peat. Plants grown on sole treated marc showed lower value of shoot diameter compared to other treatments. Mix of treated marc and peat showed no significant difference compared to 100% peat. Fresh weight of above-ground portion (shoot and leaves) was higher for basil grown on peat (2.49 g) and for treated marc mixed with peat (2.88 g), significantly different compared to the fresh weight of plants grown on non-treated marc mixed with peat (1.83 g) and 100% treated marc (1.21 g). 100% treated marc showed the lowest value of dry weight of above-ground portion compared to other treatment. No significant difference of dry weight of above-ground portion between treated marc mixed with peat and 100% peat. Root length was higher for plants grown on peat (7.99 cm) and on 100% treated marc (6.81) compared to mix of treated marc and peat (5.32 g) and non-treated

marc and peat (4.13 g). Roots fresh weight was higher for peat and for mixes of marc and peat compared to 100% treated peat. Dry roots weight showed no significant difference between 100% peat, treated marc mixed with peat and non-treated marc mixed with peat. 100% treated marc showed the lowest value of roots dry weight (0.03 g), significant difference compared to treated marc mixed with peat (0.08 g).

Table 21. Influence on growth of treated (G_t) and no treated (G_n) marc sole or mixed (1:1 V/V) with sphagnum peat (P) used as substrate for basil transplant grown. Different letter represent significant difference (Tukey test $p<0.05$).

	shoot				root		
	Height (cm)	**Diameter (mm)**	**Fr.weight (g)**	**Dry weight (g)**	**Length (cm)**	**Fr.weight (g)**	**Dry weight (g)**
P	10.7 ab	2.04 ab	2.49 a	0.24 a	7.99 a	0.76 ab	0.06 ab
G_t+P	11.3 a	2.21 a	2.88 a	0.19 ab	5.32 b	0.94 a	0.08 a
G_n+P	08.9 bc	1.75 bc	1.83 b	0.10 bc	4.13 b	0.70 ab	0.05 ab
G_t	07.1 c	1.42 c	1.21 b	0.08 c	6.81 a	0.44 b	0.03 b

Shoot Fr. weight (fresh weigh) and dry weight are referred to weight of stem and leaves.

Table 22. show the results of shoots and roots growth of basil plants in different marc based substrates with and without coir. Also seedling grown on a mix of treated marc and coir showed the highest value of stem length (11.5 cm) without significant differences compared to basils grown on coir (10.63). A reduction of plants height was shown in basil grown on non treated marc mixed with coir (6.4 cm) and basil on 100% non treated marc (7.1 cm), with significant difference compared to coir and treated marc and coir mix. Shoot diameter was high for basil grown on treated marc and coir mix, without significant difference compared to plants grown on 100% coir. Plants grown on 100% treated marc showed the lowest value of shoot diameter, non-treated marc mixed with coir showed values without significant difference compared to mix of treated marc and coir. Fresh weight of above-ground portion (shoot and leaves) was higher for basil grown on coir (2.13 g) and for treated marc and coir (2.02 g), significant different to the fresh weight of plants grown on 100% treated marc (1.21 g), without differences. No significant difference of dry weight of the above-ground portion between coir and treated marc mixed with coir (highest values), and between non-treated marc mixed with coir and 100% treated marc (lowest values). Respect to the root length, no significant differences were found between basil grown on coir, mix of treated marc and coir and 100% treated marc, plants roots grown on mix of treated marc and coir showed the lowest value of root length, significantly different compared to the other treatments. Root fresh and dry

weights were higher for plants grown on coir and mix of treated grape marc and coir compared to mix of non-treated marc mixed with coir and 100% treated marc

Table 22. Influence on growth of treated (G_t) and no treated (G_n) marc sole or mixed (1:1 V/V) with coir (C) used as substrate for basil transplant grown. Different letter represent significant difference (Tukey test p<0.05).

	shoot				root		
	Height (cm)	**Diameter (mm)**	**Fr.weight (g)**	**Dry weight (g)**	**Length (cm)**	**Fr.weight (g)**	**Dry weight (g)**
C	11.5 a	2.08 a	2.13 a	0.15 a	7.02 a	1.04 a	0.07 a
G_t+C	10.6 a	1.84 ab	2.02 ab	0.14 ab	8.02 a	1.02 a	0.08 a
G_n+C	06.4 b	1.57 bc	1.30 ab	0.05 c	2.29 b	0.26 b	0.02 b
G_t	07.1 b	1.42 c	1.21 b	0.08 bc	6.81 a	0.44 b	0.03 b

Shoot Fr. weight (fresh weigh) and dry weight are referred to weight of stem and leaves.

Figure 15. show the results of leaf area of plants grown using treated grape marc mixed or not with sphagnum peat. Basil leaf area of plants grown on substrate composed of mix of treated marc and peat showed the higher values, significantly different compared to mix of non-treated marc and peat (46.7% less than treated marc mix) and compared to 100% non-treated marc (54.9% less than treated marc mix). No significant differences were found compared to leaf area of treated marc mix and peat. Also for the combinations of marc and coir (Figure 16.), leaf area on substrate of treated marc and coir mix showed the higher value, compared to mix of non treated marc and coir (71.0% less than treated marc mix) and compared to 100% non-treated marc (48.8% less than treated marc mix).

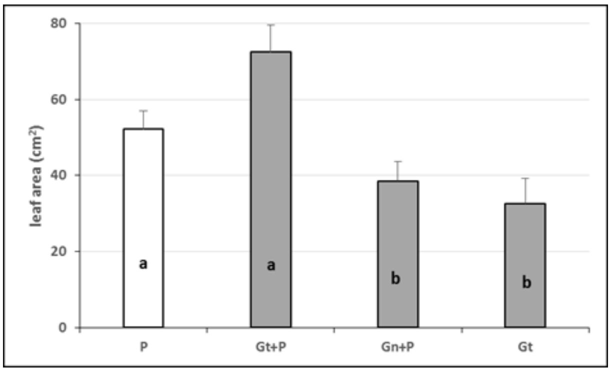

Figure 15. Leaf area of plants grown on treated (G_t) and non-treated marc (G_n) sole or mixed (1:1 V/V) with sphagnum peat (P). Bars indicate the standard error, different letters indicate a significant difference between treatments (Tukey-Krament HDS test, p<0.05).

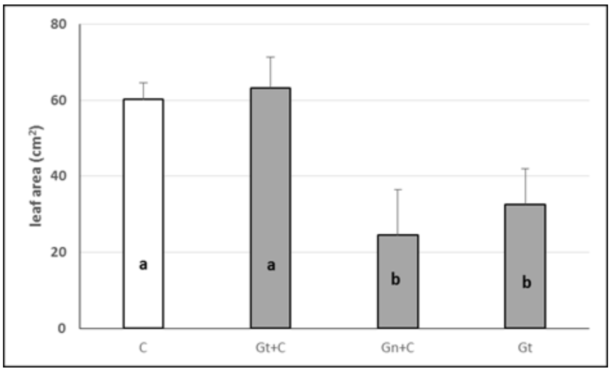

Figure 16. Influence on growth of treated (G_t) and non-treated marc (G_n) sole or mixed (1:1 V/V) with coir (C). Bars indicate the standard error, different letters indicate a significant difference between treatments (Tukey-Krament HDS test, p<0.05).

Chlorophyll content was evaluated using SPAD meter (Table 23.). No significant differences were found comparing treated grape marc with grape marc mixed with materials as coir and peat.

Table 23. Influence of treated (G_t) and no treated (G_n) marc sole or mixed (1:1 V/V) with sphagnum peat (P) or coir pith (C) on chlorophyll after 30 days of cultivation. Chlorophyll content was express in SPAD unit.

Treatment	SPAD	Treatment	SPAD
P	25.9 ab	**C**	23.9 a
G_t+P	25.5 ab	**G_t+C**	22.8 a
G_n+P	26.4 a	**G_n+C**	20.7 a
G_t	23.9 b	**G_t**	23.9 a

On the base of the results obtained in the laboratory and in the greenhouse experiments, would seems that washing operations contributed positively to increase the suitability of grape marc as growing media, reducing the electric conductivity (probably the main limiting factor affecting the plant growth), allowing to basil seeds to germinate. However, mixing with another component (such as peat or coir) seems more advantageous, indeed the plants growth using treated marc mixed with peat or coir showed no significant differences compared to the plants grown on coir or peat. Treated grape marc mix gave results comparable to peat or coir, which have proved to be suitable for container plant cultivation. The washing operations probably increased the chemical suitability of this material as substrate and the mixing with another component probably improved the physical characteristics, suggesting the possibility to use pretreated marc as a component for substrate mix.

3.2.7 Conclusions

A series of different cultivation trials were realized to evaluate the possibility to reuse different organic by-product as growing media. The vegetable transplant cultivation model was mainly used. Differences in the plants growth are on the basis of different material characteristic and their suitability to be used sole or mixed.

In all the performed experiments, a positive response of plants to substrate containing coir was detected, especially for fine fraction (100% coir pith) and medium fraction (70% coir pith and 30% coir fiber). Plants grown on substrate containing coir showed highest above-ground portion and roots growth, with a possible positive effect, without highlighting a reduction of the growth when peat was completely replaced by coir that suggested the possibility to be used as main constituent for substrate mix.

Interesting results were also obtained using compost, and the use in purity or mixed with peat did not show significant differences. Two experiments showed the highest plants growth, comparable with the growth registered using coir, in some cases higher than the growth on peat.
For coir and for green compost, the research confirmed the suitability as growing media component sole or mixed with peat. For hemp and grape marc, some limitation in their use were underlined.

Hemp fine fraction seemed to not support adequately the growth of plants, which resulted small and poorly grown. For the hemp gross fraction, its suitability seems to increase when mixed with another component like peat. This could be related to the high porosity of the material with poor water holding capacity. Mix with other media (with more capillary properties) increased the plants growth compared to 100% hemp fiber, but using 50% by volume still seems to give not good results. Probably the percentage of gross hemp use in a mix with peat should be decreased.

For grape marc, the main limit is probably the high electric conductivity. Washing operations reduced the electrical conductivity and increased the application possibility by increasing the germination rate and decreasing the number of dead plants at the end of the trial. However, the best results were obtained when the washed material was mixed with other materials suitable for cultivation.

The possibility to use hemp and grape marc as growing media components, for now, seems to be connected to pre-treatments and mixture with other components.

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4 REPLACEMENT OF PEAT WITH ORGANIC BY-PRODUCTS FOR POTS ORNAMENTAL SPECIES CULTIVATED WITH EBB AND FLOW SYSTEM

Usually made by a mix of different material, substrate plays a fundamental role in soilless production, supporting plants growth and used by the horticultural industry as well as by consumers. Peat is the main organic constituent of available substrates, which has earned a reputation among media producer and growers for a good and unique combination of useful properties for plants cultivation (Schmilewski, 2014). An example is provided to the well-known sphagnum peat, that has proven to having adapted structures which store and transfer water through a network of hollow vessels and pores (Caron et all., 2005) giving large water holding capacity and excellent capillary rise properties (Puustjarvi, 1978).

In the last decades, because of the possible environmental implication connected to peat extraction, specific actions to discourage the use of peat in horticulture are in place. In 2011 the UK Government issued a “White Paper” (HM Government, 2011) scheduling the phase-out of peat in the hobby market by 2020 and in commercial horticulture by 2030. Such developments are also reflected in the EU Commission environmental quality criteria, stating growing media may not be awarded the EU *Ecolabel* if containing peat (EU Commission, 2006).

Peat may be partially or totally replaced by renewable resources like local organic by-products such as compost and wood fiber, with possible advantage about coasts and environmental impact.

Compost for horticultural use is product with a biological decomposition under controlled aerobic condition; using a wide variety of organic matters such as animal manures, food processing, wastes, bark, tree pruning and many others (Raviv, 2013).

Wood fibre is a renewable resource produced from fresh or waste-wood (i.e. pallets) (Maher et all., 2008); usually from spruce (*Picea* spp.) or pine trees. Wood fibre generally don’t contains bark, and the production consists of material defibration and pressing and material stabilization; at temperature between 110 °C and 160 °C (Cattivello, 2009).

Reuse of organic by-products, as media component, could give added value to waste and reduce production and transport costs. At the same time, suitability of use of by-products in substrate mix must be assessed on the basis of the substrate characteristics, and connected with cultivation techniques.

The possibility to partially and totally replacement of peat with compost and wood fiber have been evaluated for two ornamental species cultivated using ebb and flow irrigation system; a subsurface system based on substrate capillary rise properties to bring irrigation solution into the root zone from below.

The comparative cultivation trials were carried out between June 2015 and September 2015, under controlled environment at Wagenigen UR Greenhouse Horticulture Bleiswijk, the Netherlands. At the same time, the main physical, chemical and biological substrate properties were evaluated, focusing on substrate/water relationship.

4.1 Materials and methods

4.1.1 Substrates chemical and biological characterisation

pH and electric conductivity (EC) were analyzed using water extract (1:1.5 V/V). Substrate volume was measured in a double ring cylinder with 5 cm height and a volume of at least 100 ml and pressed at 10 KPa. After compression, double ring were separated and sample from bottom ring (60 ml) was added in 90 ml of demineralised water and mixed, after one hour the solution was measured.

Ccompost toxicity (Blok et all. 2008), was tested evaluating the growth (shoots and root elongation) of different seed species: *Sorghum saccharatum* (sorghum), *Lepidium sativum* (garden cress) and *Sinapis alba* (mustard) germinated on a water extraction solution. The solution was obtained submerging with demineralized water a volume of different compost (ratio: 1:2 V/V), for 24 hours. Then the solution was filtered and pH and electrical conductivity, adjusted to standard values. For the bioassay, 80 ml of each extraction were used to wet the bottom compartment of a test plate (21 cm x 16 cm), filled with rock wool, and covered with 0.5 mm thick filter paper where ten seeds of each species were placed in a single row. Plates were closed and incubated for 3 days at 25 °C, in darkness. As control was used a standard solution (pH: 5.5 and EC: 2.2 mS/cm). Four replicates for each assay were made and measure roots and shoots lengths were subjected to analysis of variance (ANOVA) and differences were compared using mean separation by Tukey-Kramer HSD test. Statistical analysis was conducted using JMP Software (Release 8; SAS Institute Inc., Cary, NC, USA, 2009.

4.1.2 Substrates physical characterisation

Main physical characteristic of substrate tested, were measured according to European Standard method (EN 13041), using known volume samples placed on suction box, where different suction forces were applied.

The method is based on the principle that the substrate ability to hold water is a function of total pore space and suction force applied. Tension at which water is retained by a porous solid as substrate represents the force applied by roots to absorb water from growing media. More negative is the potential, higher will be the required force to extract water. This tension could be expressed as cm of water column or pF (logarithm base 10 of cm of water column).

Suction table (Figure 1.) consists of a rigid container, with a drainage system at the bottom connected to an adjustable overflow, partially filled by a layer of sand which allows the contact between substrate and drainage system. Equilibrium between water filled substrate pore space and sandy bed were registered using different suction forces: -10 cm (pF 1), -31.6 cm (pF 1.5) and -50 cm (pF 1.7), brought about as negative pressures related to the water level set by the adjustable overflow. Point between -10 cm and -50 cm represent easily available water (EAW) for plants, and relationships between water and substrate are described by water retention curve, which represents the amount of water hold at different pressure.

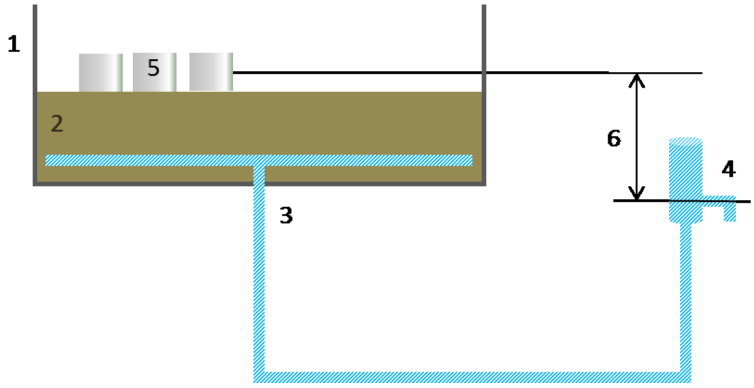

Figure1. Schematic suction table.
1 - box container
2 - Sandy bed connects (by capillarity) the moist sample with an overflow, through a drainage system
3 - drainage system
4 - adjustable overflow
5 - substrate sample
6 - Suction applied to sample is defined as the difference between the overflow and the half height of the sample

For the characterization, 2 liter cylinder were filled by substrate without applied pressure and saturate with water for 24 hours and equilibrated on a sandy box at – 50 cm. Then substrates were transferred into double ring cylinders with a diameter of 10 cm, height of 5 cm and volume of 392.5 cm^3, re-wetted and equilibrated at –10 cm water pressure head from the middle of the lower ring for 48 hours. Then ring cylinder sample were removed from sand box and carefully separated, surface of lower cylinder leveled with a straight, removing the excess of matter, and then the lower cylinder sample were weighted. Following the same method, other two different suction forces were applied and then samples weights were registered. At the end samples were dried for 48 hours in the oven at 105 °C to obtain dried weight, and substrate characteristic obtained using the following formulas:

$$D_{BD}: (D_w/V)\,x1000$$

D_{BD} is the dry bulk density in kilograms dry matter per cubic meter
D_w is the mass in grams of the dried substrate sample
V is the volume in cubic centimeter of the sample ring

$$T_{PS}: (1-(D_{BD}/P_D))\,x100$$

T_{PS} is the percentage by volume of substrate amount of empty space
D_{BD} is the dry bulk density in kilograms dry matter per cubic meter
P_D is particle density, calculates using the organic matter content and ash content measured in accordance with EN 13039.

The water volume content of substrate sample, at different suction applied was calculated as:

$$W_v = ((F_w - D_w)/V)\,x100$$

W_v express the water volume content, as percentage by volume. Wet sample at different centimeter pressure head (different suction applied: -10, - 31.6, -50 cm)
F_w is the mass in grams of the wet sample at different centimeter pressure head
D_w is the mass in grams of the dried substrate sample
V is the volume in cubic centimeter of the sample ring

The air volume content of substrate sample, at different suction applied was calculated as:

$$A_V = T_{PS} - W_v$$

A_V express the air volume content, as percentage by volume. Wet sample at different centimeter pressure head (different suction applied: -10, - 31.6, -50 cm)
T_{PS} is the percentage by volume of substrate amount of empty space
W_v express the water volume content, as percentage by volume. Wet sample at different centimeter pressure head (different suction applied: -10, - 31.6, -50 cm)

A second physical characterization was made, to evaluate the rehydration rate (Figure 2.), defined as the increase of moisture content of a dried sample over a set period of time. Cylinders set having a capacity of 500 cm^3 (double ring ccylinder with volume of 250 cm^3) closed on the bottom by a nylon canvas were filled with different substrates. Substrates were pressed at a pressure of 10 kPa (0.1 kg / cm^2, a weight of 3.0 kg on the total substrate surface). Cylinder set were placed in the suction box, with the sandy surface covered by 2.5 cm of water. After water level was increased of 6.5 cm above sandy surface and samples were saturated for 24 hours and then equilibrated to -100 cm (from the middle of lower cylinder) for 24 hours. Cylinders were separated; the lower one was levelled and dried at a temperature of 40 °C in the oven for 72 hours to obtain a constant weight.

Dry samples were placed in a box with 2 mm of water and after 1 minute placed on a scale to determinate the fresh weight. The operation of weighting was repeated after 3, 7, 15, 30, 60 minutes. Samples were dried at 105 °C for 48 hours to determinate the dry weight (Dw). The percentage of water uptake at different time was calculated as:

$$(F - D_W)/V \times 100$$

F is the mass in grams of wet sample after adsorbing water

D_W is the mass in grams of the dried substrate sample

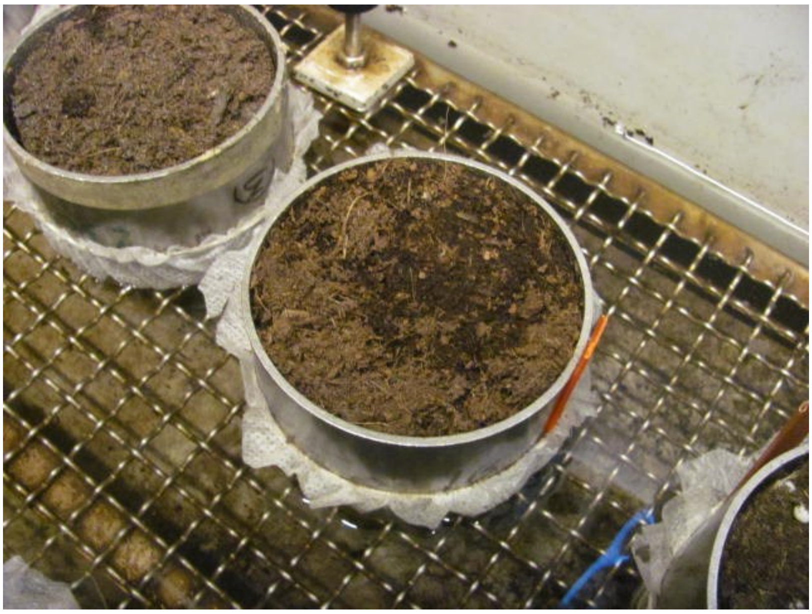

Figure 2. Rehydration rate is usually determinate using a standard dimension sample, dried and placed on a thin water layer to record the increase of water absorbed over a set period of time. A slow rehydration rate increase the risk on hydrophobicity especially in the case with high evapotranspiration.

4.1.3 Experiment 1

Treatments compared were made adding 25% of three different compost to a mix of 52.5% of white peat and 22.5% of coir. For this experiment, different kinds of compost were used: compost 1 (C1) and compost 2 (C2) produced from organic household wastes. Compost g (Cg) produced from green materials (green compost) such as tree branches, leaves, grass clipping and plants residues.
As Reference was used a substrate composed by 70% of white peat and 30%. Substrates were made mixing different amount of raw material by volume, and then fertilized, and used to fill cylinder plastic pots (volume: 750 ml).
Experiment was realized with a completely randomized block design, with three blocks and twenty replicates per block, evaluating the growth of two ornamental species: Begonia var. Elektra Pink (plug paper pots) and Chrysanthemum var. Euro Sunny (rooted cuts). For twelve days after transplanting, plants were irrigated from top by hand, than during cultivation trials, water and nutrition were provided with a fertirrigation solution (Table 1.), using ebb and flow system (Figure 3). Duration of irrigation was of seven minute for each benches, with a frequency of twice a week for Begonia and four times per week for Chrysanthemum (increased to seven times during the last week of cultivation).
At the end of experiment, after eight week from transplanting, seven plants of each replicate (21 plants per treatment) for both species were collected and fresh and dry weight of shoot and flower and shoot length were recorded. Collected data were subjected to analysis of variance (ANOVA) and differences were compared using mean separation by Tukey-Kramer HSD test. Statistical analysis was conducted using JMP Software (Release 8; SAS Institute Inc., Cary, NC, USA, 2009).

Figure 3. Flooded benches ("ebb and flow" system) are designed to submerging with water solution the bottom of the pots placed on benches. During irrigation, substrate portion submerged is above container capacity. When the irrigation is finished, the excess of water is drained, and substrate holding water on the base of its physical characteristics. To achieve maximum uniformity each pots should be submerged (simultaneously) to the same depth for the same time. The duration of the irrigation must be long enough to allow water to be drawn up into the top portions of the root zone by capillary action. The depth, the duration and frequency of irrigation are direct connecting with the substrate hydraulic conductivity.

Table 1. Nutrient solution used for plants during the trial.

Element	Unit	Begonia	Chrysanthemum(vegetative)	Chrysanthemum (reprod.)
EC	mS/cm	1.6	2.1	1.7
NO_3-	mmol/l	10.87	14.22	9.78
SO_4--	mmol/l	1.04	1.34	1.91
P-	mmol/l	1.46	2.00	1.70
NH4+	mmol/l	1.27	1.38	1.06
K+	mmol/l	4.09	7.40	7.12
Ca++	mmol/l	3.76	4.06	2.71
Mg++	mmol/l	0.75	1.00	0.85
Fe	µmol/l	20	20	20
B	µmol/l	10	10	10
Mn	µmol/l	5	5	5
Zn	µmol/l	3.0	3.0	3.0
Cu	µmol/l	0.8	0.8	0.8
Mo	µmol/l	0.5	0.5	0.5

4.1.4 Experiment 2

Three substrates tested were realized using different raw materials: white peat, coir, compost from household waste and wood fiber from soft wood, mixed as described below:

- Treatment 1 (T1): 25% peat, 25% coir, 25% compost, 25% wood fiber

- Treatment 2 (T2): 33.3% peat, 0% coir, 33.3% compost, 33.3% wood fiber
- Treatment 3 (T3): 0% peat, 33.3% coir, 33.3% compost, 33.3% wood fiber

In the second experiment also coir was completely replaced in one treatment (T2) using 66.6% of alternative materials. As reference was used a substrate composed by 70% of white peat and 30% of coir. Like described for experiment 1, substrate testes were obtained mixing different amount of raw materials by volume, which were, after mixing, fertilized. Experiment was realized with a completely randomized block design, with three blocks and twenty replicates per block, using pots Chrysanthemum var. Euro Sunny (rooted cuts) transplanted in cylinder plastic pots (volume: 750 ml). For twelve days after transplanting, plants were irrigated by hand from top to help plants rooting, then water and nutrition were provided with a fertirrigation solution, using ebb and flow irrigation system, for seven minutes, four times per week (increased to seven times during the last week of cultivation).

As for the experiments 1, at the end of experiments, using seven plants each replicate (twenty one plants per treatments) was evaluate the plants growth, using the following parameters: shoot and flower dry weight, flower number and shoot length. Data were subjected to analysis of variance (ANOVA) and differences were compared using mean separation by Tukey-Kramer HSD test. Statistical analysis was conducted using JMP Software (Release 8; SAS Institute Inc., Cary, NC, USA, 2009).

4.2 Results and dicussion

4.2.1 Experiment 1

In Table 2. and Table 3. Are summarize the results of pH and electric conductivity (EC) of pots at the beginning of trials and after eight weeks of cultivations are summarize.

Table 2. pH and electric conductivity (EC) of Begonia substrate, at beginning and at the end of the experiment. Analysis is referred to a water extract (1:1.5 V/V).

	Beginning of experiment		**End of experiment**	
	pH	**EC**	**pH**	**EC**
Reference	5.7	1.7	6.4	0.42
C1	5.6	1.4	6.5	0.79
C2	5.6	1.8	6.6	0.82
Cg	5.5	1.2	6.4	0.52

Table 3. pH and electric conductivity (EC) of Chrysanthemum substrate, at beginning and at the end of the experiment. Analyses are referred to a water extract (1:1.5 V/V).

	Beginning of experiment		**End of experiment**	
	pH	**EC**	**pH**	**EC**
Reference	5.7	1.7	6.1	1.2
C1	5.6	1.4	5.9	1.3
C2	5.6	1.8	6.1	1.1
Cg	5.5	1.2	6.0	1.0

For Begonia, after eight week of cultivation pH values increased, and electric conductivity decrease especially for reference. Look at result of chemical pots characteristics; also for Chrysanthemum was register an increase of pH at the end of cultivation and also a reduction of EC.

Results of phytotoxic test were expressed as shoot length (Figure 4.) and roots length (Figure 5.) of three species after three days of incubation and compared with control.

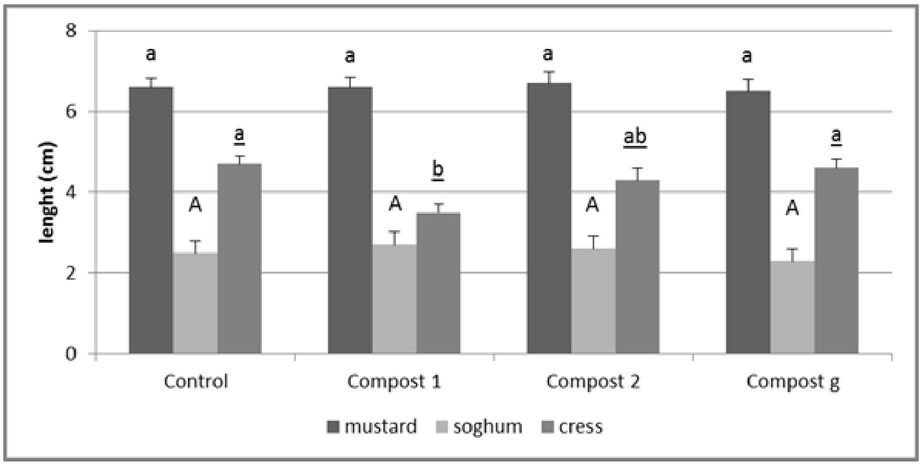

Figure 4. Shoot length of mustard, sorghum and cress, germinated and growth for three days on water extract of compost (1:2 V/V) compared to control. Bars indicate standard error, different letters meaning significant differences between treatments (Tukey test $p<0.05$).

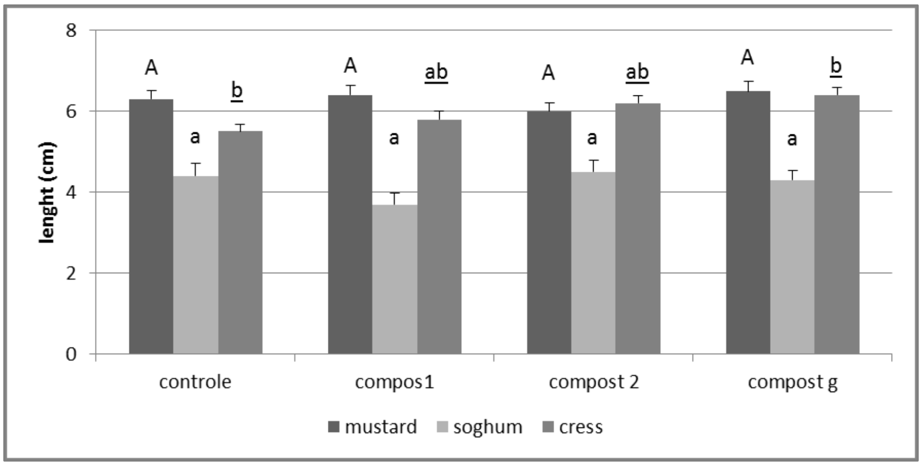

Figure 5. Root length of mustard, sorghum and cress, germinated and growth for three days on water extract of compost (1:2 V/V) compared to control. Bars indicate standard error, different letters meaning significant differences between treatments (Tukey test p<0.05).

For all species tested no significant difference were found compared shoot growth and roots growth of compost extract between treatments with control. Only cress shoot growth seems to be reduced using compost 1 (household waste), but looking at the overall results, it is possible exclude a toxic effect of three different composts used on plants development.

Begonia and Chrysanthemum growth, evaluated at the end of experiment with a series of biometric measures showed two different responses to the treatment. Begonia fresh weight (Figure 6.) of shoot (stem and leaves) was highest (126.1 g) for plants growth on reference (70% peat+30% coir) compared to the plants growth on substrate containing 25% of different composts. A reduction of begonia growth was found in treatment C1 and C2 containing household wastes, that showed the lowest values of shoot fresh weight (84 g). Also treatment Cg, containing 25% of green compost, showed low values of plants weight (98.5 g), with a result was significantly greater compared to C1 and C2. Whereas, for Chrysanthemum (Figure 7.) no significant differences were found in fresh weight of above-ground portion between treatments, showing an average values of 83.7 g

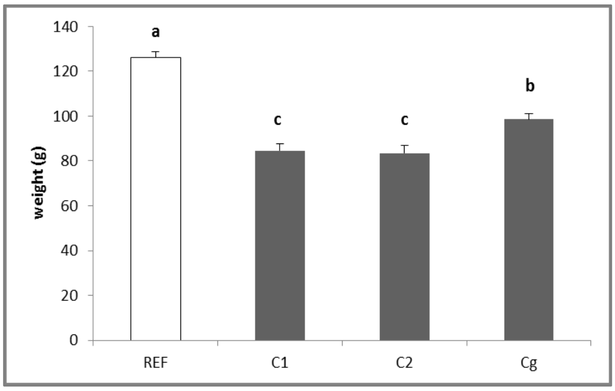

Figure 6. Begonia fresh weight of above-ground portion after eight week of cultivation. Treatment C1, C2 and Cg compared to reference. Bars indicate the standard error, different letters indicate a significant difference between treatments (Tukey-Krament HDS test, p<0.05).

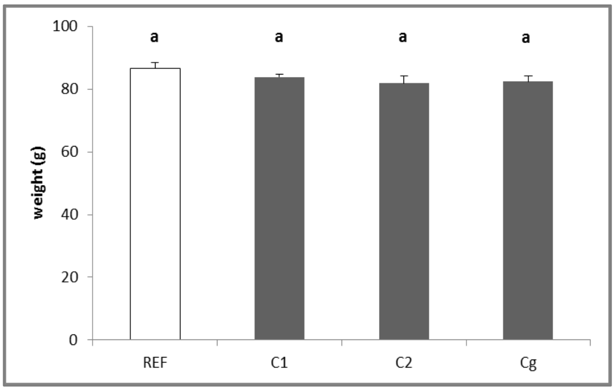

Figure 7. Chrysanthemum fresh weight of above-ground portion after eight week of cultivation. Treatment C1, C2 and Cg compared to reference. Bars indicate the standard error, different letters indicate a significant difference between treatment s (Tukey-Krament HDS test, p<0.05).

Considering plants height, for Begonia (Figure 8.), the highest values (18.8 cm) were found in plants growth on reference (70% peat and 30% coir), significant different to treatment C1 and C2 (25% household wastes composts) that showed the lowest values (16.1 cm). Also treatment Cg showed low Begonia height (17.6 cm) compared to reference, but greater than treatment C1 and C2.

For Chrysanthemums (Figure 9.), as showed for fresh weight, no significant differences of plants height between reference and treatment containing compost was found, showing an average height values of 35 cm.

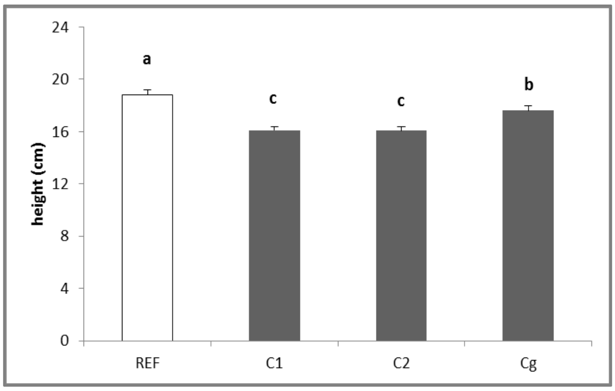

Figure 8. Begonia height after eight week of cultivation. Treatment C1, C2 and Cg compared to reference. Bars indicate the standard error, different letters indicate a significant difference between treatment (Tukey-Krament HDS test, p<0.05)

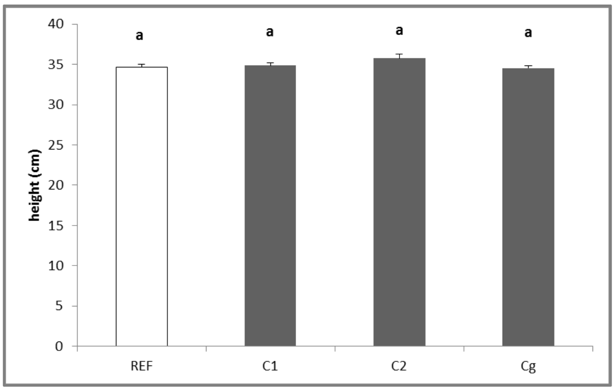

Figure 9. Chrysanthemum height after eight week of cultivation. Treatment C1, C2 and Cg compared to reference. Bars indicate the standard error, different letters indicate a significant difference between treatment (Tukey-Krament HDS test, p<0.05)

Table 4. summarize the results of Begonia growth at the end of the experiment (Figure 10.). As observed for fresh weight and height, also dry weight, confirm that there was a reduction of plants growth using substrate containing composts, especially on treatment C1 and C2. Growth reduction seems only about vegetative development (shoots), indeed flower production (fresh and dry weight) showed no significant difference between treatments.

Table 4. Effect of substrate containing 25% of different control and reference (70% peat and 30% coir) of Begonia growth after eight week. different letters indicate a significant difference between treatment (Tukey-Krament HDS test, $p<0.05$)

Treatment	Fresh weight (g)		Dry weight (g)		Height (cm)
	Shoot	Flower	Shoot	Flower	Shoot
Reference	126.1 a	15.1 a	6.9 a	0.6 a	18.8 a
C1	84.5 c	14.8 a	5.0 c	0.6 a	16.1 c
C2	83.5 c	12.7 a	5.3 c	0.6 a	16.1 c
Cg	98.5 b	13.7 a	5.8 b	0.6 a	17.6 b

For Chrysanthemum (Table 5.) no significant difference was found between treatments for all parameter measured, therefore plants grown using substrate containing 25% of compost can be consider similar to plants grown on the reference substrate (Figure 11.).

Table 5. Effect of substrate containing 25% of different control and reference (70% peat and 30% coir) of Chrysanthemum growth after eight week. different letters indicate a significant difference between treatment (Tukey-Krament HDS test, $p<0.05$)

Treatment	Fresh weight (g)		Dry weight (g)		Height (cm)
	Shoot	Flower	Shoot	Flower	Shoot
Reference	86.6 a	40.7 a	8.7 a	4.4 a	34.6 a
C1	83.7 a	41.0 a	8.4 a	4.4 a	34.8 a
C2	81.8 a	41.5 a	8.6 a	4.4 a	35.7 a
Cg	82.3 a	42.3 a	8.7 a	4.5 a	34.5 a

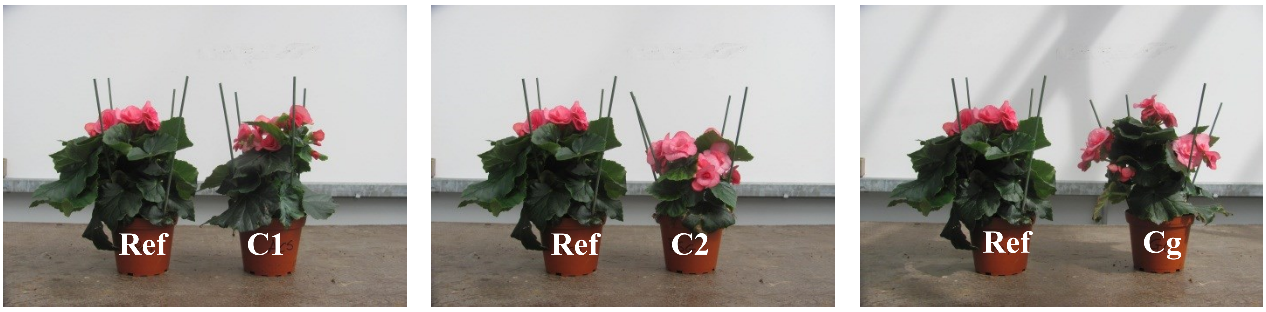

Figure 10. Begonia grown for eight week using substrate peat based containing 25% of different compost (C1,C2,Cg), compared to Begonia grown on a substrate 70% peat and 30% coir (reference). Lower growth was found for plants growth on C1, C2 and Cg compared to reference.

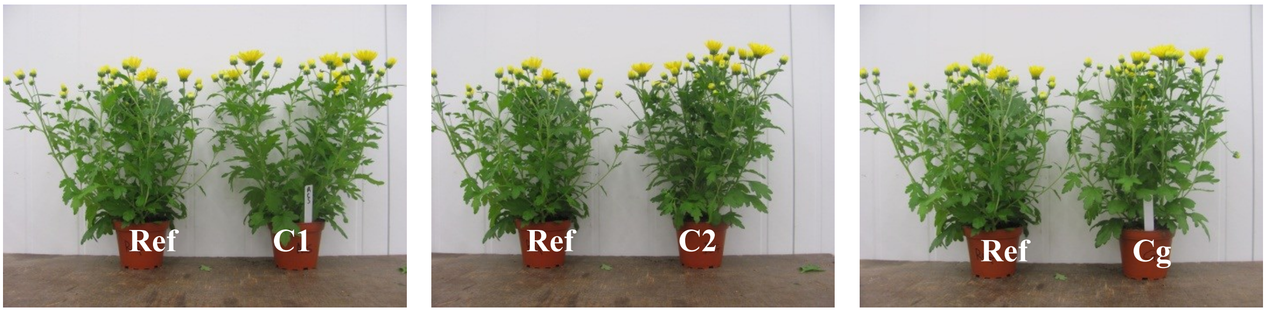

Figure 11. Chrysanthemum grown for eight week using substrate peat based containing 25% of different compost (C1,C2,Cg), compared to Chrysanthemum grown on a substrate 70% peat and 30% coir (reference). No growth difference was found comparing plants grown on different treatment.

Principal substrate characteristic were analysed, the results of water retention, are express using a curve (Figure 12.) of percentage of water retained by treatments at different suction forces. Low difference was found between treatments, probably partially due to the high percentage of peat included in all mixes. At point -10 cm the water retained for reference was 79.9%, and around 75% for the other treatment. At other two point used to describe the curve, difference between treatments are further reduced, with a percentage of water retained about 48% at -31.6 cm and about 43% at -50 cm, And so the presence of 25% of different composts mixed with peat and coir didn't create huge difference between treatments.

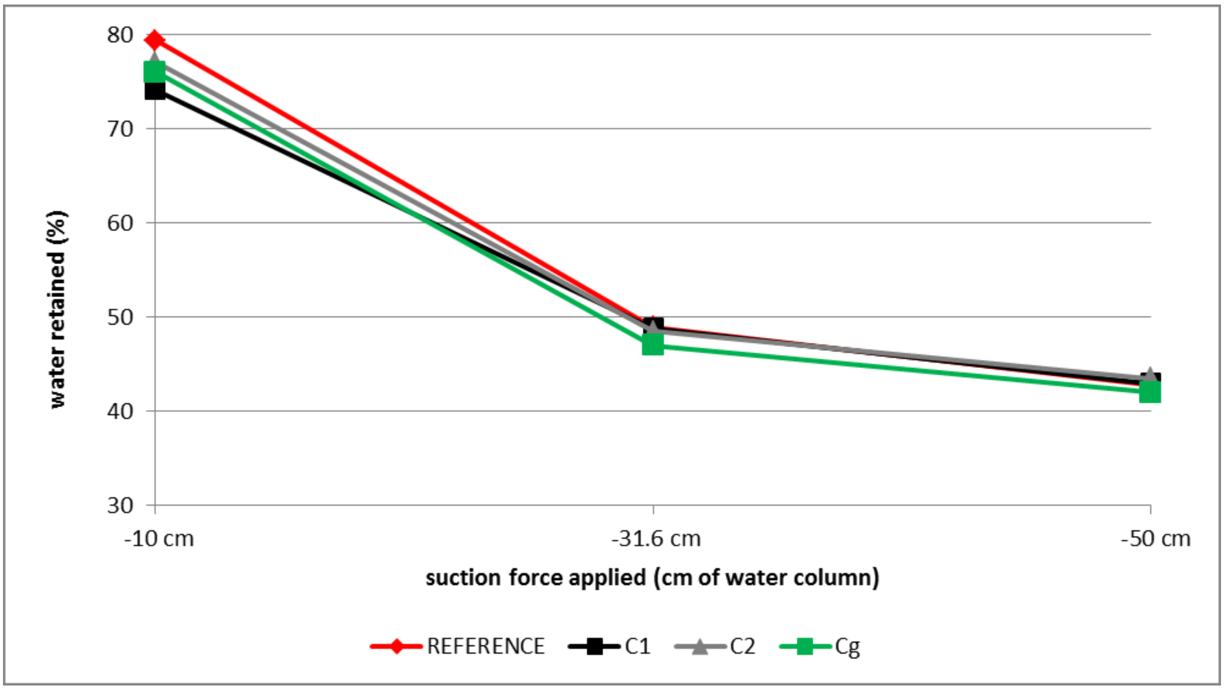

Figure 12. Water retention curve of treatment C1, C2 and Cg (52.2% peat, 22.5% coir and 25% of different type of compost) compared to Reference (70% peat, 30% coir).

In Table 6., show the results of the others main substrate characteristic: dry bulk density (D_{BD}), solids part, total pore space (T_{PS}) and air content percentage at three point used to create the water retention curves. The addition of 25% of composts increase a little bit the percentage of solid pars, and increased the dried bulk density, but substrates showing similar water retention ability also showed similar air content percentage.

Table 6. Physical properties of different substrate tested in the experiment 1. Dry bulk density (D_{BD}), volume percentage of solid parts, and total pore space (T_{PS}) and air volume at different pressure.

	D_{BD} gcm^{-3}	Solid part %	T_{PS} %	Air vol. -10 cm %	Air vol. -31.6 cm %	Air vol. -50 cm %
REF	104	6.3	93.7	14.3	44.8	50.9
C1	216	11.0	89.0	15.0	40.3	46.1
C2	202	10.5	89.5	12.5	41.1	46.1
Cg	195	10.0	90.0	14.1	43.0	48.0

At contrary, considering the results of rehydration rate (Figure 13.) calculated as percentage of water content (V/V) uptake at different time, a different attitude to absorb water was showed by treatments.

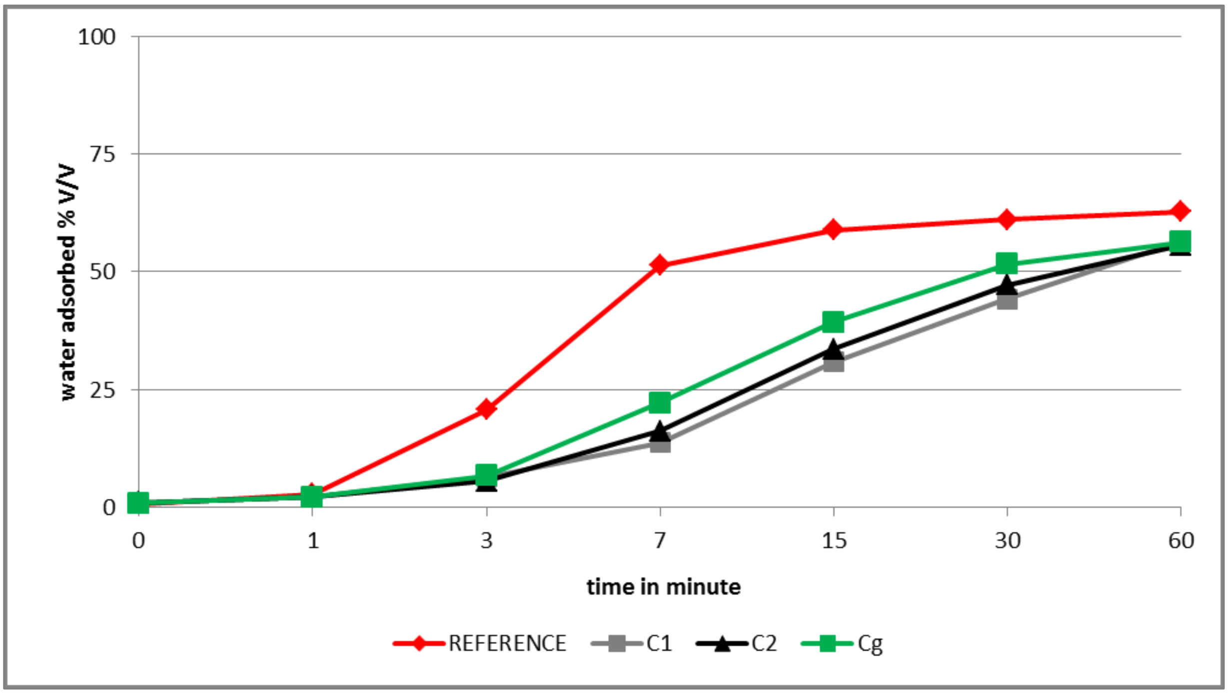

Figure 13. Rehydration rate of dry sample of C1, C2 and Cg (52.5% peat, 22.5% coir, 25% of compost), compared to reference (70% peat and 30% of coir).

The addition of 25% of compost seems to reduce substrate ability to uptake water by capillarity when substrate is dry. Reference (70% peat + 30% coir) showed the best rehydration rate compared to all treatments; adsorbing, after seven minutes (the same time of irrigation during cultivation trial), 50% of water (V/V). Treatments C1, C2 and treatment Cg showed a slow rewetting rate, absorbing less than 25% of water after 7 minutes. However, seems be a small difference between treatments Cg compared to C1 and C2. After 7 minutes the water absorbed by Cg was of 22% while C1 and C2 absorbed 15% of water. After 30 minutes, Cg absorbed 50% of water, while the other two treatments have absorbed 50% after 30 minutes. Different rewetting rate may have influenced different response of species during cultivation trial. Irrigation for Chrysanthemums was more frequent than Begonias, probably suitable to maintain constant substrate moisture, that didn't reduce to much the water content inside pots and its ability to adsorb water. While for Begonia two time irrigation per week, was too low for support plants growth using substrate containing composts. Substrate with slow water uptake require an increase of irrigation frequency, to maintain constant moisture level; during cultivation, substrate moisture decreased cause roots absorbing and evapotranspiration, a slow rewetting rate, increase risk of dry substrate and also the risk of hydrophobicity, especially with more evapotranspiration, meaning an irreversible loss of water retention.

In this experiment maintaining constant irrigation frequency and duration it benefitted plants grown on substrate with a fast rewetting rate, as detected for Reference, which showed best begonia performance. This possibility is also suggested by difference growth observed between treatment Cg and treatment C1 and C2. Begonia growth on Cg was higher than C1 and C2, and Cg seems to have faster rehydration rate compared to C1 and C2.

4.2.2 Experiment 2

In the Table 7. are summarizing results of pH and electric conductivity of raw materials used for experiment.

Table 7. pH and electric conductivity (EC) of raw materials used for the experiment. Analyses were referred to a water extract (1:1.5 V/V).

	pH	EC
Peat	4.5	0.11
Coir	6.9	0.18
Wood fibre	5.3	0.09
Compost	7.5	2.60

Peat and also wood fibre showed acid pH and the lowest electric conductivity. The pH of coir and compos was around neutrality and compost showed the highest electric conductivity. Than material were mixed for made substrate, and before to start to use fertilized water with ebb and flow system (after twelve days from transplant), pots pH and EC were evaluated, the analysis were repeated after 60 days from transplant at the end of cultivation trial. Results were summarized in Table 8.

Table 8. pH and electric conductivity (EC) of Chrysanthemum substrate, after 12 days and after 60 days from transplanting. Analyses are referred to a water extract (1:1.5 V/V).

Substrate	**After 12 days from transplanting**		**After 60 day from transplant**	
	pH	**EC**	**pH**	**EC**
Reference	5.7	0.7	6.1	1.2
T1	5.6	0.7	6.3	0.7
T2	5.6	1.1	6.8	0.9
T3	6.1	0.5	6.6	0.8

After 60 day of cultivation pH values were increased for all treatment, for EC seems to have been a slight increase for reference and treatment T3, while for treatment T1 and T2 was registered a slight reduction of EC.

Regarding compost biological properties, also in this experiments was possible exclude a phytotoxic effect because compost used for this experiment was the same compost used for previous experiment (Compost 1), for which no negative effects were observed with the bioassay.

After eight weeks, plants grown on Reference (70% peat and 30% coir) showed greater growth compared to the plants grown using alternative media. Treatment T1, T2 and T3 showed lowest plants height (31.5 cm) compared to reference (34.7 cm) (Figure 14.), also for fresh weight significant (Figure 15.) difference was found for treatment T2 and T3 (substrate without coir or peat) that showed lowest results (65.1 g). Treatment T1 made with 25% of all components showed plants fresh weight (71.3 g) lower than reference (86.7 g) but significant difference compared to treatment T2 and T3.

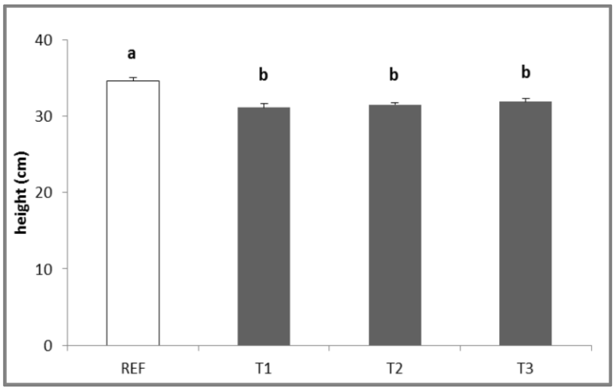

Figure 14. Chrysanthemum height after eight weeks of cultivation. Treatment T1, T2 and T3 compared to Reference. Bars indicate the standard error, different letters indicate a significant difference between treatments (Tukey-Krament HDS test, p<0.05).

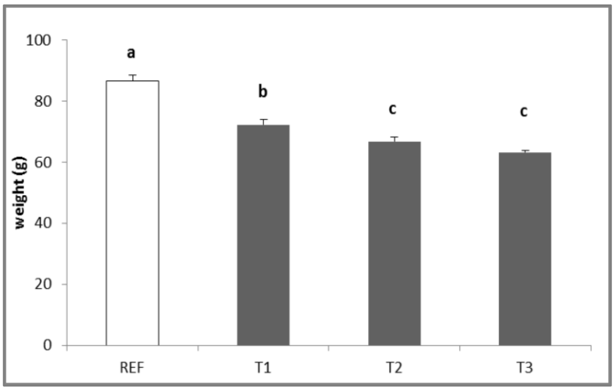

Figure 15. Chrysanthemum fresh weight of above-ground portion after eight weeks of cultivation. Treatment T1, T2 and T3 compared to Reference. Bars indicate the standard error, different letters indicate a significant difference between treatments (Tukey-Krament HDS test, p<0.05).

In Table 9. Are summarized results of Chrysanthemum growth at the end of experiment (Figure 16.). Pants dry weight (shoot) seems influenced by treatment, no significant difference between treatment T1, T2 and T3 that showed the lowest values (7.3 g) compared to reference (8.7 g). The reproductive development of plants, evaluated counting the flowers number (open flowers and buds), didn't underline differences between T1 and Reference, with an average flower number of 41, compared flowers produced in T2 and T3 with an average value of 36. No difference between treatments was found compared flower dry weight.

Table 9. Effect of substrate made with different raw materials and reference (70% peat and 30% coir) of Chrysanthemum growth after eight week. different letters indicate a significant difference between treatment (Tukey-Krament HDS test, p<0.05)

	Fresh weight (g)		Dry weight (g)		Height (cm)	Number
	shoot	flower	shoot	flower	shoot	flower
Reference	86.6 a	40.7 a	8.7 a	4.4 a	34.6 a	41.4 a
T1	72.3 b	37.6 ab	7.5 b	4.1 a	31.1 b	41.0 a
T2	66.8 c	36.8 ab	7.4 b	4.2 a	31.5 b	36.1 b
T3	63.2 c	35.9 b	7.0 b	4.0 a	31.9 b	35.6 b

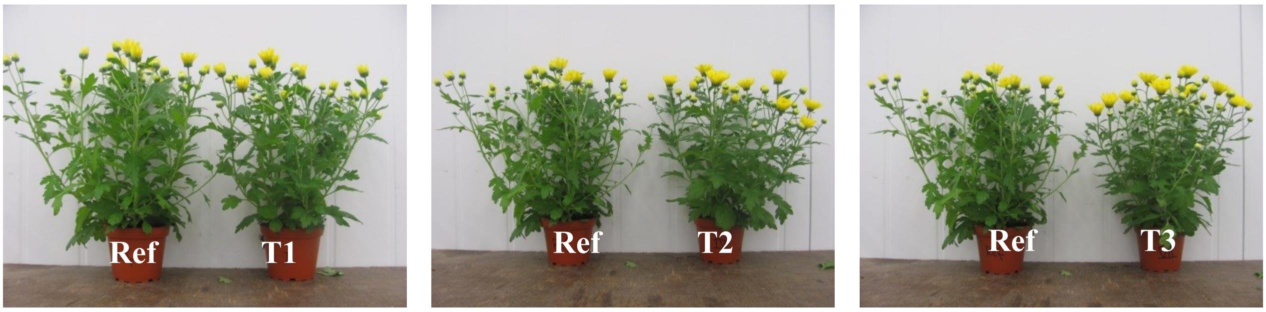

Figure 16. Chrysanthemum grown for eight week using substrate made with a mix of peat, coir, wood fibre and compost (T1,T2 and T3), compared to Chrysanthemum grown on a substrate 70 peat and 30% coir (reference). Lower growth was showed by plants grown on T1, T2 and T3 compared to Reference.

Also for this experiment the main physical characteristic of tested substrate were evaluated. In Figure 17. are represented the water retention curves of different substrate. Clear differences there are between treatments, Reference (70% peat and 30% coir) showed the highest water retention compared to others. Deletion of a component like coir or peat seems to have an effect to reducing the ability of substrate to retain water. At -10 cm treatment T2 (0% coir) and treatment T3 (0% peat) retained 58.2% of water, 21.2% less than Reference (79.4%), this difference has reduced about 11% as substrate became dry (-31.6 cm, -50 cm). Also treatment T1 (25% of all component) has been shown a reduction of water holding capacity compared to Reference, less than T2 and T3. At -10 cm treatment T1 retained 63.7% of water, 12.3% less than Reference, this difference has reduced about 6% at -31.6 cm and -50 cm. Removing one of component such as coir or peat, seems to have a gradual effect to reduce the ability of substrate to retain water. These differences could be connected with coir and peat that have known good water retention capacity, but also to the presence in the mix of other component like wood fibre that have drainage high capacity.

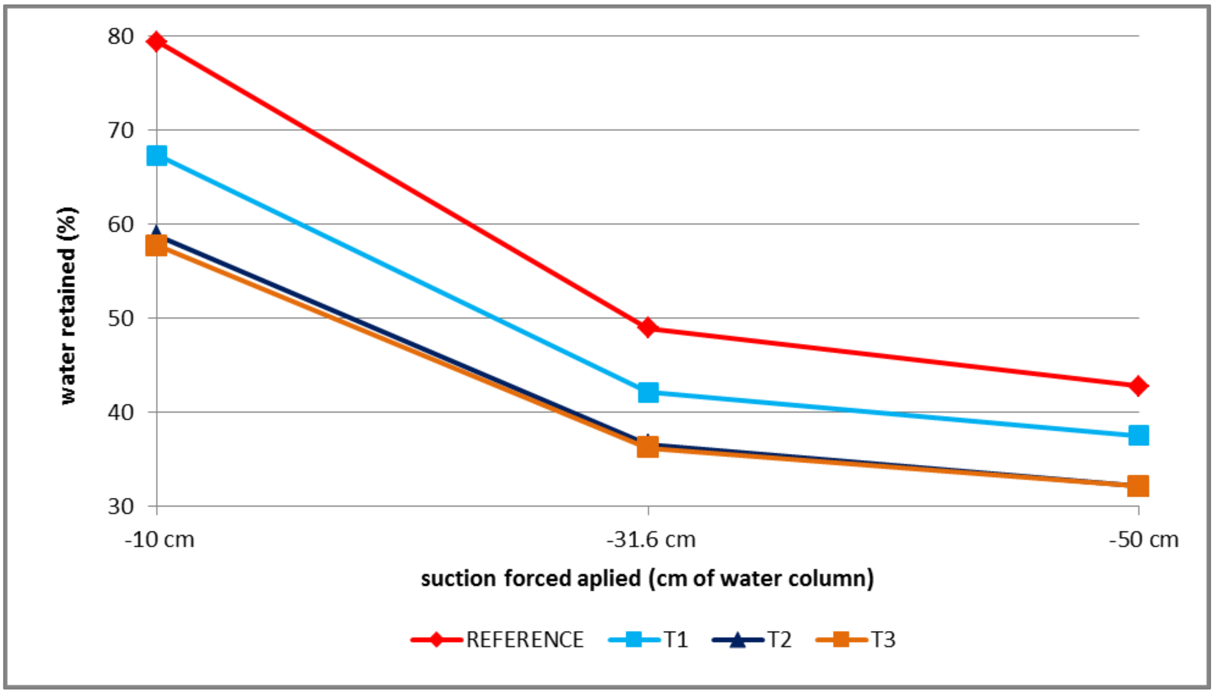

Figure17. Water retention curve of treatment T1 (25% peat, 25% coir, 25% compost, 25% wood fiber), T2 (33.3% peat, 33.3% compost, 33.3% wood fiber) and T3 (33.3% coir, 33.3% compost, 33.3% wood fiber) compared to Reference (70% peat, 30% coir).

Table 10. Summarize percentage of solids parts, total pore space and air content at three pressure points. Percentage of air content is inversely proportional to the sum of water content and volume of solids. When water content decreases, air content increases with the same volume. Substrate showed lower water retention compared to Reference, showed higher air content especially at -10 cm. less capacity to retain water and increase in air volume is probably connected to a difference in distribution of micro and macro-pore. The replacement of peat and coir with compost and wood fibre increased the macro pore, increasing air content and drainage ability to disadvantage of water holding capacity. About wood fibre, other research confirmed that this material have lower water holding, but higher air capacity compared to peat (Grunda et Schitzer, 2001).

Table 10. Physical properties of different substrate tested in the experiment 2. Dry bulk density (D_{BD}), volume percentage of solid parts, and total pore space (T_{PS}) and air volume at different pressure.

	D_{BD}	**Solid part**	**T_{PS}**	**Air vol. -10 cm**	**Air vol. -31.6 cm**	**Air vol. -50 cm**
	gcm^3	**%**	**%**	**%**	**%**	**%**
REF		6.3	93.7	14.3	44.8	50.9
T1		10.4	89.6	22.3	47.5	52.1
T2		10.6	89.4	30.7	52.9	57.3
T3		12.2	87.8	30.2	51.6	55.7

Considering rehydrating index (Figure 18.), starting from a water percentage of 1%, substrate tested showed similar rewetting rate after 1 and 3 minutes. After 7 minutes (same time of irrigation), Reference showed to have quick ability to uptake water by capillarity compared to other treatments, adsorbing about 50% of water (% V/V). After 7 minutes water absorbed by treatments T1, T2 and T3 was under 40%, higher in T1 (25% of all component), compared to T2 and T3. Results seems to suggest that T1 and T2 80% coir) have a similar attitude, rewetting quicker than T3, indeed after 15, 30 and 60 minutes they adsorbed similar percentage of water, greater than that adsorbed by treatment T3. T1 and T2 adsorbed 50% of water after 30 minutes, while T3 arrived to absorb the same percentage of water 30 minutes later. Differences between treatments could be connected to the amount of peat used for substrates, its reduction in the mix and its replacement with other materials probably reduced the speed at which substrate absorbs water by capillarity, which is further reduced in the treatment T3 where peat was completely replaced.

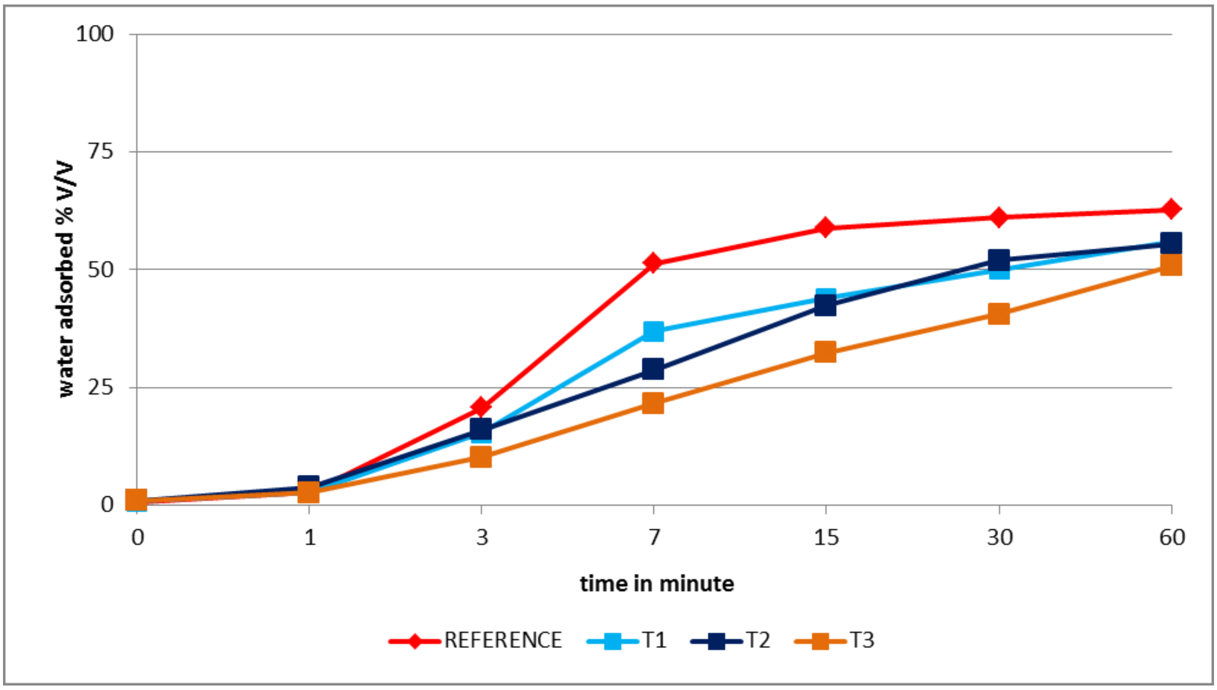

Figure 18. Water retention curve of treatment T1 (25% peat, 25% coir, 25% compost, 25% wood fiber), T2 (33.3% peat, 33.3% compost, 33.3% wood fiber) and T3 (33.3% coir, 33.3% compost, 33.3% wood fiber) compared to Reference (70% peat, 30% coir).

The reduction of water retention and rewetting rate showed by alternative substrate tested may involve the need to change the irrigation management when peat and coir are substituted by wood fibre and compost. A modification of irrigation management when peat is replaced by wood fibre seems also confirmed by literature. Other research has emphasized possibility to use substrate containing wood fibre for production of lettuce seedling, however related to increase of irrigation frequency (Gruda and Schitzer, 2001). An increase of irrigation frequency was necessary for the cultivation of Saintpaulia and Gloxinia using a substrate made with 100% of wood fibre, because of its limited water retention (Roeber and Leinfelder, 1997). A visible compaction of plants grown using wood fibre, probably due to water stress connected to a lower water retention compared to peat based substrate, has been observed in different ornamental species (Cattivello, 1998).

4.3 Conclusion

Two experiments were realized with the aim to evaluate the possibility to use substrates, made with local by products, replacing peat, for ornamentals pots plants cultivated with ebb and flow system. The results underline, a lower plants growth using alternative substrates, compared to a standard substrate peat based mixed with coir (control). This seems partially explainable looking at different physical properties of alternative mix compared to control in relationship with irrigation system. Substrate tested, compared to control showed to have lower water holding capacity, slow rehydration rate (less capillarity properties) and high air filled porosity. This is probably due to the shape and size of different component used, wood fibers and also compost are more coarse compared to peat or coir, that usually prove to have good water holding capacity and good capillarity properties.

The results are indicative of the ease of water and nutrition uptake by plants as well as the wetness in growing system based on sub irrigation water management. Less available water or a low rewetting ability may cause a non uniform water distribution in the root zone, which can easily lead to having a critical point at which the plant will begin to dehydrate, with a consequent growth reduction.

A growth reduction may represent a drawback that will forced growers to use more frequent irrigation cycles, but in same case a desirable results, that increase quality of pot plants (i.e. more dense plants) or quality transplant production, when hardy plants are preferred by growers.

In any case the possibility to use alternative growing media is unavoidable connect to water management on the base of specific irrigation system. Considering that is not possible exclude other factors (i.e. cultivation techniques, water management, etc.) to have a complete suitable information to improve the develop of alternative growing media. Future advances of present research, may relate to the use of alternative growing media with different water management or new mix development according to different cultivation model and irrigation system.

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5 CONCLUSIONS

The goal of the research was to evaluate the possibility of using organic by product from different source such as growing media (or media component in the mix) for container plants cultivation, replacing peat. Peat represent the principal material used in soilless cultivation, thanks to a unique combination of useful properties for container plants growth. However, some limitation related to its extraction cost, variability in quality and availability from a year to another and a perceived environmental impact, moving the attention of scientific world and substrates manufactures to on possible alternative materials.

In this context, in addition to the possible potential benefits of peat reduction in soilless cultivation; the use of alternative materials derived from by-products, could have the advantage of provide add value throughout a circular economy (re-use, re-cycling) with a consequent waste reduction from production / transformation processes.

The reseach was focused on some organic materials, mainly deriving from agricultural and urban activity: coir (coconuts production), compost (green waste and household waste), grape marc (vine production), hemp residues (hemp cultivation) and wood fiber (wood processing).

Some materials, such as coir, compost and wood fiber have already a manufacturing process that make them available on the substrates market, but with limited application. For grape marc and hemp, residues there are few information about their application in soilless cultivation and, excluding composting, a manufacturing process to relate them to the use as growing media component is not available yet.

For marc and hemp residues, the first step was to hypothesize a way to make them suitable as substrate. For grape marc was essential reduce the initial humidity (about 81%) to make it storable. Considering that coir, compost and wood fibers were obtained starting from a grind of raw mass, also grape marc and hemp residues were grinded obtaining 1 fraction for gram marc, and two fraction for hemp residues.

In the part of the research dedicated to the characterization; coir, green compost, grape marc and hemp residues were considered. Materials showed a big diversity about principal physical, chemical and biological properties. High hydraulic properties (water retention and capillary rise) were shown from coir, in particular with a pesence of 70% or more of coir pith (finer particles). With a content of 70% coir pith (mixed with coir fiber) the percentage of water retained by a known volume of material was 56% increasing to 91.9% whith 100% coir pith. A presence of 60% coir fiber mixed with coir pith decreased hydraulic properties (water holding capacity: 25.3%), increasing air filled porosity. In the same way the two hemp fractions tested, (fine and coarse/gross) showed a big drop of water holding capacity. Very low in the coarse fraction (14%) compared to gross fraction (54.5%) and scarce was also the water holding capacity of marc (29.8%). Low hydraulic properties on the one hand may limit the application as growing media, for the risk of water stress and the need to increase irrigation. However, at the same time the high air filled porosity showed by coir fiber, hemp gross fraction and marc, could suggest an easy drainage and good rate of aeration if used in a substrate mix, important in the case of low transpiration and high level of water availability.

Considering chemical properties (pH and electric conductivity), only coir and grape marc showed in sub-acid pH around 6; pH of the hemp and green compost resulted neutral and basic, respectively. EC was low for all the materials tested, except for compost (1.52 $mScm^{-1}$) and grape marc, which showed an extremely high value (3.43 $mScm^{-1}$). The EC value showed by grape marc represents a serious drawback for the use as substrate, cause an inhibition of plants germination and growth, that requiring pre-treatments, for reduce salts concentration.

The use of materials in cultivations test, confirmed the suitability of coir, since in all tests plants responded positively when coir was used as substrate. Growth experiment with laurel, basil and lettuce have shown the possibility to using a mixture of 70% of coir pith and 30% coir fiber as substrate, replacing partial and totally peat. In particular for basil and lettuce was highlighted a significant roots growth using coir compared peat, suggesting a possible good effect on root production and growth.

Basil transplant plants cultivation; suggest also a suitability of 100% coir pith and green compost as growing media. Use of hemp residues as growing media, for now, seems to have some limits. Basil growth was scarce using hemp fine fraction sole or mixed with peat, and the use of 100% of gross hemp fraction limited plats growth. A growth increased was obtained when gross hemp fiber was mixed with peat (50% by volume), suggesting that, the possible use of this by-product in container cultivation is connect to the mixing with materials that improve physical characteristics. Suitability of hemp in soilless growing media remains to be confirmed and represent a possible starting point for future research.

Considering grape marc, for this research, is suitability as growing media is linked to pre-treatment that reduce its high EC. Through washing, electric conductivity was reduced from 3.3 $mScm^{-1}$ to 0.12 $mScm^{-1}$, increasing the applicability and obtaining basil germination and growth in a cultivation cycle of 30 days. An added advantage was obtained mixing washed (treated) grape marc with peat or coir pith. Basil growth using treated marc mix with peat or coir, showed no significant difference to the growth of basil on coir and peat.

The possible benefit of mixing may be linked to an improvement of physical characteristics. Also in this case, the results obtained, can be represent the starting point for future research with the aim to better clarify the applicability of marc in soilless cultivation and investigating more specific aspect.

The last part of the research focused on the use of substrate mix where peat was totally or partially replaced by wood fibers and different types of compost. Experimentations focused on the production of ornamental species in a cultivation system based on ebb and flow irrigation. Peat replacement with materials with less capillary properties modified growing media characteristics, such as water retention and ability to absorb water from the bottom and to spread it. These changes lead to a different plant growth compared to standard substrates. In these conditions, irrigation management (frequency) appeared to be pivotal in controlling plant growth.

Use of by-products as growing media seems connected to the specific characteristics, different for different materials, and is unavoidable connect to the specific management during the growing cycle. In fact, in accordance with the key concept that a substrate may be suitable for a cultivation system but not for every system depending on the species, container and cultivation management, peat replacement with alternative materials must also consider different specific management during the growing cycle. Future research should not only focus on the material characteristics or the combination of different materials, but also on the interaction with irrigation and fertilization management according to the cultivation cycle.

Results presented in this research thesis are important for further research studies in order to expand the knowledge about the suitability of different local value-chain by-products and on their potential use in soilless cultivation.