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Pathways to phase-out contentious inputs from organic agriculture in Europe

Deliverable 5.8:

Report on trials with alternative growing media (replacement of contentious input peat)

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1 Introduction

This report describes studies and experiments conducted to replace peat in growing media for certified organic growers. Peat in growing media is one contentious input which has been extensively studied in Organic-PLUS, under the lead of Rafaela Caceres (IRTA) who coordinated Task 5.5, "Examination of promising alternatives, peat". While some of the studies referred to here have already been described in other publications, some studies are primarily described in the present report. Hence, the level of detail described here varies between the studies.

Studies on peat replacement within Organic-PLUS were conducted in countries with greatly different climatic conditions. They range from raising of olive saplings (cuttings) in Turkey (MFAL), **various crops in Catalonia** (IRTA, EAM), production of **extruded fibre from many different plant materials in Germany** (ATB), tests to reduce the need for **vermiculite in growing media from composted woodchips in UK** (CU) and **composted horse manure with leaves from hardwood trees for vegetable transplants in Norway** (NORSØK).

This report includes the main results of the activity done during the project. The structure of the document has been divided into the conceptual sections of peat replacement activities. Still, each sub-section corresponds to each partner's activity and differs in details and the level of information that have been provided. The degree of development of the peat replacement in each country is different and this is one of the reasons why the experiments were planned in a variable ways. Other reasons for the diversity of experiments are rooted on the different expertise and conditions of the different groups involved in this subtask WP5.5 and the feedback received from growers regarding their research needs. In addition to this report, publishing activities have been carried out (Knebl et al., 2022; Friis, Pedersen and Løes, 2022) to describe studies which have until now not been presented in English. Other publications are being produced, e.g. the experiments performed at IRTA with lavender and at CU with woodchip compost.

The present report is also related to the **deliverables D5.9 and D5.12.** Both are dealing with the spreading of the knowledge obtained through the project which has been shared with the different stakeholders of the project or other interested sectors in 'open days' and dissemination activities (D5.9); the relationship of the different partners dealing with peat replacement have provided the possibility to get possible barriers for the implementation of the solutions found within the project (D5.12). Moreover, dissemination activities like seminars, webinars, have also been also reported in the WP2 IMPACT deliverables. A key event in this is impact delivery is the International Course on Contentious Inputs, which is already largely pre-recorded including participants of Organic-PLUS and RELACS, and will be held online in June 2022. Further part of the dissemination of our activities will be delivered within one of the weeks of this online course, in the week commencing 14th June 2022.

2 Production of potential alternative materials through fibre production or compost, by ATB (Germany), MLT (Turkey), CU (United Kingdom) and IRTA (Catalonia)

2.1 Fibre production. ATB (Germany)

Authors: Ralf Pecenka and Christian Dittrich

The fibre used as an alternative growing media in these trials were produced by the project partner ATB (*Leibniz Institute for Agricultural Engineering and Bioeconomy*) in Potsdam, Germany.

At the ATBs pilot plant, a small industrial scale twin-screw extruder has been investigated in detail for the processing of a large variety of lignocellulosic raw materials (Fig. 1 and Fig. 2). As Dittrich et al (2021) showed, it is possible to produce fibres with satisfactory physical properties (e.g. water holding capacity WHC) from several of the 13 tested materials: laurel (*Laurus nobilis* L.), olive tree (*Olea europaea* L.), thyme (*Thymus vulgaris* L.), sage (*Salvia* spp. L.), oregano (*Origanum vulgare* L.), black locust (*Robinia pseudoacacia* L.), poplar (*Populus* spp. L.), sea buckthorn (*Hippophae rhamnoides* L.), hop (*Humulus lupulus* L.), grape (*Vitis* spp L.) and forest biomass, mainly Scots pine (*Pinus sylvestris* L.) as well as holly oak (*Quercus ilex* L.) Besides the raw material properties, the process parameters during extrusion are of great influence on the properties of the produced fibre and their potential to be used for peat replacement. The fineness of the fibre affects the water holding capacity and results from the aperture setting of the extruder. A small aperture results in more fine particles and therefore a better WHC but also in a higher energy consumption. The water content during extrusion also affects the fineness. A high water content reduces the friction between the extruder twin screws and the processed material. This results in less comminution and therefore coarser fibre. Best WHC compared to peat at an exact same test setup was measured for sage, forest biomass and poplar at a 20 mm aperture setting.

The whole process of defibring lignocellulose biomass in a twin-screw extruder is not easy to control. A lot of tentative testing was required to produce a fibre, which could be considered as a peat substitute due to its physical properties. However, the extrusion process is very energy-intensive, so that raw material-specific process optimisations should be carried out as part of future investigations for cost-effective productions. Whether extruded material can ultimately be used as a peat substitute does not only depend on the physical characteristics, but also on its chemical–microbiological suitability. Results from pot trials with olive saplings cultivated in a substrate consisting of a high proportion of fibres from olive pruning material have been published in Kir et al, 2021.

Figure 1. Twin-screw extruder for fibre production at ATB opened to show the mechanism

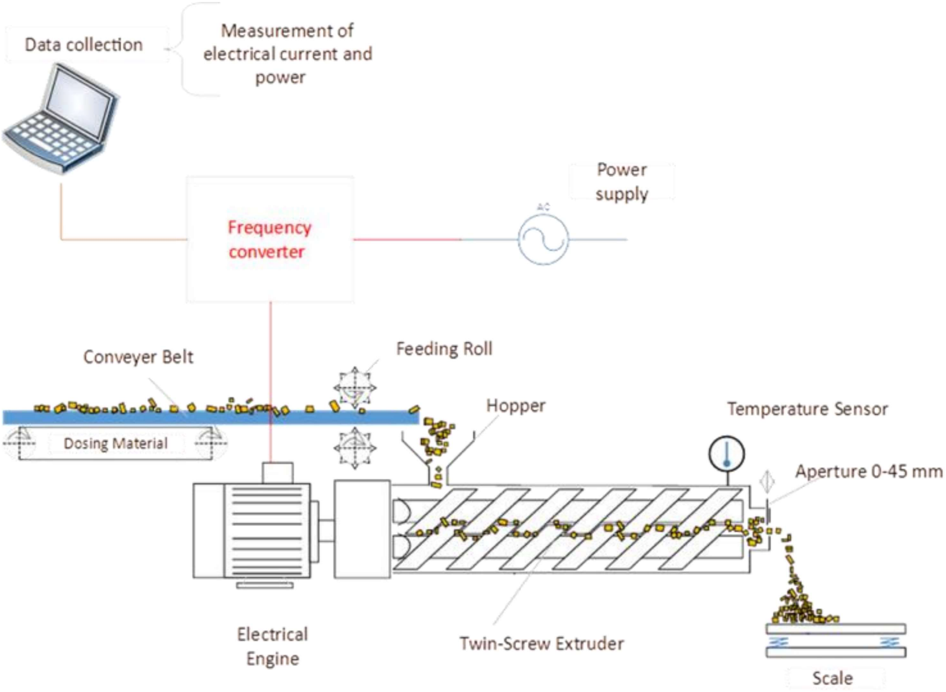


Figure 2. Schematic illustration of the experimental design of the twin-screw extruder unit Dittrich et al (2021).

2.2 Compost production and characterisation in Mediterranean and Oceanic climates, by MAF (Turkey), CU (United Kingdom) and IRTA (Catalonia)

2.2.1 Compost from olive pruning and aromatic plants at Izmir (Turkey).

Author: Alev Kir, Ministry of Agriculture and Forestry (MAF), Izmir, Turkey

The compost (COMP) was made from 70% (by volume) chipped olive branch pruning materials, 10% (by volume) chipped medicinal and aromatic plant residues 18% (by volume) freshly cut grass from a lawn at Olive Research Institute - ORI (Izmir-Turkey) and 2% horse manure was applied as an activator to facilitate initiation of self-heating and aerobic decomposition by microorganisms. The compost windrow was set up in March 2019. A *Trichoderma* fungus isolated from forest soil was added. Application of *Trichoderma citrinoviride* was conducted by a motorised back sprayer (1.2 mm drop diameter). Green mycelium indicating occurrence of *Trichoderma citrinoviride* was observed on 25th April 2019, showing that the inoculation was successful. On 23rd May 2019, the first *Coprinus* sp. mushrooms were found on the compost. *Coprinus* spp. species are known as cellulose enzyme producing fungi. During 24-27th September 2019, isolated bacteria from free-range goat stomach were isolated and applied to the windrow as described for *Trichoderma*. Goat stomach bacteria and *Trichoderma* species have cellulose enzymes, which are known to be beneficial for achieving a mature compost. *Coprinus* spp. species can also produce cellulose enzymes. When the experiment with sapling was initiated on 15th April 2020, the compost had a black colour and the smell was like humus after 8 months of composting process and maturation.

The physical and chemical properties of a compost mostly depend on added type of organic material and its quantity, which have a wide variability in the compost windrow on-farm co-composting procedure. Samples we collected according to the following schedule:

- Initial compost: Mature compost before pot trial. Collected randomly from the compost heap which composted for 8 months.
- 6th month compost: After 6th month, samples were collected from each pot of the COMP (compost) treatment and the harmonised in a pot. The final sample was collected from this pot.
- Initial peat: commercial peat was sampled randomly
- 6th month peat: After 6th month, samples were collected from each pot of the PEAT+ (commercial peat) treatment and the harmonised in a pot. The final sample was collected from this pot.

In the COMP treatment pots compost used at 100%. Nothing was mixed into the compost material.

In the PEAT+ treatment pots peat used at 100%. Nothing was mixed into the compost material.

The properties of compost and a commercial peat are presented in Table 1.

The physical and chemical characteristics of the treatments were all found to be within the limits of EU Ecolabel-EU Commission (2015) and were compatible with a Turkish law on compost and soil conditioners that was legislated on February 23, 2018 with Turkish Legal Gazette No.30341. The positive plant growth results for compost (Figure 3a, 3b), were in agreement with the reports from many previous studies suggesting that different compost can provide effective replacements for peat, and also in accordance with previous reports no diseases were observed on the plants grown in compost. Possibly, there could be a risk of transferring fungal disease to the saplings via the pruning material, but no such disease has been detected so far in this study. The stable C/N ratio of the compost growing media being 12.3 at the start and 12.0 and the end of the pot study shows that the material was mature after a treatment process of 8 months, due to goat stomach bacteria and *Trichoderma* species have cellulose enzymes, which are known to be beneficial in achieving a mature compost. *T. citrinoviride* (beneficial fungi isolated from forest and applied to the compost) was isolated from the suspensions of the compost (initial) and COMP (6 months) samples, even if the temperature in the compost windrow reached 65-70 ^{0}C.

Table 1. The chemical and physico-chemical properties of ***commercial peat*** *and* ***initial mature compost*** *and* ***6th month compost used in the pots for olive sapling growth****. All values in % or ppm are given as proportions of dry weight.*

	COMP Compost (Initial)	**Peat (Initial)**	**Compost (6th month)**	**Peat (6th month)**
pH	8.2	6.4	8.2	6.6
EC (µS/cm)	570	1116	1038	1561
OM (%)	58	46.5	54.5	57.9
C (%)	26.9	26	25,5	27
N (%)	2.2	0.4	2.2	0.9
C/N	12.3	60.4	12	30
P (%)	0.1	0.1	0.3	0.1
K (%)	1.4	0.4	1.1	0.6
Ca (%)	2.9	1.5	3.4	2.3
Mg (%)	0.4	0.1	0.4	0.4
Fe (ppm)	8132	6957	9652	8240
Mn (ppm)	332.8	129.6	294	151.4
Zn (ppm)	89.6	33.2	90.1	41.2
Cu (ppm)	28.7	22.9	15.8	19.7
B (ppm)	43.7	12.5	41	22.8
Na (ppm)	450	1088	131.1	229
Mo (ppm)	2	4.7	1.9	7.5
Cd (ppm)	0.3	0.1	0.3	0.2
Co (ppm)	4.1	1.9	3.6	3.4
Cr (ppm)	51.6	19.4	29.8	37
Ni (ppm)	28.2	8.1	33.6	31.9
Pb (ppm)	**7.9**	**4.1**	**12.1**	**8.9**
Al (ppm)	**12936**	**5310**	**9514**	**4965**

Compost heap moisture and temperature measurement.

Compost temperature was increased to about 65^{0}C during composting.

Initial materials of compost in Turkey: laurel (*Laurus nobilis* L.) (the picture on the bottom and middle), olive tree (*Olea europaea* L.) (top - left and middle), thyme (*Thymus vulgaris* L.) (bottom- right), sage (*Salvia* spp L.) and oregano (*Origanum vulgare* L.) mix (right side) pruning residual chips, and grass cutting material (bottom- left side).

Horse manure used in the compost pile

Figure 3. Production steps of compost used in the experiment

2.2.2 Peat alternatives based on woodchips, at Coventry University (UK).

Authors: Francis Rayns, Judith Conroy, Dennis Touliatos and Ulrich Schmutz. CU, (UK)

Our experiments were focused on using composted woodchip as a base material for growing media in vegetable transplant production. This was inspired by innovations by Iain Tolhurst (Tolly) of Tolhurst Organics – a very well established (over 40 years) organic producer of vegetables in the field and in protected cropping. Tolly uses mixed wood biomass obtained from a local tree surgeon, composted for 18 months in open windrows with small amounts of crop residues. After sieving, the compost is mixed with 30% vermiculite and used, predominantly without additional feeding, in module trays.

The method has been the subject of an Innovative Farmers Field Lab in the UK (www.agricology.co.uk/resources/peat-free-woodchip-compost-growing-media). Some other growers in the UK have taken up the idea but further research is needed to eliminate the use of vermiculite (which has considerable environmental impact) and explore the role of feeding (considering the very high initial carbon content).

Compost trial. The aim of this work was to evaluate the necessity of adding additional materials to the woodchips in order to facilitate the composting process and enhance the quality of the final product. Fresh ash woodchips (*Fraxinus excelsior*) made from twigs and roundwood up to 10 cm diameter were obtained in July 2021 (C:N ratio 71:1). These were composted alone or in combination with hay made from phacelia (*Phacelia tanacetifolia, C:N 19:1*) grown an overwinter green manure and fresh comfrey leaves (*Symphytum* spp., C:N 26:1) – these materials were chosen because of their likely availability on a horticultural holding. Table 2 describes the treatments and their initial C:N ratios. Duplicate 0.7m^3 polypropylene bags of each mixture were set up in the open air (Figure 4). After mixing they were covered with woven polypropylene sheeting to conserve moisture; 20 litres of additional water was added to each bag at the time of mixing and additional water added each time the bags were turned (in October 2021 and March 2022). Temperatures within each heap were monitored using EasyLog dataloggers (Figure 5).

Addition of one third by volume of the leafy materials to the woodchip had relatively little effect on the overall C:N ratios – all the blends had a ratio much greater than 30:1 which is normally recommended for effective composting. However, compost temperatures were generally elevated well above ambient, especially in the first three months after mixing. This is likely to be because the microbial activity was concentrated on the surface of the chips and so the large amounts of carbon inside were not available to have any inhibiting effect.

Because of the Coronavirus pandemic this composting experiment could not be set up as soon as was planned; it is expected that the composts will not be ready to be evaluated as growing media until 2023. However, it can already be concluded that woodchips on their own will compost satisfactorily, although it is a long-term process, dominated by fungi. Farmers wishing to make growing media in this way would need to plan well ahead.

Blending of the materials by volume in July 2021

The composts (after uncovering) in October just before turning in October 2021

Figure 4. The UK woodchip composting trial.

Table 2. Blended materials used in the UK woodchip composting trial.

Volume per bag (litres)			**Dry matter per bag (kg)**			**Overall C:N ratio**
Woodchip	**Phacelia**	**Comfrey**	**Woodchip**	**Phacelia**	**Comfrey**	
660			161			71:1
523	220		128	7		61:1
523		220	128		44	66:1

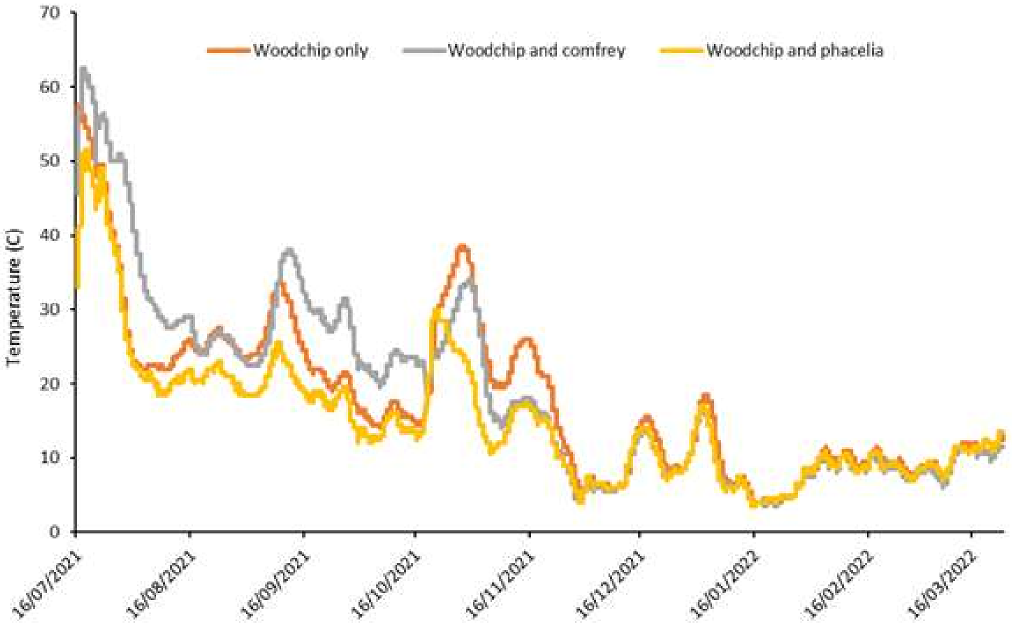


Figure 5. Temperature profile of the UK woodchip compost trial; the materials were blended in mid-July and the bags turned in mid-October.

2.2.3 Peat alternatives: from potential new materials to selected compost in Catalonia, by IRTA

Authors: Rafaela Cáceres, Gorka Viana, Anna Puerta. IRTA (Catalonia)

2.2.3.1 Introduction

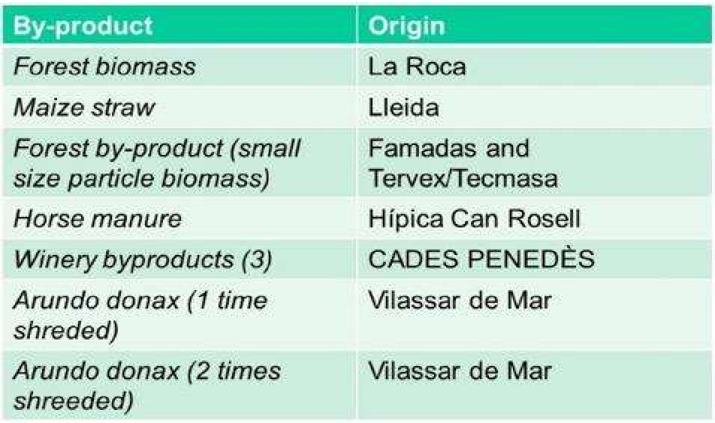
Previously to the trial with alternative growing media, at IRTA, the following tasks were performed:

- Prospection for new materials which theoretically could be used as raw material for their use as growing media. Selected ones (Mediterranean Forest Biomass and *Arundo donax* biomass) were sent to ATB premises in Potsdam so as to be extruded.

- Within the period 2018-2020, different raw (fresh) new materials were prospected. Table 3 shows the description of these materials.

- Additionally wool (which nowadays has little commercial value) and compost from green biomass were obtained from the cooperative Conreu Sereny (2021-2022) (CONREU SERENY, SCCL).

Table 3. Description and location of the raw (fresh) materials prospected. Forest Biomass was from Belloch Forestal Forest.



By-product	Origin
Forest biomass	La Roca
Maize straw	Lleida
Forest by-product (small size particle biomass)	Famadas and Tervex/Tecmasa
Horse manure	Hípica Can Rosell
Winery byproducts (3)	CADES PENEDÈS
Arundo donax (1 time shreded)	Vilassar de Mar
Arundo donax (2 times shreeded)	Vilassar de Mar

Figure 6. The variety of the investigated materials in Catalonia, shown at source and as processed product.


Mediterranean Forest


Crushed Forest Biomass


Bale of corn straw


Decompressed corn straw


Peach fields


Crushed peach prunings


By-product from biomass


Detail of by-product from biomass


Horse stable


Horse manure with bedding material (small size particles of waste from biomass)

Vineyards

By-products from wineries

Arundo donax cuttings

Arundo donax shredder

Figure 6 continued. The variety of the investigated materials in Catalonia, shown at source and as processed product.

These by-products were characterised in order to know possible drawback for their use in compost mixtures. The main results were shown in the Seminar held in Manresa on 29th, December 2019 and are also presented within this report (Figures 7 to 9).

Several criteria were applied to select some for composting to produce a substrate. Mainly, the selected products had to have a low pH and electrical conductivity which are normally high in commercial Catalan composts (Cáceres et al., 2015). One material was rejected because of possible allergic effects on IRTA's personnel (*Arundo donax*).

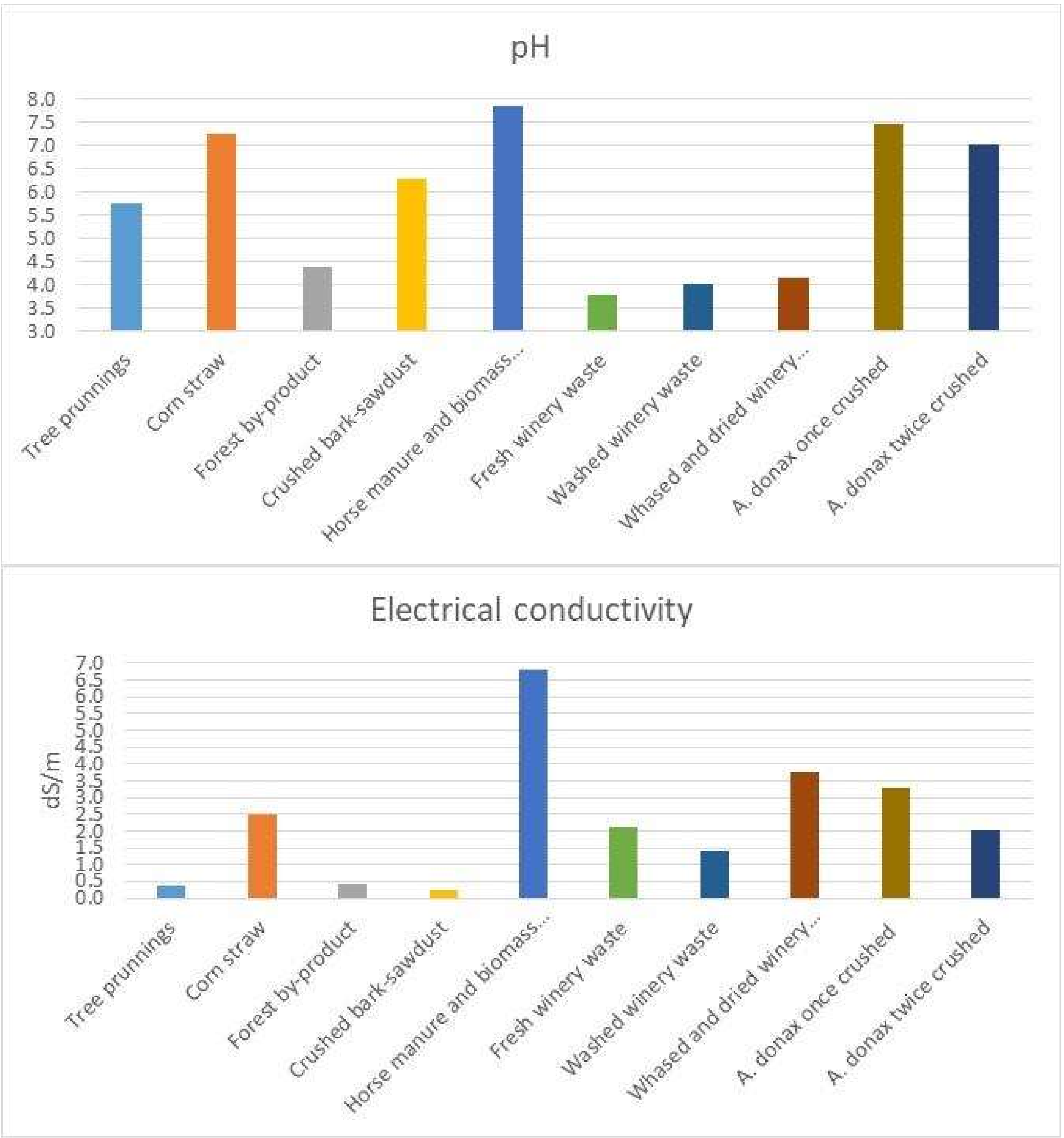
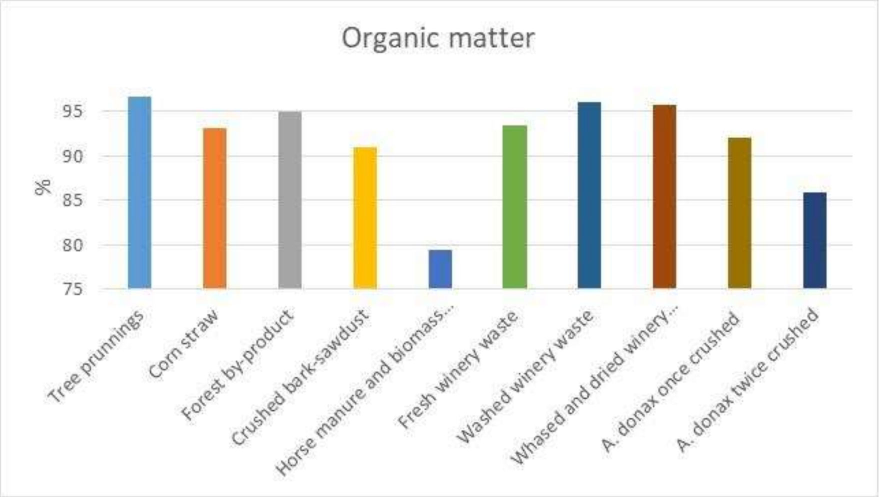


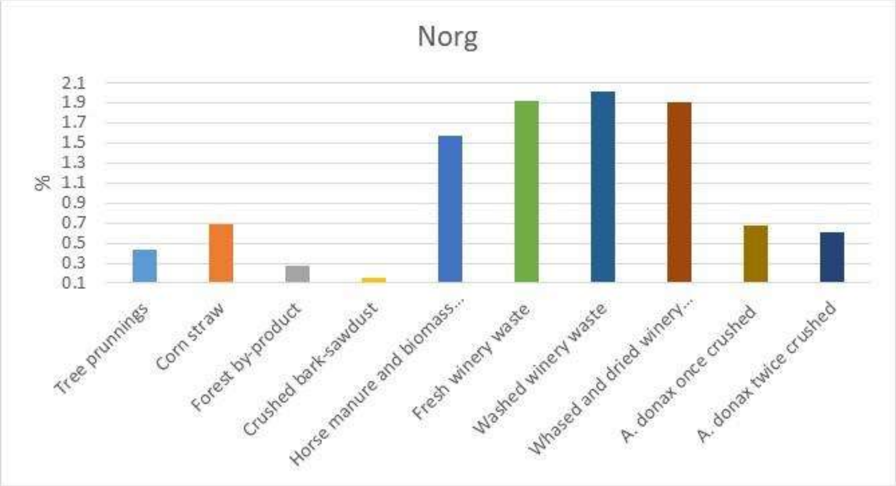
Figure 7. pH (top) and electrical conductivity EC (bottom) measured in raw materials investigated by IRTA.

Figure 7 shows the physico-chemical properties of the prospected materials. Horse manure, *Arundo donax* and corn straw have relatively high pH value. The other materials have relatively low pH. In any case, the co-composting of some of such materials could be appropriate. Similar results come from the electrical conductivity figure (Figure 7). The horse manure has the higher electrical conductivity and also the washed and dried winery wastes, as well as *Arundo donax* trimmings.

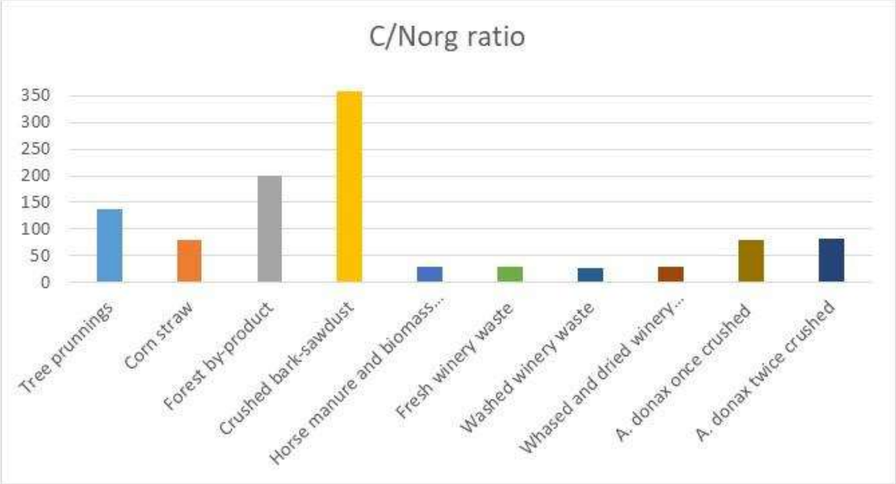
The organic matter contents of the materials are high, in general (Figure 8a). A major part of them is above 85% and only the horse manure has OM lower than 80% (dry basis). Norg are particularly high in winery wastes and horse manure. These materials would complement other woody materials in the composting mixture (Figure 8b). Regarding the C/N ratio, we found high values for the bark-sawdust and the Forest biomass; tree prunings have also high C/Norg ratio (Figure 8c).



a) Organic matter



b) Organic N



c) C/Norg ratio

Figure 8. Organic matter content (a), Norg content (b) and C/Norg ratio (c) of the investigated materials at IRTA.

All materials prospected had high porosity, above 75% (Figure 9a), a fact which is quite important for the use of the by-products for growing medium mixtures. However, during composting porosity will tend to decrease. Air capacity was very high in corn straw (Figure 9b) and also in tree prunings and, in general, in the winery by-products, as it can be seen in Figure 9b. On the contrary, water retention was high in crushed bark with sawdust, forest by-product and horse manure (Figure 9c).

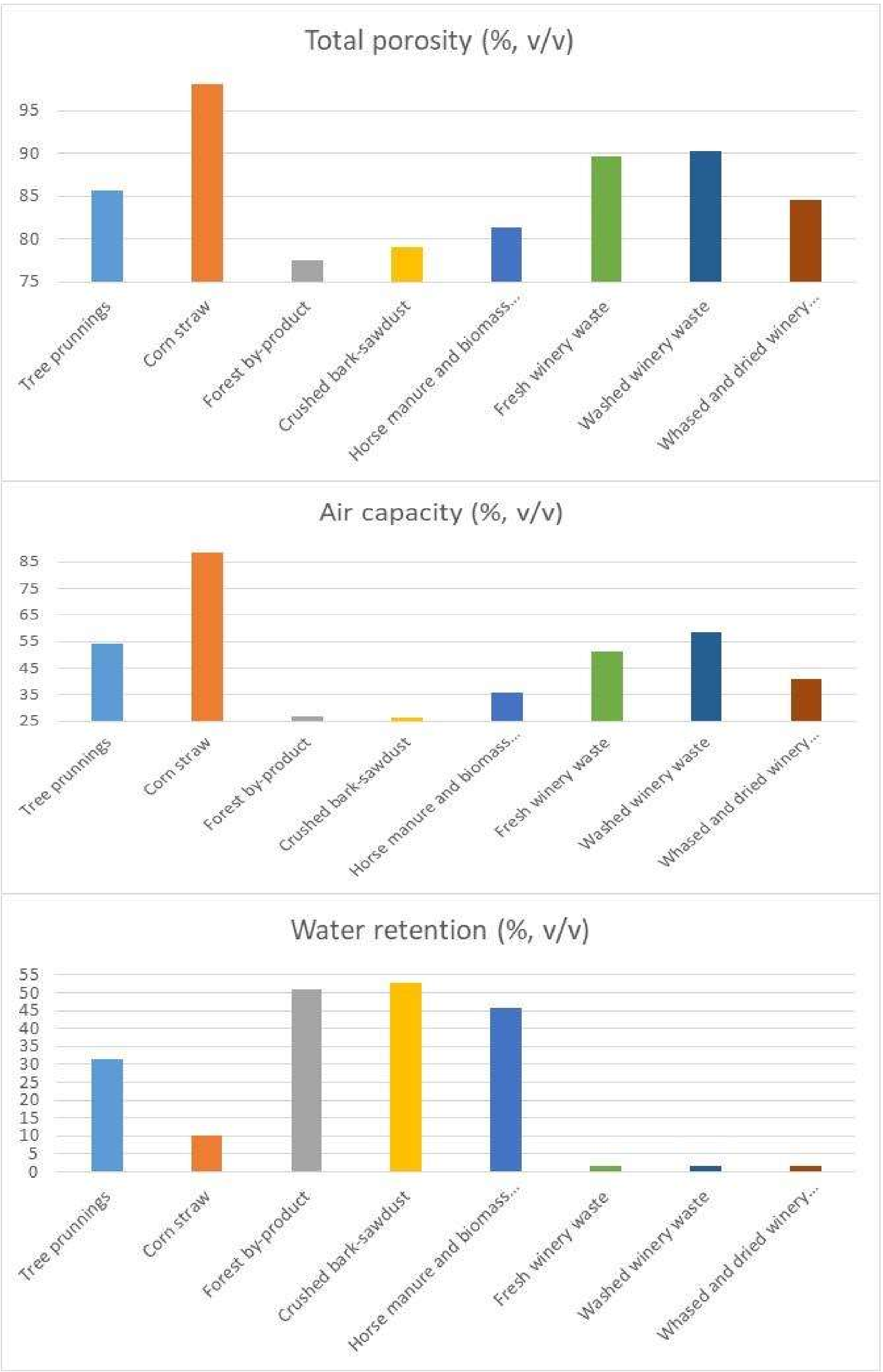


Figure 9. Physical characteristics (total porosity, air capacity and water retention) of the prospected materials at IRTA.

Two of the materials (crushed Mediterranean Forest biomass and crushed *Arundo donax* biomass), were dispatched to ATB (Potsdam, Germany) to contribute to the study extrusion of materials (see section 2.1).

2.2.3.2 Description of the composting activity of selected materials (Mediterranean biomass and horse manure) and compost

Experiments for obtaining compost based on Mediterranean Forest biomass (MFB) and horse manure with biomass by-product bedding (HM) were performed at the pilot composting plant at IRTA premises Cabrils (Catalonia) (Figure 10). This experiment was started at the end of 2019.

Figure 10. Six m^3 composting piles based on Mediterranean forest biomass and horse manure (pilot composting plant in Cabrils)

In the first instance the following mixtures of raw materials were prepared:

- PO1. 100%, 0% HM
- PO2: 83% MFB, 17% HM
- PO3: 67% MFB, 33% HM

However, as the PO1 composting pile was not triggering the increase in temperature, it was decided to increase the amount of the available N for increase the microbial activity. In order to keep a different proportion of HM among the three different piles, the same amount of HM (0.25 HM/1, v/v of each mixture) was added in all piles at date (20/01/2020). Emissions with impact on the atmosphere pollution were not measured, but compared to other processes held in the pilot composting plant, the smell inside the composting plant was nice because of the Mediterranean forest biomass and the low proportion of HM which had a biomass by-product for bedding, too.

After the addition of HM, all piles were active. However, the process was quite slow due to the nature of the raw materials. The process lasted one year. It should be taken into account that some necessary operations were stopped due to the lockdown because of the COVID-19 pandemic.

At the end, there different products were obtained, and they had different physical and chemical properties. A low level of nitrification was achieved at the end of the process, and this was probably due to the low N content of the HM and the relative low inclusion of this material in the mixtures. The IRTA team have studied the nitrification within composting using manure, mainly, as a raw material and nitrification with natural acidification have been achieved (Cáceres et al., 2006; 2016, 2018). However, the pH of the materials was not too high, as is usual in commercial composts (Cáceres et al., 2015); the electrical conductivity was acceptable as well. Section 4.2 of this report describes the performance of two selected compost (PO1 and PO3) in a lavender pot culture.

2.2.4 Lab evaluation of cocoa shells as an alternative to peat at University of Thessaly (Greece).

Authors: Christos Lykas, Martha Kazi and Nikolaos Katsoulas. University of Thessaly

2.2.4.1 *Abstract*

Cocoa bean shells were mixed with agricultural soil in different proportions to produce a plant growth media. A high content of lignin and tannins inhibits a rapid degradation of cocoa shells, but mixing with soil in a Mediterranean climate may be a good way to decompose lignin and release the N. The effect of substrate temperature and humidity conditions on the metabolic activity of microorganisms decomposing the organic material was evaluated. The stage of decomposition required for replacing peat, and the time needed for such sufficient decomposition, was determined. It was found that the increase of temperature during the first weeks of the incubation period may increase the microbial population in mixtures, facilitating the composting. After 6 weeks of incubation, the temperature of the composting material could be lowered to 25°C. Incubation of mixtures with high proportion in cocoa bean shells can accelerate nutrient mineralisation.

2.2.4.2 *Introduction*

Different raw materials of mineral and organic origin can be used, pure or in mixtures, to compose substrates for crop cultivation, such as peat, vermiculite, and organic compost. Peat has been widely used as a growing medium for many years, especially with seedlings. It comes from the partial degradation of aquatic vegetation that grows in swampy areas and generally in wetlands. In these areas, over time, whole deposits were formed, from which the peat is mined, undergoes some processing (shredding, grinding, disinfection, etc.) and then packaged on an industrial scale; other key properties should also be appropriate as pH and salinity (Cáceres et al., 2015a).

Now, so much peat moss has been harvested for use in gardens and landscapes that in many places it has become a scarce resource. Harvesting peat moss destroys that ecosystem, and the supply will be depleted given the slow regeneration rate. Thus, alternative growing media will have to be used. When preparing substrate mixtures, it is important that the inputs used be of low cost and easy availability in the region, what favours their acquisition by nurserymen/farmers (Sodré et al. 2007, Arrigoni-Blank et al. 2013). According to Fermino et al. (2010), the use of agro-industry residues, regionally available as a component for substrates, may reduce costs and minimise pollution, due to the accumulation of these materials in the environment. In this context, the cocoa/chocolate industry that generates large amounts of shell, originating from fruit breaking for the extraction of cocoa in the manufacture of chocolate. Cocoa shell contains about 4% of K on a dry basis (Sodré et al. 2012) and can have several uses, such as composting for the production of organic fertilisers (Chepote 2003).

Coco coir (the outer husk of coconuts) is considered a waste product. In fact, the large accumulation of coco fibres as by-product of rope manufacturing, has led to the need to find its possible exploitation as substrate for plants cultivation. Following the same pattern, the increasing production of cocoa beans, which are used primarily for chocolate production, generates substantial quantities of waste (Vriesmann et al., 2011). Since the commercial interest is focused on cocoa nibs, the pod shells of the cocoa fruits (commonly known as cocoa husks accounting 52–76% of the pod wet weight), usually not transported to chocolate factories and is often not even collected on farms where the cocoa is grown. When they are not allowed to decompose into the field, generating foul odours and causing disease inoculum like black pod rot (Donkoh et al., 1991), pods are used as a fertiliser and animal feedstuff.

Cocoa husks have been shown to be suitable substrates for edible mushroom cultivation (Kinge et al 2016). Furthermore, this by-product is considered as a natural ground cover and soil conditioner. Cocoa shells can absorb and hold a significant amount of water and release it gradually to the ground prevents dehydration. In addition, it has a proper fertilising value since cocoa pod husk ash analysis reviled that its pH is closed to 7 and contains approximately 1.2% N, 40.26 mg·kg^{-1} P, 5.1 cmol ·kg^{-1} K, 1.8 cmol kg^{-1} mg and 3.6 cmol ·kg^{-1} Ca (Sodré et al. 2012; Adejobi et al 2013). For this reason can be used as composting for the production of organic fertilisers (Chepote 2003) or as substrate in mixtures with other organic materials for the production of pot ornamental plants. However, additions research is needed to determine seedlings adaptation as well as the morphological and physiological characteristics of the plants grown in such substrates.

Although cocoa husk is an organic material it has a high content of slowly biodegradable components like hollocelulose (74%), cellulose (35.4), hemicellulose (37%) and lignin (14.7%). This property makes the cocoa husk a material suitable for the production of substrates for use in hydroponic cultures (similar to coco coir substrates are in use today in soilless cultures). However, in order to develop a final commercial product, additional research is needed to determine some important physicochemical characteristics of cocoa husk such as the nutrients release and decomposition rate, the content in some elements that may cause toxicity on plants (Na and Cl), the content in microelements (Cu, Zn, Mo, Mn, Fe, Bo), the content in heavy metals (Cr, Co, Cd) and develop nutrient solution formulas for main vegetable cultivations on this substrate. Thus, objective of this work was to study the effect of substrate temperature and humidity conditions on the metabolic activity of microorganisms decomposing the organic material.

2.2.4.3 Materials and Methods

The study took place in three stages: 1) Evaluation of different cocoa mixtures, 2) Effect of temperature and humidity on the metabolic activity of microorganisms and 3) Composting period, as presented below.

1st stage/period - Evaluation of different cocoa mixtures

During the first period of reference (September to December 2018), ground shells from organic cocoa beans were mixed with sandy clay soil in different proportions. Specifically, 50 g of ground shells were mixed with 15, 30, and 50 g of soil respectively. Before mixture, measurements as well as chemical and microbial analyses were performed, to estimate the microbial count (fungi and bacterial colonies), the pH, the electrical conductivity and nutrient elements content (ammonium and nitrate nitrogen, phosphates, potassium, calcium, magnesium and sulphates) in both cocoa ground shells (S0) and soil samples. After preparing the substrate mixtures, these were placed in 0.5 L plastic containers. Temperature and humidity were measured during decomposition period.

2nd stage/period- Evaluation of different cocoa mixtures

During this period (January to August 2019), experiments for temperature, humidity and microbial count estimation in the substrate mixtures during the decomposition period were performed. Samples of mixtures contained 50 g of ground shells and 15 (S15), 30 (S30), and 50g (S50) sandy clay soil. During the decomposition period of 25 weeks (January to August 2019), three samples of S0, S15, S30 and S50 treatments were placed in controlled condition chambers with 25°C and 35°C. During the first three weeks of the incubation period, the moisture was maintained at two-thirds of their water holding capacity (WHC), while for the next three weeks mixtures were left to dry. This process was repeated until the end of the incubation period. Measurements concerned the pH and EC of the samples as well as their chemical and microbial analyses were performed after 6 and 25 weeks of incubation.

3rd stage/period- Composting period

During the third period (October 2019 to August 2020), forty litres of ground shells from organic cocoa beans were used for cocoa-soil mixture preparation. The ground cocoa beans shells had biochemical features similar to those used during the 2nd period. The soil used for mixtures preparation was classified as sandy clay loam, with alkaline pH, moderate to low organic matter; it was collected from the experimental field of University of Thessaly which is located at Velestino (Latitude 39o 23′ North, Longitude 22o 45′ East, elevation 70m above the sea level). Soil samples used for mixture preparation were dried at 45°C for three days until their moisture content reached 2% ±0.2 and then were sieved through a 2 mm sieve. The moisture content of cocoa ground shells used for mixtures preparation was estimated as 7%±0.3.

Mixture samples prepared during this period had the following composition:

- DC0: 3kg ground shells + 0 kg of dried soil
- DC0,3: 3 kg ground shells + 0.9 kg of dried soil
- DC0,6: 3 kg ground shells + 1.8 kg of dried soil
- DC1: 3 kg ground shells + 3 kg of dried soil

The above-mentioned mixtures were moistened and, after their homogenisation, they were placed in 12 L containers at 25°C for approximately 8 months, until the composting period was over.

During the first three weeks of the incubation period, the moisture was maintained at two-thirds of water holding capacity while for the next three weeks the soils were left to dry. This process was repeated until the end of the composting period. The mixtures were stirred frequently for adequate ventilation. Finally, when the composting period was over, the mixtures were spread on trays for a week at 35°C ± 0.5 until their moisture content reached 9 %± 0.5. Ten litters of each mixture were tagged and packed in plastic bags.

The experiment was carried out with a total randomised design, with three repetitions per treatment. Mean differences between treatments were assessed by one-way ANOVA.

2.2.4.4 Results and Discussion

Moisture holding capacity

At the end of the experiments conducted during the 1st stage/period, mixtures containing 15 to 50 g of soil had higher water capacity compared to S0 as presented in Figure 11. No significant difference in water capacity was observed between S15, S30 and S50 mixtures, in exception to S50 mixtures incubated at 35 °C, probably due to the higher water evaporation rate occurred in these mixtures. The water capacity of S50 mixtures that remained at 35 °C was similar to S0.

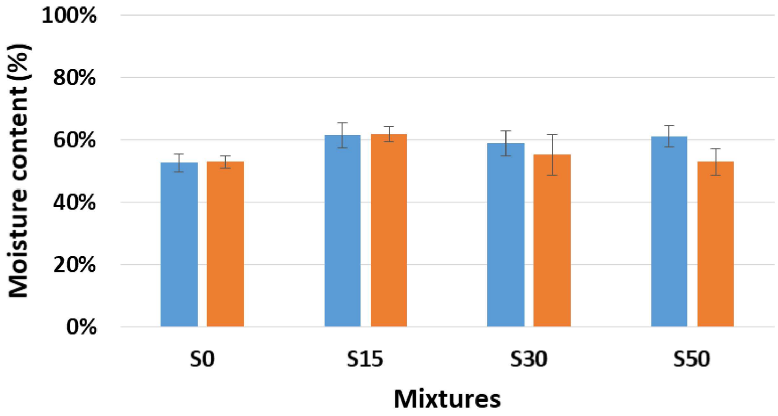


Figure 11: Moisture content of S0, S15, S30 and S50 mixtures remained at 25°C (■ blue) & 35 °C (■ orange) Vertical bars indicate the standard deviation (SD) of the mean (n = 3)

Microbial load

Cocoa ground cells and soil did not show statistically significant difference concerned their Total Microbial Count (TMC). In contrast yeasts and moulds was less in soil (Figure 12). TMC of the S0, S15 and S30 was higher from that of S50, six weeks after the composting initiation when samples remained at 25°C. However, at 35°C, no statistical difference was observed among the four mixtures probably because of the rapid growth of microorganisms (Figures 13 and 14). During this period a rapid growth of microorganism population is desirable, in order to facilitate nutrients mineralisation. Twenty five (25) weeks after the incubation initiation, S0 that remained at 35°C had the lower TMC compared to the other mixtures, probably because in these substrates the mineralisation it was completed.

In Figure 13, it can be observed that the yeasts and moulds population in all mixtures is over 7 log when samples placed at 25°C, whereas they placed at 35°C (Figure 14) yeasts and moulds population was less than 6 log at the 6th week of composting in experiments conducted during the 2nd stage/period. Similar observation is made during the 25th week of composting.

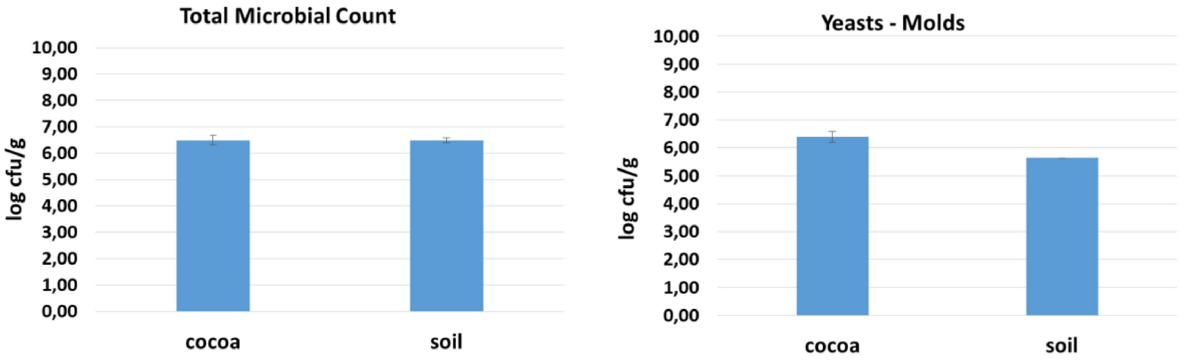


Figure 12: Mean values of Total Microbial Count (log cfu/g), yeasts and moulds in cocoa and soil samples before the preparation of the mixtures. The vertical bars indicate the standard deviation (SD) of the mean (n = 3)

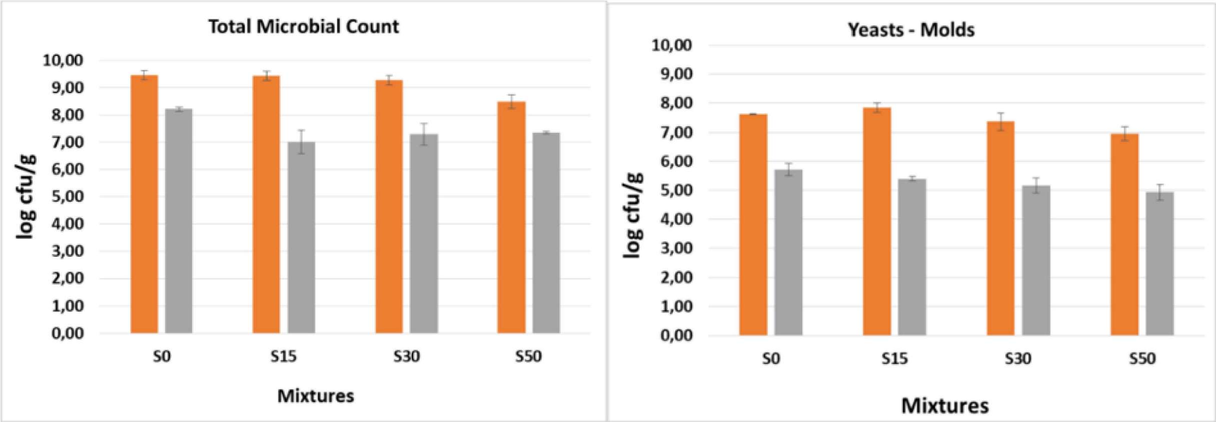


Figure 13: Mean values of Total Microbial Count (log cfu/g) and yeasts and moulds population of the four mixtures after incubation at 25°C for 6 weeks (■ orange) and for 25 weeks (■ grey). The vertical bars indicate the standard deviation (SD) of the mean (n = 3)

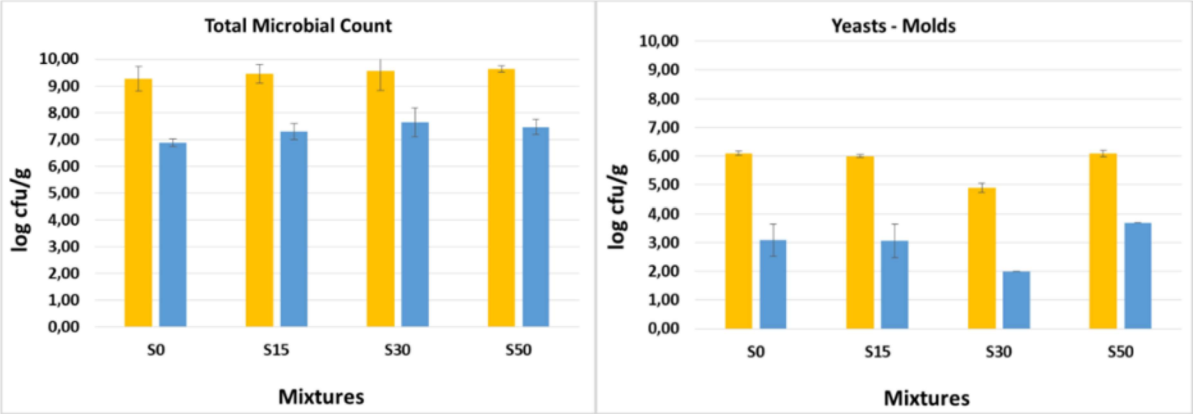


Figure 14: Mean values of Total Microbial Count (log cfu/g) and yeasts & moulds of the four mixtures after incubation at 35°C for 6 weeks (■ yellow) and for 25 weeks (■ blue). The vertical bars indicate the standard deviation (SD) of the mean (n = 3).

As shown in Figure 15, NO_3^- concentration at the end of the incubation in experiments conducted during the 2nd stage/period was higher in samples contained the higher amount of organic matter (S0 and S15 compared to S30 and S50 mixtures), regardless of the temperature the samples remained. In addition, S15 samples that remained at 25°C had the lower NH_4 content, compared to all other treatments (Figure 16), that indicates a high nitrification rate occurred in S15 samples.

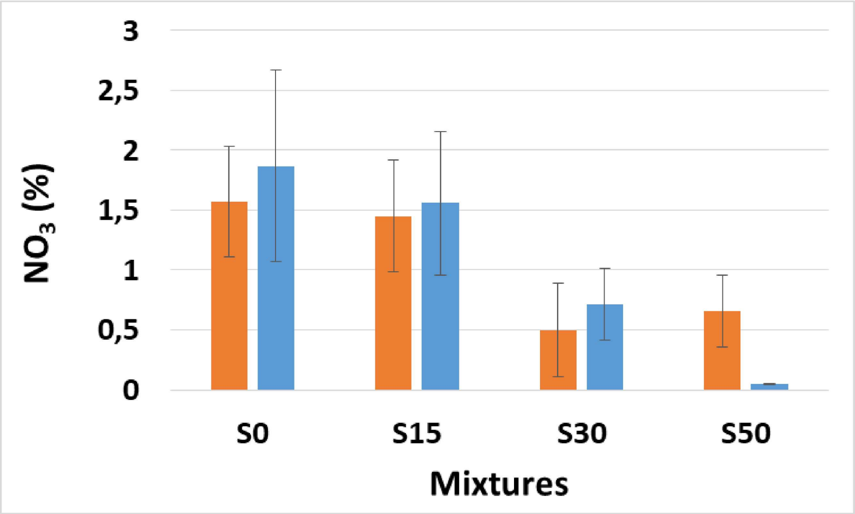


Figure 15: Mean NO$_3$ content (%) of the S0, S15, S30 and S50 mixtures after 25 weeks of incubation at 35°C (🟧 orange) and at 25°C (🟦 blue). The vertical bars indicate the standard deviation (SD) of the mean (n = 3).

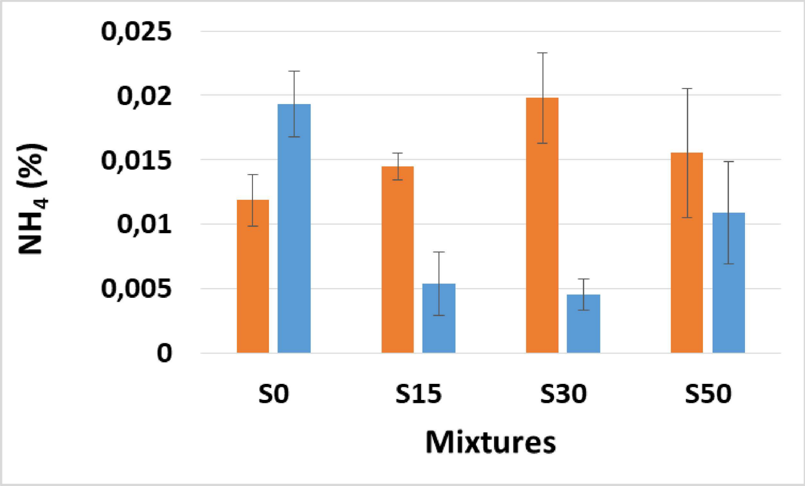


Figure 16: Mean NH$_4$ content (%) of the S0, S15, S30 and S50 mixtures after 25 weeks of incubation at 35°C (🟧) and at 25°C (🟦). The vertical bars indicate the standard deviation (SD) of the mean (n = 3).

S0 also had the higher content of phosphate, compared to all other treatments, regardless of the temperature that the samples remained (Figure 17), whereas K content was significant higher in these samples only in the case they remained at 25°C during the incubation period (Figure 18).

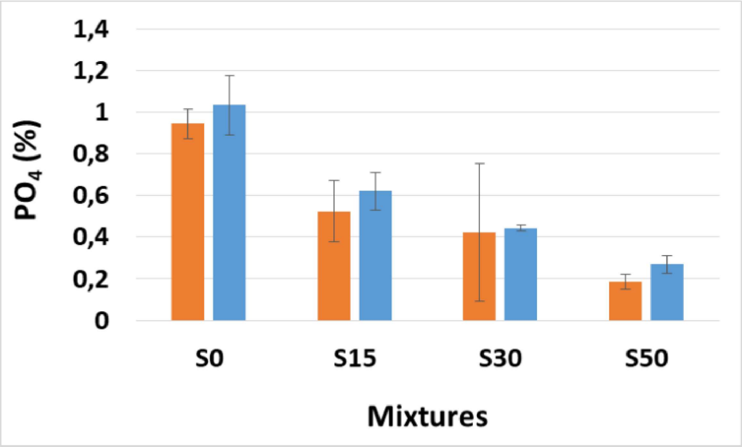


Figure 17: Mean PO_4 content (%) of the S0, S15, S30 and S50 mixtures after 25 weeks of incubation at 35°C (🟧) and at 25°C (🟦). The vertical bars indicate the standard deviation (SD) of the mean (n = 3).

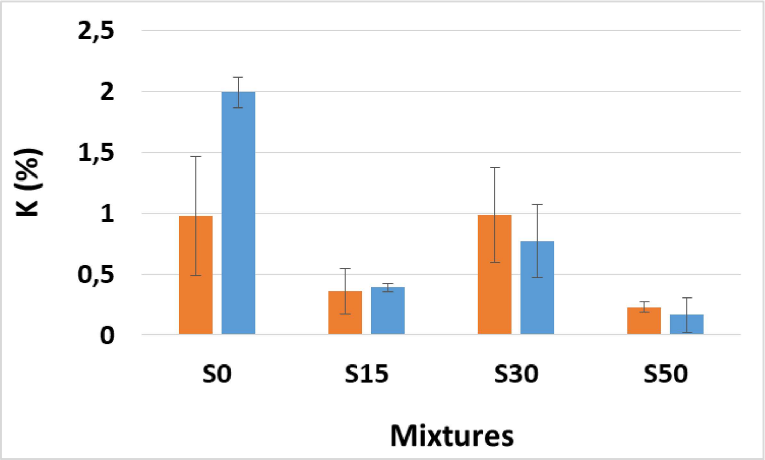


Figure 18: Mean K content (%) of the S0, S15, S30 and S50 mixtures after 25 weeks of incubation at 35°C (🟧) and at 25°C (🟦). The vertical bars indicate the standard deviation (SD) of the mean (n = 3).

Finally, S0, S15, S30 and S50 mixtures remained at 25°C during the incubation period had the higher content in Mg, compared to those remained at 35°C (Figure 19). No statistically significant differences were observed between S0, S15, S30 and S50 mixtures remained at 25°C as concerned Mg content.

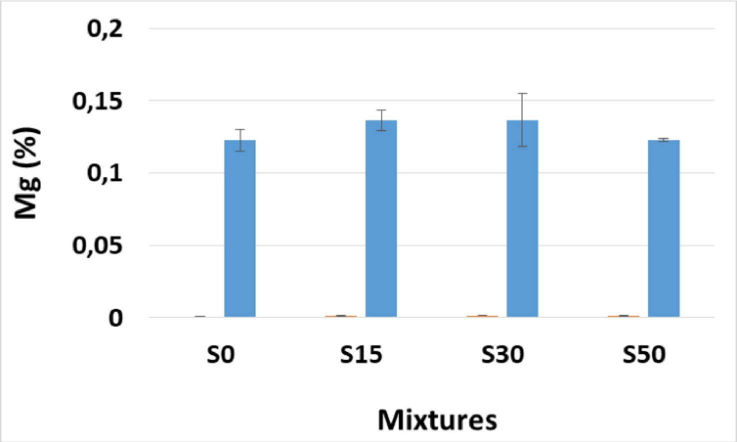


Figure 19: Mean Mg content (%) of the S0, S15, S30 and S50 mixtures after 25 weeks of incubation at 35°C (🟧) and at 25°C (🟦). The vertical bars indicate the standard deviation (SD) of the mean (n = 3).

2.2.4.5 Conclusions

The increase of temperature during the first weeks of the incubation period may increase the total microbial count, in mixtures containing a larger proportion of soil, facilitating the release of nutrients.

After 6 weeks of incubation, the temperature of the composting material could be lowered to 25°C, since maintaining higher incubation temperatures does not appear to have favoured the increase of the total microbial count. Mineralisation of nutrient elements in samples contained high amount of organic matter (or less amount of soil) was facilitated when they were incubated at 25°C.

In the case of S0, increased incubation temperature for a period farther than 6 weeks, seems to inhibit the increase of the total microbial count. Organic matter decomposition completed in S0 after 25 weeks of incubation (when no soil was mixed with cocoa shells) while in the other mixtures seems to be in progress. These samples (S0) had the higher content in K and PO_4 and very high content in NO_3. However, this may be due to the fact that mixtures containing soil (DC0.3, DC0.6, DC1) were not fully homogenised because the soil forms agglomerate each time the mixtures were moisturised. Especially mixtures with the highest soil content (DC0.6, DC1) showed the greatest inhomogeneity having soil lumps.

Because of the soil content DC0.3, DC0.6, DC1 mixtures needed more time to dry, while after drying these mixtures were easily separated into soil and composted cocoa shells, had dust remaining and they cannot be used as substrate. In DC0 samples the composting did not reduce the particle size to such an extent that this material could be used directly as a substrate. However, they were more homogeneous and after proper treatment the material could be used as a substrate.

3 Seedling production in different climates: Mediterranean, Oceanic and Northern

3.1 Seedling production of horticultural plants using extruded materials and compost in Mediterranean conditions (Catalonia).

Authors: Glòria Colom and Joan Manubens, Escola Agrària de Manresa-Catalan Government (Catalonia).

3.1.1 Materials and Methods

Different materials for substrates have been tested in three consecutive trials at the Escola Agrària de Manresa. In each next trial, materials less effective in the previous test have been removed and other materials have been added. All the extruded materials were processed at ATB.

Table 4. Seedling experiments performed at the Escola Agrària de Manresa.

SUBSTRATES	**1st TRIAL**	**2nd TRIAL**	**3rd TRIAL**
(A) Conventional fertilised peat (control)	X	X	X
(B) Vegan compost from “EAM”	X	X	X
(C) Compost from Belloch Forestal*	X	X	X
(D) Extruded poplar mixed with “C” (1:1 V/V)	X		
(E) Extruded cane *Arundo donax* mixed with “C” (1:1 V/V)	X		
(F) Extruded vineyard pruning residues mixed with “C”(1:1 V/V)	X	X	
(G) Extruded vineyard pruning residues mixed with “C”(1:4 V/V)		X	X
(H) Extruded forest residues mixed with “C” (1:4 V/V)		X	
(I) Organic fertilised peat (second control)			X
(J) Commercial growing media with composted pine bark, extruded forest residues and peat			X
Total number of substrates tested:	6	6	6

*Compost from Belloch Forestal: Mediterranean forest biomass and solid fraction of dairy slurry. 2017-2019. Operational Group *Production and use of km0 growing media*. Belloch Forestal and IRTA.

Three consecutive trials (Table 5) were conducted in greenhouse (without heating system). In each trial, three repetitions per treatment were made, in different trays (as Figure 19 example), under the same conditions. Discarding margins, between 18 and 24 cells were sawn in each repetition (depending on the trial).

Table 5. Description of the trials regarding species, fertilisation, dates and duration of the experiments.

	FIRST TRIAL	**SECOND TRIAL**	**THIRD TRIAL**
SPECIES	tomato	lettuce	tomato & pepper
INITIAL FERTILISATION	Own fertility	with & without fertiliser added (4g/L of DCM®)	fertiliser added (4g/L of DCM®)
DATES	20/02/2020	24/09/2020	18/03/2021
TRIAL DURATION	10 weeks	6 weeks	8 weeks

Figure 19. View of the 3rd trial experimental design.

In the first trial tomato seeds was sown in the end of winter without any additional feeding in order to observe just the response of the raw materials.

In the second trial, evaluation was not only to substrate treatment, but also to the response to added fertiliser. A commercial granulated fertiliser made from organic poultry manure DCM was applied in half the samples of the trial.

In the third trial, evaluation was not only to substrate treatment, but also to the sensitivity to salinity. The two crops were chosen related with the sensitivity to salinity (tomato - low sensitivity and pepper - high sensitivity). All treatments were amended with the DCM® fertiliser.

Table 6. Design (sources of variation) of the different trials

VARIATION SOURCES	SUBSTRATE	FERTILISER	SALINITY
FIRST TRIAL	X		
SECOND TRIAL	X	X	
THIRD TRIAL	X		X

At the end several biometrical and chemical measurements were taken, listed below:

- Germination: maximum number of germinated plants.
- Germination curve (only in the third trial): maximum and 50% germination days.
- Survival: final number of plants.
- Plant height (aerial part).
- Total weight (including radicular system and substrate).
- Plant fresh weight.
- Plant dry weight.
- pH.
- Electric conductivity.
- Nitrate.
- Phosphate.
- Potassium.

All chemical measurements were made from lixiviates collected with induced percolate method (IPM) (Cáceres and Marfà, 2013), three times during each trial (initial, half term and final conditions).

3.1.2 Results

In the first trial, the two composts performed even better than the control growing media (Figure 20 and 21). Extruded plant fibres did not support plant growth.

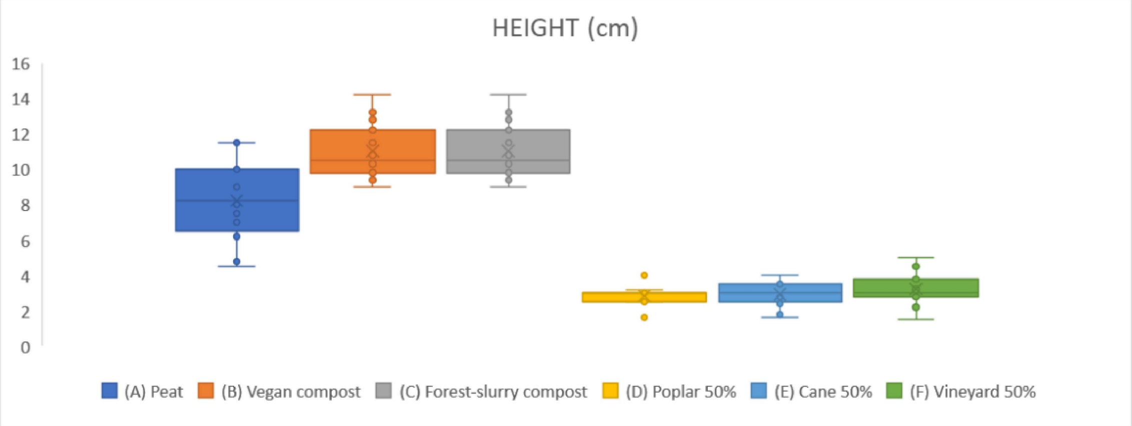


Figure 20. Height of the seedlings in the 1st trial

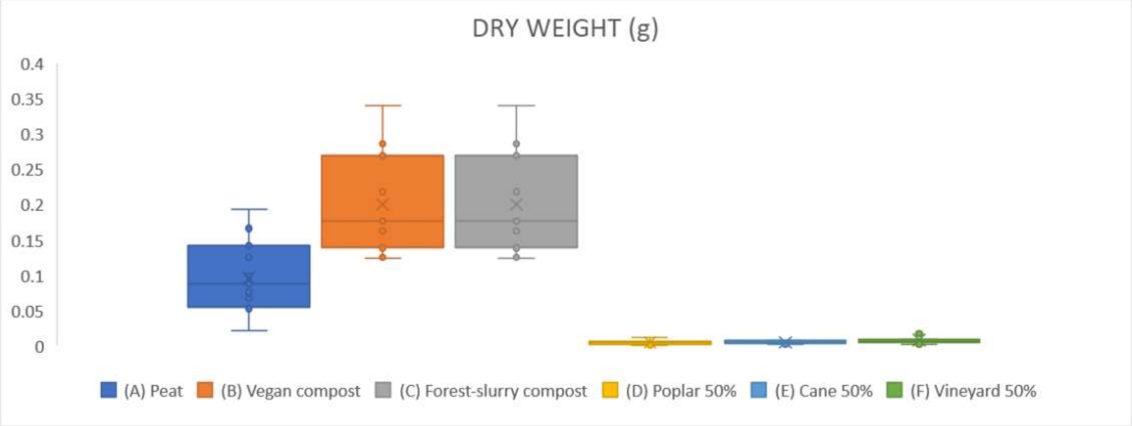


Figure 21. Dry weight of the seedlings in the 1st trial

This can be explained because of the initial fertility of these media (Figure 22) and the nitrogen starvation effect of the extruded materials.

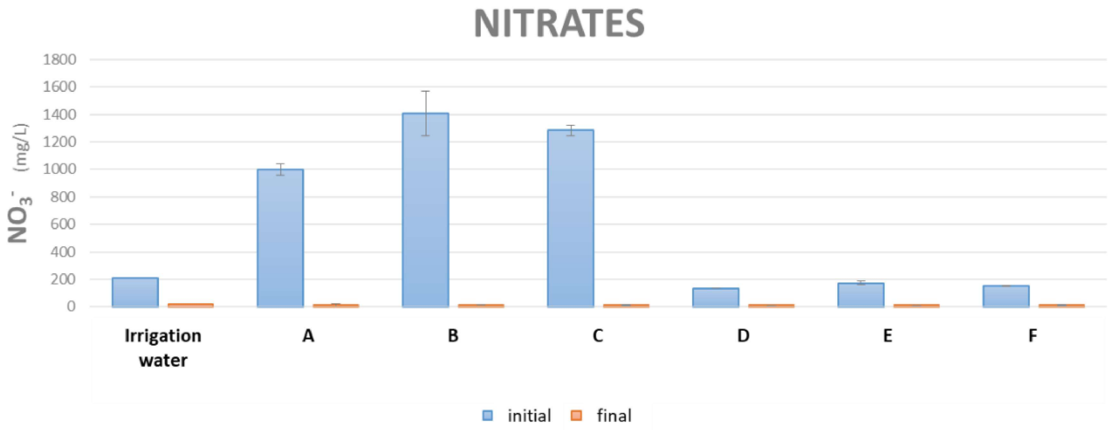


Figure 22. Nitrate composition of the leachates in the 1st trial

In the second trial, the two composts again performed even better than the control growing media (Figure 23 and 24). Extruded vineyard pruning residues did not support plant growth at 50%, but improved results at 20%. This reduced proportion of extruded material in the mixture enhance the response in growth and plant development, especially in fertilised treatments. Extruded forest residues had not very interesting results.

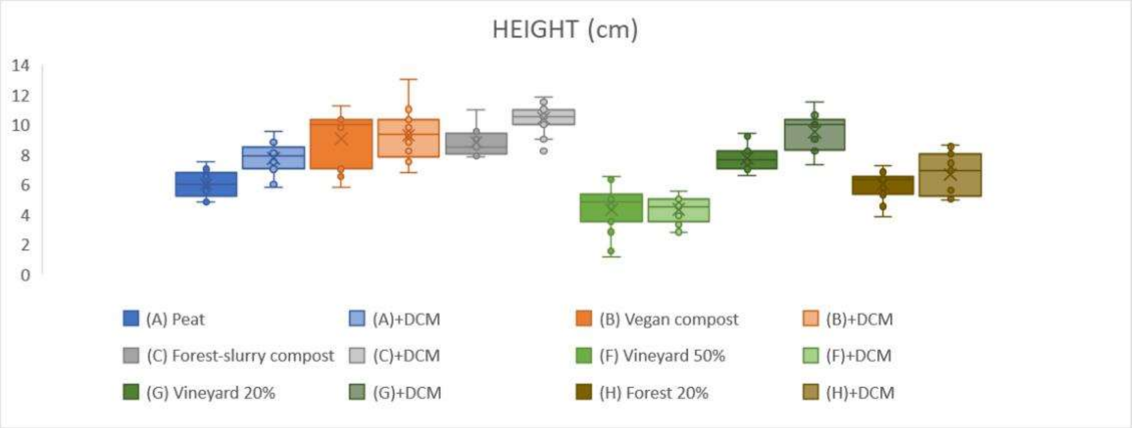


Figure 23. Height of seedlings of the 2nd trial

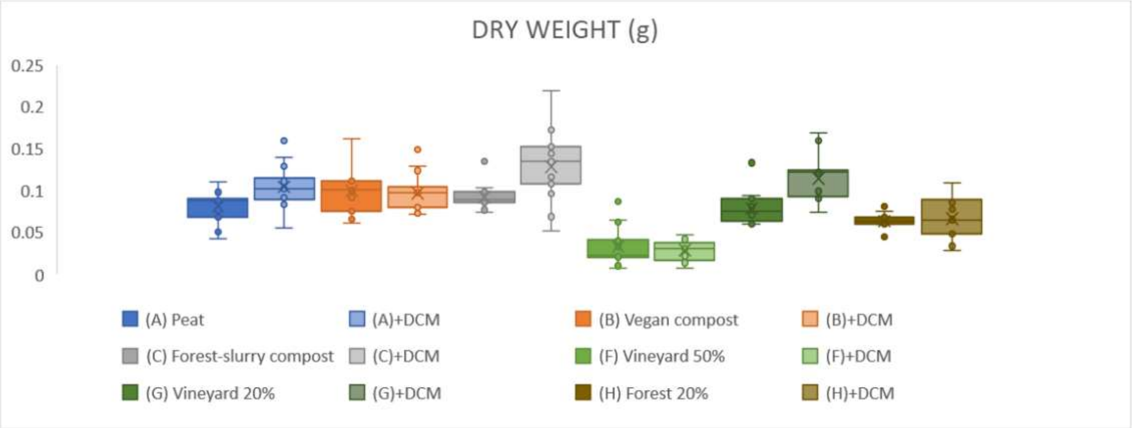


Figure 24. Dry weight of the seedlings in the 2nd trial

In the third trial, the two composts and the extruded vineyard pruning residues results were better than the control growing media (both conventional and organic ones). Commercial growing media with composted pine bark, extruded forest residues and peat had the worst results (Figure 25 and 26).

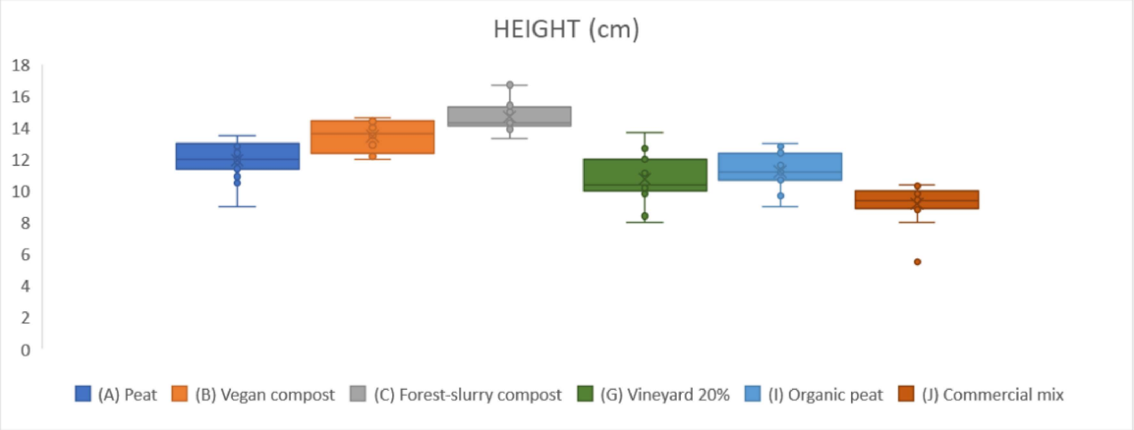


Figure 25. Height of tomato seedlings in the 3rd trial

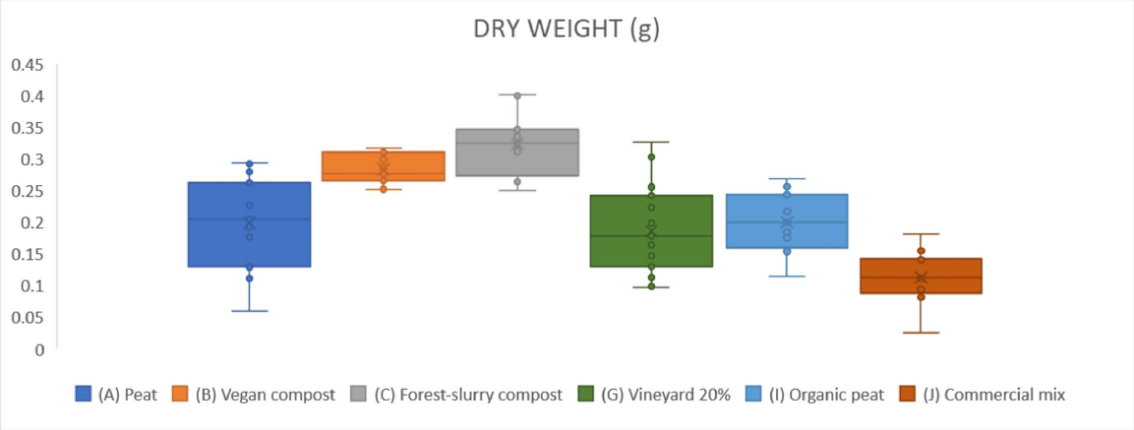


Figure 26. Dry weight of the tomato seedlings in the 3rd trial.

The scheme is repeated with pepper seedlings (Figure 27 and 28), despite the high electric conductivity of the treatments with compost (B, C and G in Figure 29).

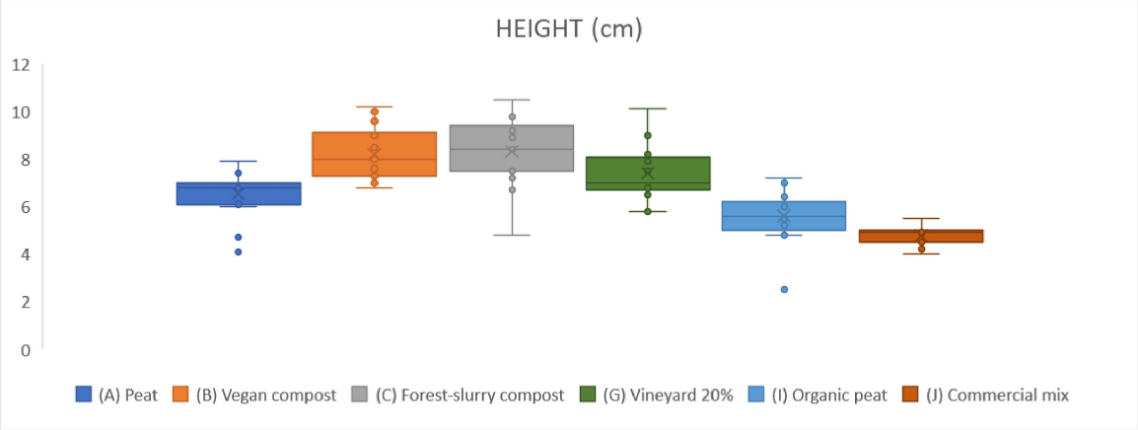


Figure 27. Height of the pepper seedlings plants in the 3rd trial

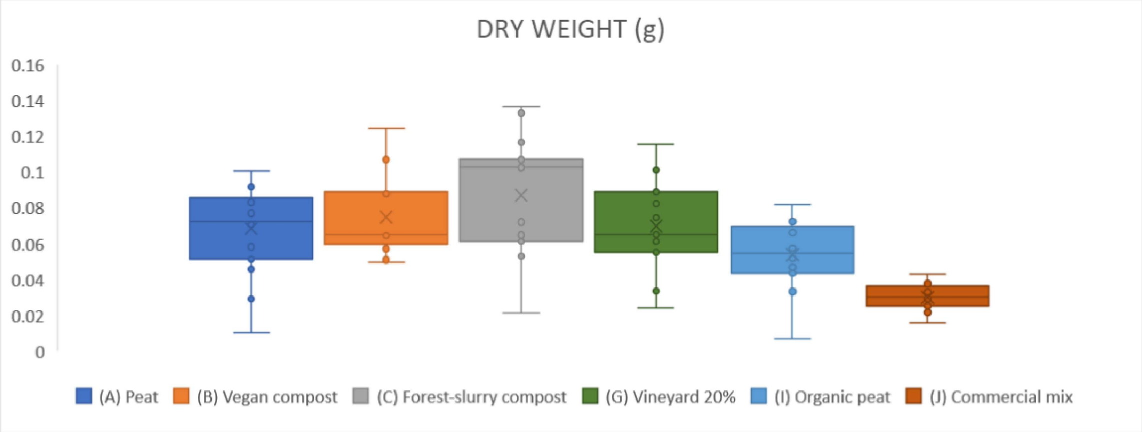


Figure 28. Dry weight of the pepper seedling plants in the 3rd trial

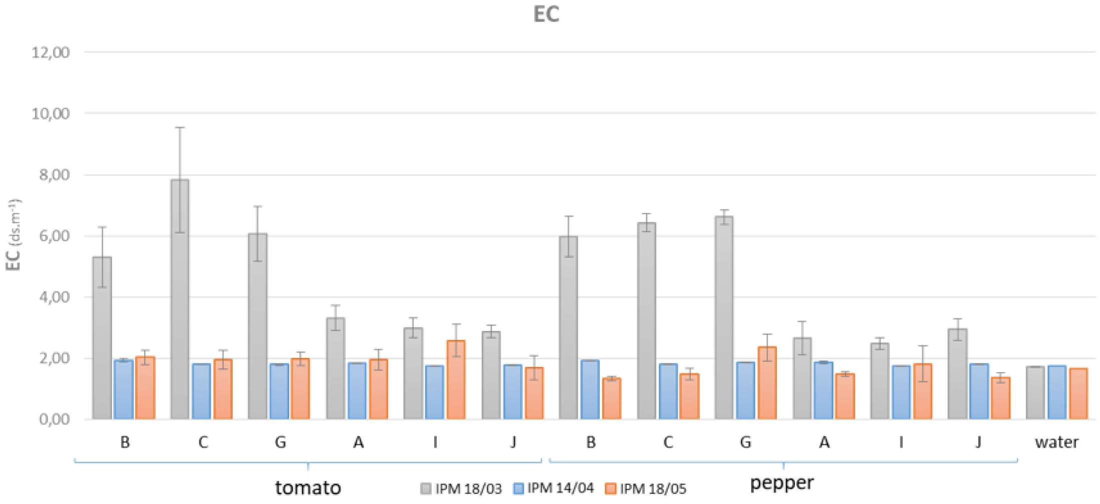


Figure 29. Electrical conductivity of induced percolates in the 3rd trial

There were not many differences between species looking at the emergence curve (Figure 30 and 31).

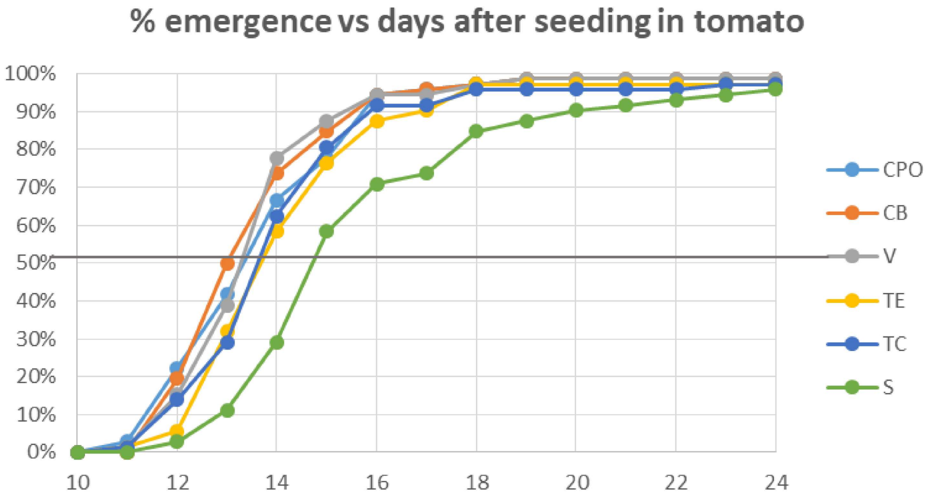


Figure 30. Cumulated emergence after seeding in tomato (3rd trial)

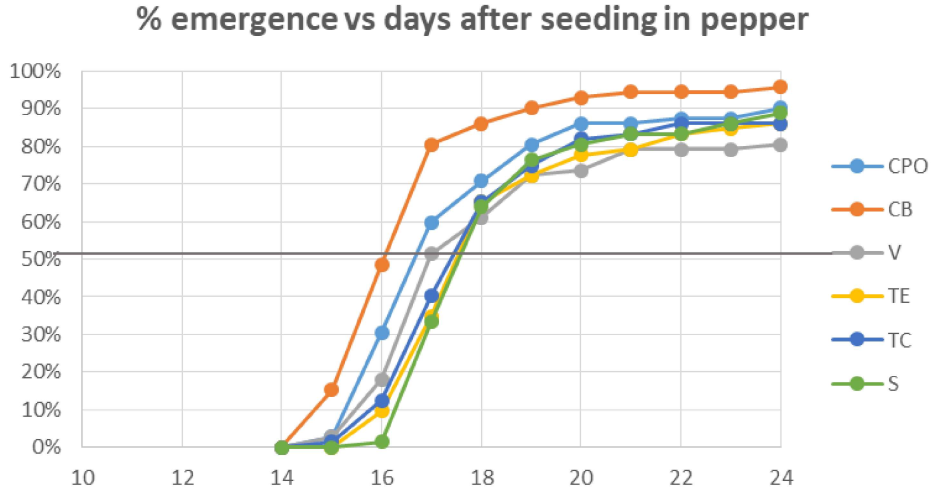


Figure 31. Cumulated emergence after seeding in pepper (3rd trial)

3.1.3 Conclusions

Under these experimental conditions, the optimal response is seen in treatments **exclusively made of compost**. This treatment performed even better than peat ones. Mixtures with 20% extruded materials also had a similar response as peat, and we can discard substrates with higher proportion of extruded material.

Also under these experimental conditions, the salinity level of composts materials **does not hinder** seedlings emergency and growth (we would expect germination issues).

On the other hand, initial fertility of substrates, referring to the nitrate initial concentration, is related with its final growth. Probably substrates which showed higher nitrate level **contained more nitrifying bacteria,** leading to a larger plant growth.

Fertility is an important limiting factor in these trials. **Fertigation** could enhance growth in most treatments, and maybe highlight other media issues. However, this kind of limited growth observed could be helpful for controlling the production cycle by producers, being able to speed the process when required.

3.2 The production of seedlings using commercial peat-free growing media by Coventry University (UK)

Authors: Francis Rayns, Judith Conroy, Dennis Touliatos and Ulrich Schmutz, CU (UK).

3.2.1 Introduction

The aim of this work was to assess the effectiveness of composted woodchip as a growing media for vegetable transplants grown in plastic module trays. It was originally intended that this would be done in collaboration with Delfland Nurseries Ltd, the largest supplier of organic vegetable transplants in the UK (www.delfland.co.uk/acatalog/About-Delfland.html). Unfortunately, this was not possible because of Coronavirus restrictions. Instead, in depth interviews were conducted with staff at Delfland to explore the potential of on-farm sourced growing media in contrast to commercially manufactured products; this is described in Deliverable 5.7. Practical work was conducted on Coventry University premises. Our experiments were focused on minimising the use of vermiculite of other contentious products frequently used as additives to woodchip compost.

3.2.2 Material and Methods

All work was conducted on benches in glasshouses at the Ryton Gardens campus of Coventry University located in the English Midlands. These were heated with hot water pipes and vented to provide cooling.

There were two cycles of experimentation with the growing media treatments tested, blended according to volume, listed in Table 7 and 8. Details of the materials are given in Table 9. In each case the media were freshly blended and used to fill plastic module trays (27cm^3 cell size, 45 cells per tray). Three different test crops were used: lettuces (*Lactuca sativa* cv Matilda), leeks (*Allium ampeloprasum* cv Blue Green Winter/Avano) and cabbages (*Brassica oleracea* cv Marner Laagerweiss). There were four replicate trays for each medium/species combination. In each case one seed was sown per cell. The plants were watered as required and no additional feeding was applied. A central block of 12 plants from each tray was used for the final biomass assessments. In May 2021 the lettuce transplants were planted out into a sandy loam to determine their ‘take off’ potential; crop yield was assessed after 50 days of growth.

In addition, sets of 750cm^3 pots were filled with the growing media at the same time as the module trays and incubated, without plants, under the same temperature and watering regime in the glasshouse. Four replicate sets of pots were destructively sampled periodically; 30cm^3 of sample media was extracted into 150cm^3 water during a one hour shaking period. After centrifuging and filtering a range of key chemical parameters were determined: pH, electrical conductivity, nitrate-N, ammonium-N, dissolved P, K, Mg, Ca, S, Mn, B, Fe, Na, Cl, Na, Cu, Zn, and Mo.

Table 7. Treatments used in the first cycle of the UK growing media trials (set up in March 2021)

Treatment	Growing media
1	Woodchip compost, 100%
2	Woodchip compost, 90%, Vermiculite 10%
3	Woodchip compost, 80%, Vermiculite 20%
4	Woodchip compost, 70%, Vermiculite 30%
5	Woodchip compost, 90%, Extruded poplar (ATB) 10%
6	Woodchip compost, 80%, Extruded poplar (ATB) 20%
7	Woodchip compost, 70%, Extruded poplar (ATB) 30%
8	Commercial control – Melcourt Sylvamix Natural

Table 8. Treatments used in the second cycle of the UK growing media trials (set up in November 2021)

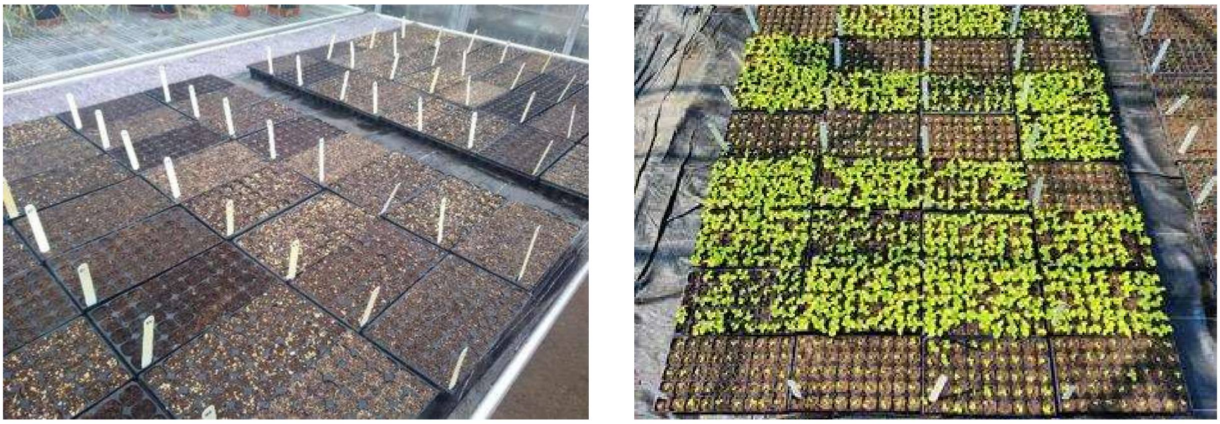
Treatment	Growing media
1	Woodchip compost, 100%
2	Woodchip compost, 85%, Vermiculite 15%
3	Woodchip compost, 70%, Vermiculite 30%
4	Woodchip compost, 85%, Extruded poplar (ATB) 15%
5	Woodchip compost, 70%, Extruded poplar (ATB) 30%
6	Woodchip compost, 85%, Extruded conifer 15%
7	Woodchip compost, 70%, Extruded conifer 30%
8	Commercial control – Melcourt Sylvagrow
9	Commercial control – Fertile Fibre Seed

Table 9. Details of materials used in the UK growing media trials

Material	Details	Organic matter %
Woodchip compost	Composted woodchip was obtained from Tolhurst Organics. It had been made from mixed chipped hardwood tree prunings and composted for two years. Before use it was sieved to 7mm to remove undecomposed material and stones.	30
Vermiculite	Obtained from Sinclair: 'Pro, graded for horticulture, Medium (2.00 - 5.00mm)'.	0
Extruded poplar	Obtained from ATB in Germany. Produced from coppiced poplar (*Populus nigra* x *populus maximowiczii*) chipped and processed at a moisture content of 53% through a Lehman twin screw extruder (90-120^{o}C) then flash dried.	99
Extruded conifer	Obtained from a UK commercial growing media producer who used the ‘steam explosion’ process. Produced from chipped pine, larch and spruce species that were steamed (150°C for at least 90 seconds), conditioned and processed under pressure (3.5 bar) before being fed through a defibrator. The expanded fibres were then shredded.	99
Melcourt Sylvamix/ Sylvagrow	Obtained from Melcourt Ltd (Gloucestershire, UK): an organically certified growing media made from conifer bark.	77
Fertile Fibre Seed	Obtained from Fertile Fibre Ltd (Herefordshire, UK): an organically certified growing media made principally from coir.	60

3.2.3 Key results – plant growth

A visual record of the trials is presented in Figure 32. The effect of the various growing media on plant germination in the first experimental cycle is shown in Figure 33. There was a different response from each of the test crops; in the case of the lettuces germination in the commercial control was markedly slower than all the woodchip compost media whilst germination of the leeks tended to be better in the media containing extruded wood. After germination growth of all three species in media containing both types of extruded wood was clearly inhibited; as an example the final biomass of the lettuces in the first experimental cycle 49 days after sowing is shown in Figure 34; the best growth occurred in the woodchip compost treatment without any amendment. However, after transferring into soil in the field even the smallest transplants survived and grew on to produce marketable, although small, lettuce plants (Figure 35).



The blended media immediately after sowing with lettuces and leeks (March 2021)

The lettuce trial showing treatment differences (April 2021)

Cabbage trial showing treatment differences (December 2021)

Lettuce take off trial shortly after planting out (May 2021)

Figure 32. Visual record of the UK growing media trials

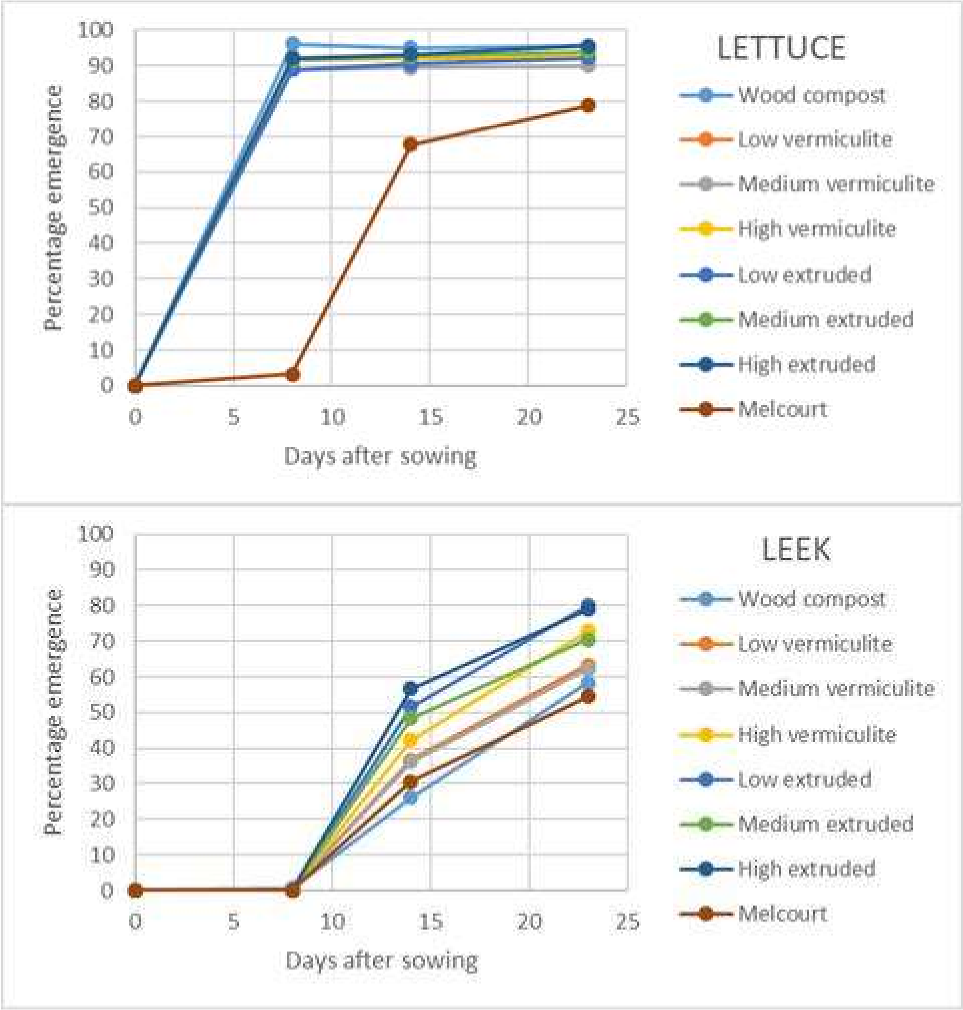


Figure 33. Germination (percentage of emergence after 25 days of sowing) of lettuce and leek in the first experimental cycle of the UK growing media trials

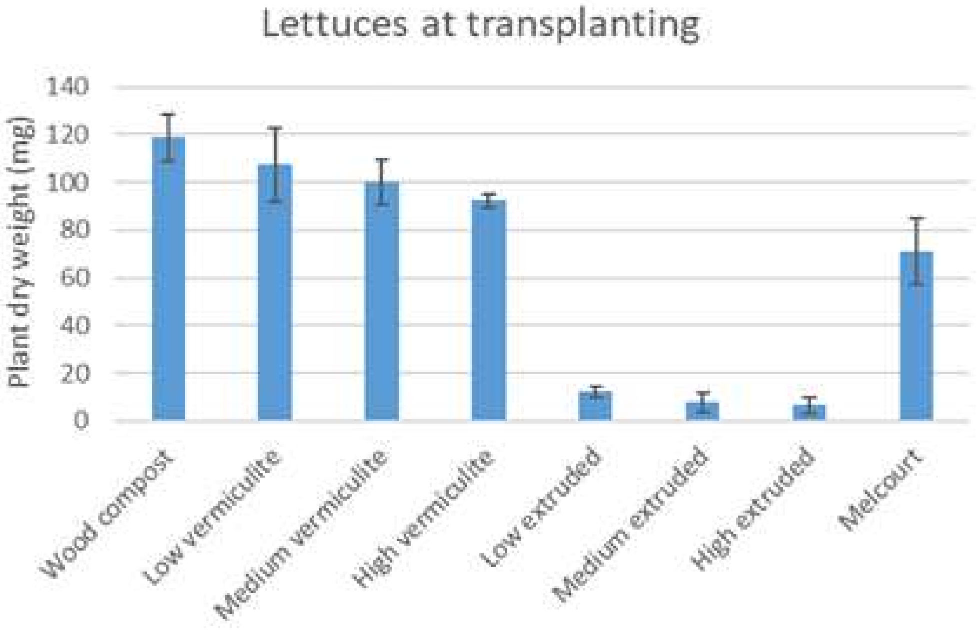


Figure 34. Final biomass (plant dry weight in mg) of lettuces at transplanting in the first experimental cycle of the UK growing media trials. Vertical bars indicate the standard deviation (SD) of the mean (n = 4)

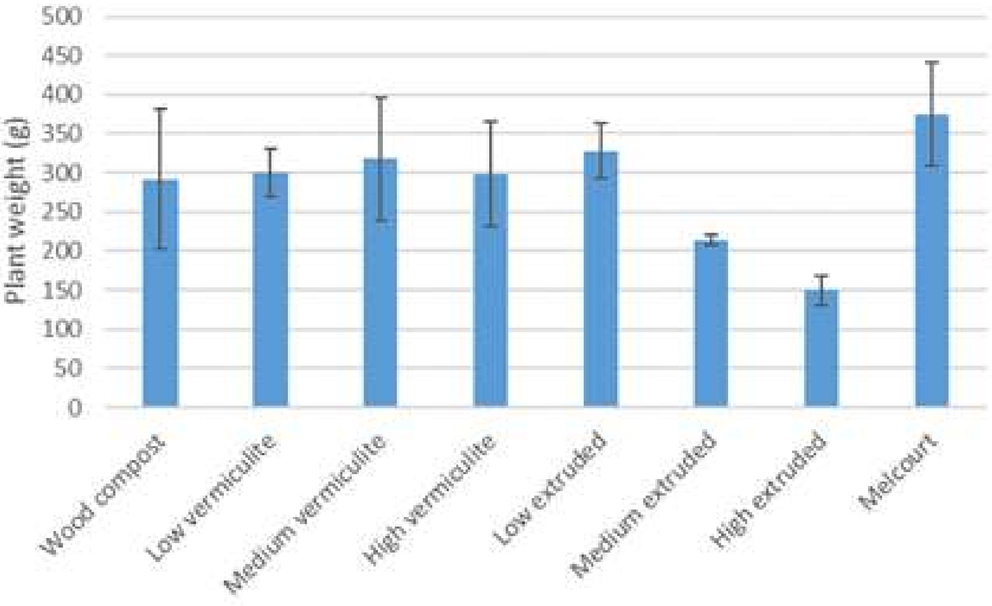


Figure 35. Final yields (plant dry weight in mg) of lettuces 50 days after planting out transplants in the open field from the UK growing media trials. Vertical bars indicate the standard deviation (SD) of the mean (n = 4)

3.2.4 Key results – nutrient availability

Chemical analysis of the compost showed that there were similar levels of conductivity in all the treatments except the commercial control (Figure 36); higher conductivity then in this media, compared to others, was probably responsible for the poor lettuce germination. Changes in mineral nitrogen (nitrate-N and ammonium-N) over a 94 day period are shown in Figure 37. In most treatments the concentration of nitrate, in the absence of plants, increased steadily. This is despite the high carbon content of the wood from which the compost was made. However, the ‘woodchip compost’ did have a low organic matter content of 27% as the composting was carried out on a soil base which became mixed in as the heap was turned. When extruded wood was included in the media, even at only 10% by volume, only very low concentrations were detectable. This was observed in the case of both extruded poplar from ATB and extruded conifer material that is currently used as an ingredient in commercial conventional growing media (see further discussion in D5.9); a readily available nitrogen source could perhaps have overcome the immobilisation of N whilst still enabling its inclusion to bring physical benefits to improve the structure of the compost.

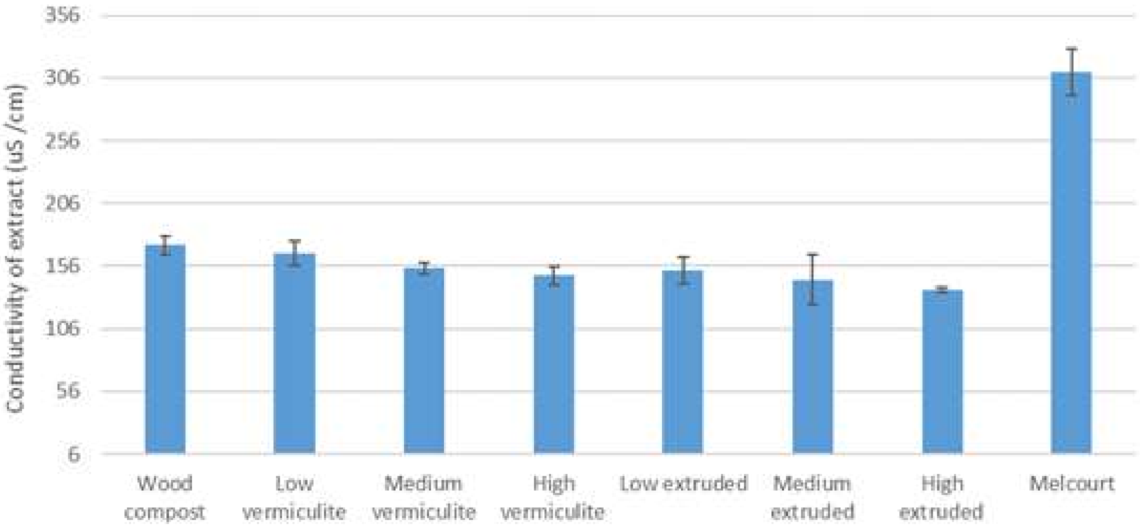


Figure 36. Conductivity of eight growing media in the first cycle of the UK growing media trials. Vertical bars indicate the standard deviation (SD) of the mean (n = 4)

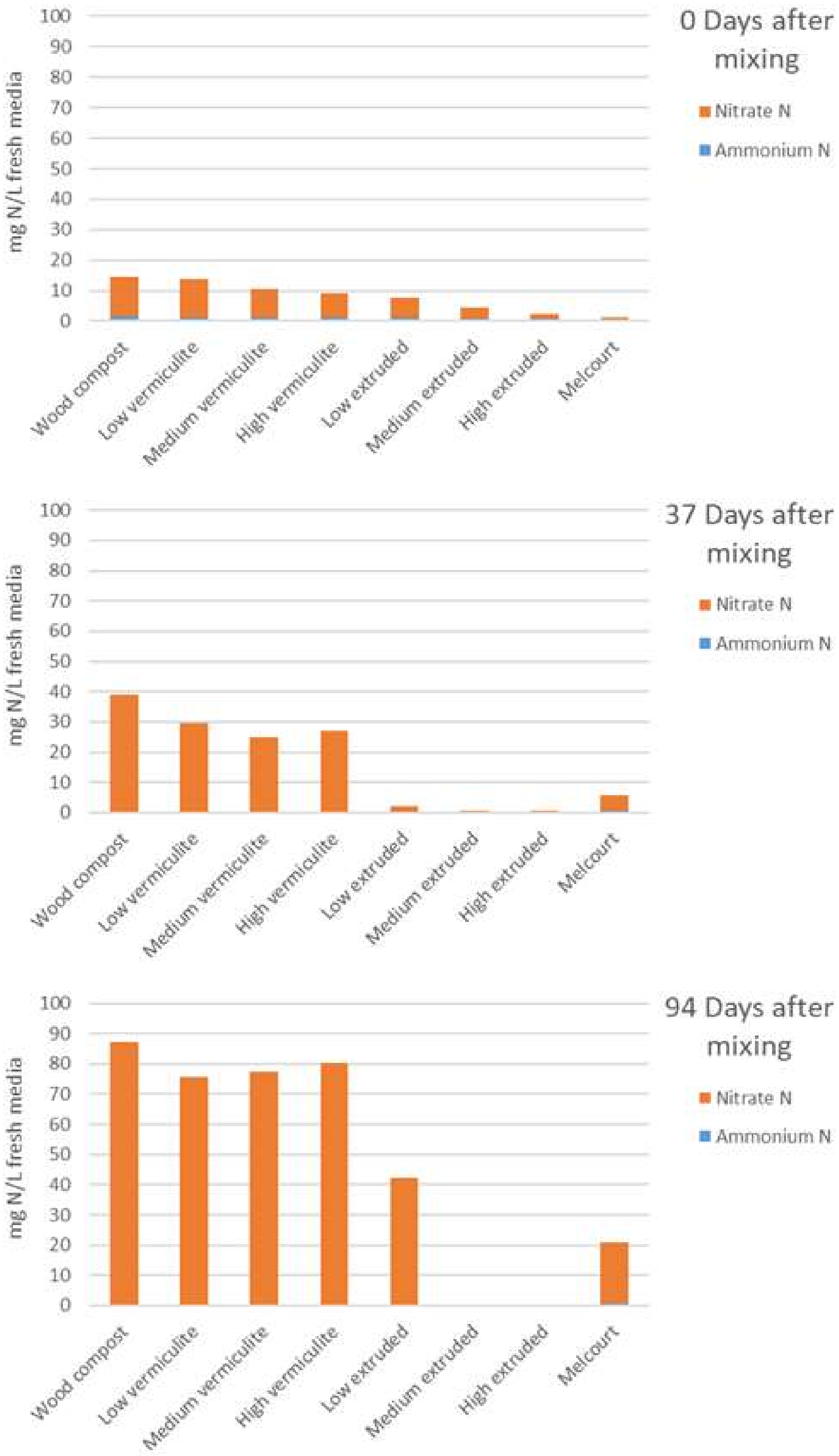


Figure 37. Changes in mineral nitrogen concentration after 0, 37 and 94 days in the first cycle of the UK growing media trials with unplanted pots.

3.2.5 Conclusions

- **Composted woodchip, produced on-farm, can perform as well as, or even better than, commercial peat free growing media.**

- The addition of **vermiculite** to the growing media appears to bring **little benefit** – it can even depress plant growth possibly because the nutrients available in the modules are excessively diluted.

- The inclusion of **as little as 10% extruded wood fibre in the growing media severely depresses transplant growth** as a result of nitrogen immobilisation; it is possible that this could be overcome by appropriate feeding.

- In the absence of plants all woodchip growing media not containing extruded wood fibre exhibited a marked increase in nitrate concentration over a 90 day period.

3.3 Compost from horse manure and hardwood leaves as growing media, by Norwegian Centre for Organic Agriculture (NORSØK)

Authors: Kirsty Mc Kinnon, Anne-Kristin Løes, NORSØK (Norway)

3.3.1 Material and Methods

As briefly presented in D5.2 (Oudshoorn et al., 2019), commercial growing media intended for use in organic growing do not always perform satisfactorily. Mature composts from locally available materials such as leaves from hardwood trees, and horse manure, have shown to perform well (McKinnon 2018). To investigate the importance of compost maturity, a study with composted leaves and horse manure was conducted at NORSØK in 2019.

3.3.1.1 Growing media characteristics

The leaf mould was made from birch (*Betula pendula*), salix (*Salix cinerea*) and aspen (*Populus tremula*) leaves. Leaves were collected from the ground in late October and stored in a heap in an open wooden composting bin for decomposing under a fleece cover. In spring, the material was turned over and moved to another bin for further decomposition. This procedure was repeated the following year for older composts. Leaf composts established in the autumn of 2018, 2017 and 2016 are abbreviated here as L1, L2 and L3. Chemical characteristics are shown in Tables 11-13.

The horse manure compost was made from solid horse manure collected during the winter and stored in a heap on the ground under a fleece cover. After one year of decomposition, the heap was turned. Horse manure composts established in the spring of 2018, 2017 and 2016 are abbreviated here as H1, H2 and H3.

Sieving of compost at NORSØK, Tingvoll in July 2019, to prepare growing media for the transplant test in September. Photo Kirsty McKinnon, NORSØK.

The six composts produced at NORSØK were compared with a commercial potting soil from Klassman-Deilmann, a product recommended by a Norwegian organic greenhouse grower of potted herbs and transplants (De Haes). This grower usually applies the product without additional fertilisation when producing transplants. This treatment was abbreviated O.

The chemical characteristics of the seven growing media applied in the NORSØK study are shown in Tables 11-13. Representative samples of each growing media were collected on September 6, 2019, frozen and sent to Eurofins (Germany) for chemical analysis.

Table 11. Concentrations of total and mineral nitrogen (N), carbon (C), C:N ratio, pH, dry matter (DM), ashes and compacted density (CD) in six composts (H1-3, L1-3) and one commercial growing media permitted for use in organic growing (O). l = litre.

Treatment	Tot-N, g/100g DM	NH_4^+-N, mg/kg DM	$NO_2NO_3^-$-N, mg/kg DM	TOC, % of DM	C/N	pH (H_2O)	DM, %	Ashes, %	CD, g/l
H1	2.5	180	2700	26	10.4	5.6	23.4	36	590
H2	2.1	24	1600	19	9.1	4.8	25.1	46	600
H3	2.1	7.0	1000	15	7.1	6.5	21.1	23	670
L1	1.4	8.0	830	36	25.7	5.4	38.2	67	710
L2	2.1	93	610	33	15.7	6.4	19.9	22	680
L3	1.8	3.7	1200	25	13.9	5.8	29.0	38	630
O	1.8	1100	<7.3	30	16.7	7.0	27.4	31	510

Table 12. Concentrations of ammonium acetate-lactate (AL)-soluble phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca) and sodium (Na) in mg $100g^{-1}$ air-dry material; sulphur (S), iron (Fe) and manganese (Mn) in g kg^{-1} DM; boron (B), cobalt (Co), molybdenum (Mo) and chloride (Cl) in mg kg^{-1} DM in six compost treatments (Tr.) (H1-3, L1-3) and one commercial growing media permitted for use in organic growing (O).

Tr.	P-AL	K-AL	Mg-AL	Ca-AL	Na-AL	S	Fe	Mn	B	Co	Mo	Cl
H1	170	510	210	660	39	2.8	7.7	0.8	<20	3.0	2.8	600
H2	63	160	150	380	12	2.5	7.4	1.2	<21	5.0	4.7	70
H3	42	65	200	1300	8	1.7	4.6	0.6	48	5.1	<1.1	27
L1	99	140	100	420	8	1.8	10	0.5	<20	4.4	2.6	61
L2	36	51	200	1200	11	1.8	4.8	0.7	50	5.0	<1.1	61
L3	34	51	180	990	10	1.7	7.8	0.6	41	6.8	1.5	72
O	44	220	110	870	24	1.9	2.1	0.2	<21	<1	5.6	790

Table 13. Concentrations of copper (Cu), zinc (Zn), nickel (Ni), cadmium (Cd), lead (Pb), mercury (Hg), Chromium (Cr) and arsenic (As) in mg kg^{-1} DM; in six compost treatments (Tr.) (H1-3, L1-3) and one commercial growing media permitted for use in organic growing (O).

Tr.	Cu	Zn	Ni	Cd	Pb	Hg	Cr	As
H1	25	140	8.8	0.21	3.4	0.12	20.0	<5.1
H2	26	150	13.0	0.14	3.2	0.11	43.0	<5.2
H3	15	510	4.5	0.75	<2.1	0.16	5.4	<5.3
L1	20	100	11.0	0.11	6.0	0.11	25.0	<5.1
L2	14	380	4.9	0.59	<2.2	0.14	5.5	<5.4
L3	20	360	17.0	0.51	3.1	0.18	38.0	<5.3
O	20	58	<3.1	0.26	11.0	0.11	4.7	<5.2

The concentration of N was slightly higher in composts made from horse manure (H) than leaves (L). The tot-N concentration was lowest in the control (O) and the oldest leaf compost (L3). The control had very low concentrations of nitrate, whereas the composts had low concentrations of ammonium, demonstrating that nitrification occurred in the composts. The content of total C seemed to decrease over time (table 11) especially in L composts, affecting the C/N ratio, which was much higher in fresh leaf compost (L1: C/N= 25.7) than in any other growing media. Composts from solid manure and plant materials may often have pH values > 7.5, which may affect negatively on uptake of micronutrients, but the composts studied here all had pH well below 7, H2 even quite low (pH = 4.8, table 11).

The concentrations of AL-extractable P and K seemed to decrease over time in the composts (table 12), but since initial contents were not analysed, this is only an assumption. Concentrations of minerals which are not easily leached out with excess precipitation, such as zinc and cadmium, increased from H1 to H3 and L1 to L3 (table 13).

3.3.1.2 *Experimental crops*

Lettuce (cv. Diamantinas RZ) and cauliflower (cv. Goodman) were used as test crops. Seeds were certified organic and supplied by Lindbloms Frö, Sweden. Each experimental unit consisted of a module tray with 24 modules for lettuce (Vefi 96, weight 63.5 g) and 18 modules for cauliflower (Vefi 54, weight 75.6 g). The experiment had 3 replicates, and 21 trays were applied for each test crop. For each crop, the trays were arranged in a randomised block design a, b, c where b (Figure 38). Growing conditions were quite even, with a light period of 18 hours per day after germination.

H1 a	H3 b	H1 c
L1 a	L1 b	0 c
0 a	H2 b	L2 c
L3 a	0 b	L1c
H2 a	L2 b	L3 c
L2 a	L3 b	H3c
H3 a	H1 b	H2 c

Figure 38. Distribution of growing media in 21 trays with 18 modules each of cauliflower test plants, grown in the autumn of 2019. H1, 2, 3 = horse manure decomposed since spring 2019, 2018 or 2017. L1, 2, 3 = leaf compost decomposed since autumn 2018, 2017 or 2016. O = commercial test soil certified for use in organic growing produced by Klassman-Deilman.

To prepare the growing media for sowing, on July 11, 2019, all composts except L3 were sieved through a chicken wire mesh (photo 1), and thereafter stored in open plastic containers indoors until the experiment started. L3 was sieved at the onset of the experiment, September 4, 2019. On the same day, 3 bags of control soil, O, were mixed in a container. The amounts of material available per treatment ranged from about 8 to 14 kg. On September 4, each material was sampled for determination of dry matter. It was observed that L composts contained lots of millipedes.

On September 5, all test materials were mixed thoroughly, and water added as assessed required for optimum germination. The amount of water applied to each material was recorded. The DM content of the moistened materials varied from 46 to 67% (Table 14).

The bulk density in a 1160 ml beaker was measured for moistened materials by filling up the beaker with loose material to the top, knocking it gently a table 5 times and filling it up again. This procedure was repeated 3 times until the beaker was full and the surface levelled off by a ruler. Portions of each growing media to be tested were then weighed out according to the bulk density (table 14), to ensure that comparable volumes were applied in all treatments and equal weights of growing media in each replicate unit. The trays were filled up with material according to the experimental plan (Figure 38) and one seed per module of each crop was placed just beneath the soil surface. Trays were covered by a plastic sheet to ensure an even moisture content during the germination phase. The temperature during germination was 22-24 ˚C.

The available number of lettuce seeds did not allow for comparing all growing media in the test and H3 was excluded. Further, in O (control treatment) the number of plants (seeds) was reduced by 50% to 12 per tray. The first seeds germinated on September 9. The plastic cover was removed and the temperature was reduced to 18-21˚C.

Figure 39. Lettuce transplants on September 27, 2019. Photo Kirsty McKinnon, NORSØK.

Figure 40. Cauliflower transplants on October 11, 2019, showing different growth and development between treatments. Photo Kirsty McKinnon, NORSØK.

Water was applied to the trays regularly, initially with equal volumes to each tray, and after September 14 with somewhat more water applied to trays with cauliflower. From October 5, ebb and flow watering was conducted regularly until the experiment was completed, on October 17, 2019. The number of plants per experimental unit was then recorded. Both plant species grew satisfactory during the experiment (figures 39, 40), with some differences between treatments.

The compiled fresh weight and dry weight of plants per experimental unit was recorded by cutting each plant at the soil surface (Figure 41) and recording the accumulated fresh weight (FW) and dry weight (DW) of the total number of plants, adjusted for the number of surviving plants by computing the average plant weight and multiplying by 18 for cauliflower and 24 for lettuce (for treatment O: 12 for lettuce).

Figure 41. Weighing a single plant cut at the soil surface on the harvest date of the experiment, October 11, 2019.Photo Kirsty McKinnon, NORSØK.

3.3.2 Results

3.3.2.1 Germination and survival

The germination of cauliflower was very rapid in L composts, and more than 80% of the seeds had germinated in L 1, 2 and 3 after 5 days on September 10 (Table 14). On this date the H compost were more variable with germination rates between 56 and 67%, but still superior to the control treatment where only 32% of the seeds had germinated. On the final counting date during germination, September 12, the germination rate was close to 100% in all composts, and 82% in the control (Table 14). At the completion of the study, 1 or 2 additional plants had germinated in 8 experimental units, whereas 1 or 2 plants had died off in 6 units and the number of plants had not changed in 7 units. The number of plants per treatment on October 17 was slightly lower in the control treatment, (15.3), and in L2 and 3 (16.3) whereas the other treatments had on average 17.3 or 17.6 plants per unit.

For lettuce the germination percentage was very high in all treatments, 92% In O, 96% in L3, 98% in H2 and 100% in L1, L2 and H1 on September 12. At the completion on October 17, no plants of lettuce had died off but one more plant germinated in O, increasing the proportion of seeds producing viable plants in O to 97%.

We may conclude that all composts performed better than the control substrate with respect to germination, but that the control substrate was also satisfactory for germination of lettuce and cauliflower. Somewhat less plants survived in the control treatment, on average 15.3 plants per experimental unit as compared with 17.6-16.3 plants in other treatments. The difference between treatments, assigned by variance analysis with a General Linear Model (Minitab) was statistically significant (p = 0.003).

Table 14. Germination of seeds in percent on September 10 and 12, and survival of transplants of cauliflower on October 17, 2019, average values for 3 replicates per treatment in % of the maximum value of plants (= 18 per experimental unit). Dry matter content of each growing media after wetting to appropriate humidity before filling the plant trays (DM%). Bulk density was measured in an 1160 ml container after moistening of materials. H1, 2, 3 = horse manure decomposed since spring 2019, 2018 or 2017. L1, 2, 3 = leaf compost decomposed since autumn 2018, 2017 or 2016. O = commercial test substrate (Klassmann-Deilmann).

Treatment	% Sep 10	% Sep 12	% Oct 17	DM, %	Soil density, kg/dm^3
H1	52	96	98	67	645
H2	83	98	96	56	681
H3	57	96	98	61	896
L1	89	94	98	47	790
L2	83	94	90	48	719
L3	90	93	90	47	752
O	32	82	85	46	491

3.3.2.2 Harvest and production of aboveground plant material

On the harvest day, October 17, 2019 it was clear that the growing media had affected growth and development quite significantly of both cauliflower and lettuce (figures 42, 43), but the results were somewhat different for the two crops.

For cauliflower, which demands more nutrients than lettuce, the largest plants which were also best developed, were produced in the control substrate (figure 42, table 15). These plants also had the highest concentration of N, which was measured in a compiled sample of plant material across replicates (one per treatment). However, plants in the youngest horse manure compost (H1) were not statistically significantly smaller (Table 15), and all horse manure compost as well as the oldest leaf compost (L3) produced transplants that would have performed well in the field. Especially in the youngest leaf compost, cauliflower transplants showed symptoms of nutrient deficiency and reduced growth.

Figure 42. Transplants of cauliflower ready for harvest and for recording of plant weight, October 17, 2019. Photo Kirsty McKinnon, NORSØK.

The lettuce plants (Figure 43, table 15) performed generally better than the cauliflower, and transplants that would have performed satisfactorily in the field were produced with all growing media, even if the youngest leaf composts again gave the smallest plants. Similar to what was found for cauliflower, the control soil and one-year old horse manure H1 gave the largest plants with the highest concentration of N.

Figure 43. Photo N6. Transplants of lettuce ready for harvest and for recording of plant weight, October 17, 2019. Photo Kirsty McKinnon, NORSØK.

Table 15. Fresh weight (FW), dry weight (DW), DM% and total-N concentration (% of DM) for 18 plants of cauliflower or 24 (or 12) plants of lettuce grown in different growing media (H, L, O). For each characteristic, values with different letters (a, b) are statistically significantly different at the 5% level.

	------------ Cauliflower ----------------- ----				------------ Lettuce --------------------			
Treat-ment	**FW, g**	**DW, g**	**DM, %**	**Tot-N, % DM**	**FW, g**	**DW, g**	**DM, %**	**Tot-N % DM**
H1	72.1 ab	12.7 ab	17.7 ab	1.77	116.8 ab	11.9 ab	10.3 a	1.58
H2	70.6 b	13.9 a	19.7 b	1.52	87.8 bc	10.4 ab	11.9 a	1.27
H3	59.2 b	11.8 ab	20.1 b	1.38	--	--	--	--
L1	21.0 d	4.4 c	20.8 ab	1.06	51.2 d	7.0 b	13.6 a	1.01
L2	39.2 c	9.1 b	23.6 a	1.05	70.9 cd	10.2 b	145.4 a	0.98
L3	57.0 b	11.7 b	20.5 ab	1.30	86.2 bc	9.8 b	11.3 a	1.37
O	89.1 a	14.5 a	16.2 b	1.86	134.6 a	14.6 a	10.3 a	1.62

3.3.3 Conclusions

We conclude that the reference media (0), horse manure composted 1, 2, and 3 years (H1, H2 and H3) and leaf mould, 3 years (L3) produced cauliflower and **lettuce transplants of satisfactory quality**. When plants are grown in smaller modules, we suggest that H2 and H3 might need additional nutrient supply during the transplant production period.

Both cauliflower and lettuce showed better plant development in well-matured leaf mould (3 years) suggesting that collected leaves need 2-3 years of decomposition in our climate conditions before using as transplant medium. Horse manure, on the other hand, produced healthier and better-developed transplants after only one year of composting.

This study demonstrated that it is possible to produce and to use growing media for transplants from locally available resources, such as leaves from hardwood trees, and horse manure. The use of the contentious input peat is not required to achieve satisfactory quality transplants.

4 Pot production experiments in Mediterranean climate.

In two Mediterranean areas, the compost produced (section 2) were tested to produce olive saplings (in Turkey) and an aromatic plant (lavender, in Catalonia).

4.1 Olive sapling trials by Ministry of Agriculture and Forestry (MAF), Olive Research Institute (ORI) (Turkey)

Author: Alev KIR, MAF (Turkey)

4.1.1 First growing period of olive sapling trials

Abstract of the congress contribution (*Kir, A., Loes, A.K., Cetinel, B., Turan, H.S., Aydoğdu, E., Pecenka, R., Dittrich, C., Caceres, R., Turner, M.L., Rayns, F., Conroy, J., Schmutz, U.* (2021). Testing peat-free growing media based on olive wood residues for olive saplings. II International Symposium on Growing Media, Soilless Cultivation, and Compost Utilisation in Horticulture. ISHS Acta Horticulture, https://doi.org/10.17660/ActaHortic.2021.1317.4).

For environmental conservation, peat-based growing media are being phased-out in many countries. Peat-free alternatives need to be developed, preferably from local biomass ingredients. This paper describes the performance of peat-free substrates containing olive branch pruning materials in comparison with commercial growing media controls for olive saplings grown during April-October 2020 at the Olive Research Institute (ORI) in Turkey. The trial was conducted using a randomised plot design with 4 replications and 4 treatments: 1) (COMP) compost made of locally available plant materials with 70% olive prunings (100%, v.v-1; 2) (FIBRE) mixture of chipped and extruded olive prunings (50% chipped+50% extruded, v.v-1); 3) (SAND) a commercial mixture(sand 90%+vermiculite 10%, v.v-1)(control); and 4)(PEAT+) a commercial mixture (peat 40% +coco coir 40% +perlite20%, v.v-1)(control). The vegetative growth parameters and weed status (density and coverage) were recorded and root fungal diseases commonly found in Turkey were analysed. After the first six months of growth, there were statistically significant differences between the treatments ($p \leq 0.05$); COMP and PEAT+ were comparable and produced the largest plants with 100% survival rate. 98% of plants survived in SAND, and 81% in FIBRE.FIBRE, which was the only treatment with no weed growth, had about 30% reduced growth as compared to SAND, which had 90% and 78% growth compared with PEAT+ and COMP. Still, it was remarkable that it was possible to grow olive saplings in treated olive prunings. It is very promising that a peat-free growing media like COMP performed as well as the commercial growing media with 40% peat. During the extrusion of olive material, the temperature rose to ca. 120°C and during composting the COMP reached 65-70°C; temperatures at which the materials are expected to be effectively sanitised from any fungal diseases.

In Turkey, extruded plant fibre (from ATB) and composted plant materials were tested as replacement for peat in growing media for olive saplings at MFAL. In Turkey, MFAL is conducting a study to raise olive saplings in various growing media, aiming at producing the growing media with locally available resources instead of commercial peat or sand-based growing media. Preliminary results after the first 6 months of growing were recently accepted for publication in Acta Horticulture, the scientific journal of International Society of Horticultural Science. The paper is entitled “Testing peat-free growing media based on olive wood residues for olive saplings” (A Kir, AK Løes, B Cetinel et al.) and is linked to an upcoming conference on growing media in Belgium (https://www.growingmedia2021.com/en/). The paper describes the performance of peat-free substrates containing olive branch pruning materials in comparison with commercial growing media controls for olive saplings grown during April-October

2020 at the Olive Research Institute in Turkey. The figures related the trial are shown in Figure 44a and 44b.

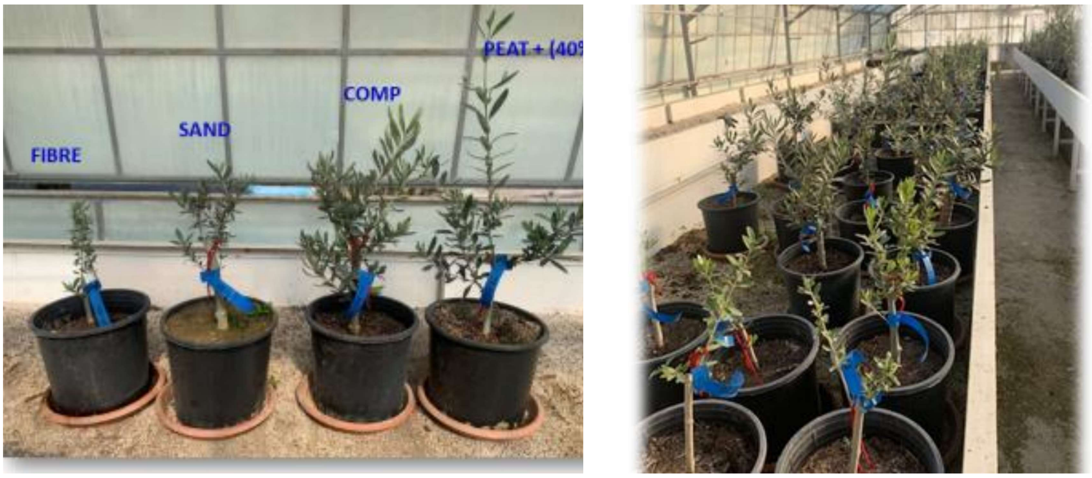


Figure 44a. 6th month results of olive saplings grown in tested substrates

Figure 44b. Tested pots and measurements of the saplings in the greenhouse

4.1.2 Further studies on olive sapling pot trial results of Month 12 are as follows

After 6th month the existing trial extended 6 months more. Finally, the trial observations and measurements were performed totally 12 months between April 2020 and April 2021.

Treatments

The trial was conducted using a randomised plot design with 4 replications and 4 treatments. Each replicate was composed of 48 pots and hence there was a total of 192 pots (4 replications x 4 treatments x 12 pots). The following growing media treatments were tested:

- (COMP) compost made from locally available plant waste material (chipped olive branch pruning 70% v/v, medicinal and aromatic plant residues 10% v/v, grass cuttings18% v/v and, horse manure 2% v/v; (compost used in pots: 100% v/v);

- 2) (FIBRE) mixture of chipped and extruded (to fibre) olive branch pruning (50% extruded+ 50% non-extruded chipped material, v/v),
- 3) (SAND)a commercial mixture (sand 90%+vermiculite 10%, v/v) (control), and
- 4) (PEAT+) a commercial mixture) (peat 40% +coco coir 40% +perlite20%, v/v) (control).

Fibre

Chemical analysis of the substrates revealed a need to apply additional nutrients to the FIBRE treatment and this was done by application of freeze-dried fish powder and vermicompost tea, both inputs permitted for use in organic growing. No fertiliser was added to any of the other treatments at the start of the experiment. Young trees are known to need higher rates of phosphorus and potassium than nitrogen to establish a strong root system. The fish fertiliser was derived from haddock (*Merlangius euxmus*) which had been freeze-dried and ground to a powder (supplying 75 mg P_2O_5 per pot), before planting and 1 month after planting.

Additionally, locally produced, commercially available, and organic certified vermicompost tea (supplying 100 mg N, 200 mg P_2O_5, 200 mg K_2O per 5 litre pot), *Bacillus* spp. ($6x10^7$cfu/ml), and *Glomus* spp. ($1x10^4$cfu/g) were applied. *Glomus* was only applied 1 month after planting, whereas the tea and *Bacillus* were applied at planting and after 1 month. The extrusion procedure of twin-screw-extruder [Model MSZK B90e (Lehman Maschinenbau GmbH, Jocketa, Germany)] for five month aged chipped olive branch pruning was explained in detail in a publication released in 2021.

4.1.3 Results of 12 months of the pot trial:

The compost has successful capability as a growing media in olive saplings as we compared to peat and sand-based substrates can be attributed **the stability and maturity** properties of the on-farm compost (Figure 45). Due to ***Glomus*** enrichment in fibre treatment, and because of the root improvement achieve (number of roots and length of architecture root) we obtained a good fibre substrate performance (in the same group with compost) (Figure 45).

Figure 45. Compost treatment effect on the root (left) and fibre (plus Glomus) treatment effect on the root length (right).

4.2 Lavender pot experiment (Catalonia) using compost based on Mediterranean forest compost and horse manure, by IRTA (Catalonia)

Authors: Rafaela Cáceres, Alejandra Landers, Anna Puerta, Carme Biel and Mar Carreras.

4.2.1 Introduction

An experiment, to raise up lavender seedlings in pots, under organic management, was arranged to compare the selected compost (PO1 and PO3) (section 2.2.3.2) with a commercial peat based growing media (organic production certification). As the inclusion of a fertiliser is a key issue, the "fertiliser strategy" as an additional source of variation was added. An usual organic fertiliser was included in the experiment, as well as another one that is being produced in European countries from wastewater treatment plants (struvite); this product was used in other horticultural crops at IRTA in the framework of the LIFE ENRICH project Enrich (life-enrich.eu).

The approach of the study not only includes the agronomic performance of the plants, but also the impact that could produce the horticultural activity as the release of the nutrients to the environment (leachates with high nutrient content).

4.2.2 Materials and Methods

The suitability of compost PO1 and PO3 produced in the pilot composting plant in Cabrils (section 2.2.3.2) as sustainable growing substrates for *Lavanda angustifolia* cultivation was evaluated by comparing agronomic and environmental parameters with commercial substrate based on peat. As for the plant performance in pot cultivation it is very important the fertility of the media, also a fertilisation strategy was added as a source of variation.

The experiment was carried out from February to July 2021 on an outside container, located at the IRTA research facilities in Cabrils (Catalonia) (latitude 41º25'N, longitude 2º23'E, altitude 85 m). Seedling plants were purchased in a organic nursery dealing with aromatic plants of the Maresme area (Riera-Villagrasa, Inici - Riera Villagrasa).

Seedlings of lavender were transplanted into 4.5L pots, filled with three different substrates and three fertilisation strategies (Figure 46). Therefore, nine different treatments were tested (Table 16). The alternative substrates produced at IRTA premises were used without mixtures. Bioverde® substrate (CONTROL) was certified for organic production, based on peat and amended with fertilisers.

The fertilisation strategies used were: a) DCM® (solid commercial fertiliser used in the Maresme area for organic production), b) STR (solid and milled struvite from Denmark, available thanks to the LIFE ENRICH project executed also by IRTA), c) no fertilisation. The different treatments are listed in Table 16.

Figure 46. Filling the pots with the different growing media.

Table 16. Treatments applied in the lavender trial.

Acronym	Growing medium	Fertilisation strategy
CON-DCM	Control-Bioverde®	DCM®
CON-STR	Control-Bioverde®	Struvite (STR)
CON-NO	Control-Bioverde®	No fertilisation
PO1-DCM	PO1	DCM®
PO1-STR	PO1	Struvite (STR)
PO1-NO	PO1	No fertilisation
PO3-DCM	PO3	DCM®
PO3-STR	PO3	Struvite (STR)
PO3-NO	PO3	No fertilisation

Boxes for collecting leachates from 4 pots were included in the experiment (Narváez et al., 2012 and 2013) (Figure 47). This allowed, on one hand, the quantification of leachates in order to adjust the irrigation doses, as stated before. On the other hand, the leachates were analysed in order to monitor (to some extent) the nutrient composition of the rhizosphere (Cáceres and Marfà, 2013), and on the other one, to check the possible impact of nutrient leaching of the different treatments. The plants were irrigated with water according to a schedule based on solar radiation and leachate percentage.

Figure 47 a) left: detail of a box for gathering the leachates (Narváez et al., 2012 and 2013) b) right: arrangement of the experiment in February 2021 with boxes on the left.

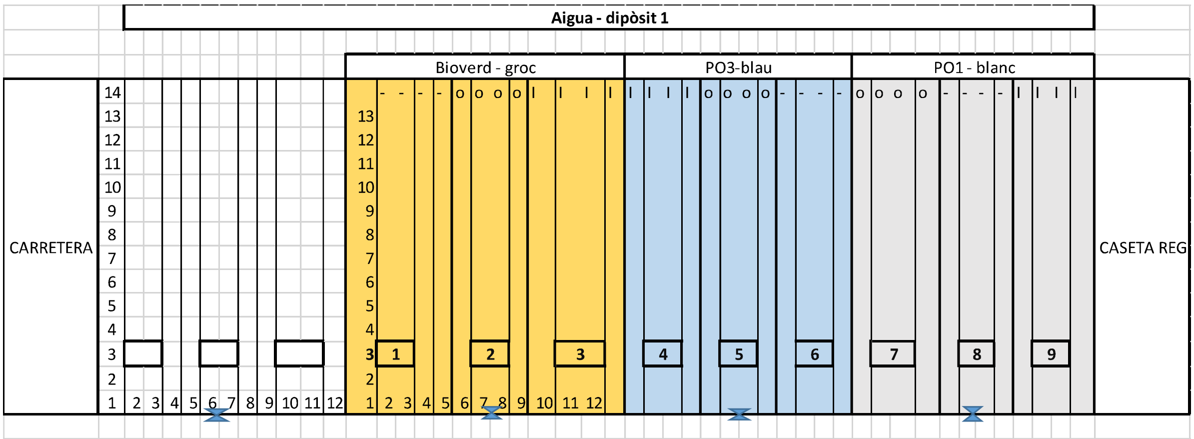


Figure 48. Layout of the experiment

Regarding the agronomic parameters, eight plants were measured for: height and floral stems' number at intermediate (13/04/21) and final time point (6 months after transplant, when most of the plants achieved marketable size). At the end of the experiment, five plants were measured for fresh and dry biomass weight, chlorophyll content (SPAD), foliar area and leaves' specific weight.

Figure 49. Aspect of the experiment in the intermediate stage of the culture of lavender.

Chemical analyses of leachates (pH, CE, P-PO_4^{3-}, N-NO_3^- and N-NH_4^+) and volume leachate were analysed every two weeks. The pH and EC were determined using a selective ion analyser (Thermo Scientific Orion model Dual Star selective ion) and Crison conductivity meter (model GLP31), respectively. The P-PO_4^{3-} and N-NH_4^+ content were analysed by APHA Standard Method 4500-P C. Vanadatemolybdate method and Spectroquant®Ammonium Reagent Test, respectively, using a SPECTROQUANT nova 60 Spectrophotometer. N-NO_3^- was analysed by Nitracheck 404, MERCK.

4.2.3 Results

The results were quite clear in the early weeks from the transplant of the seedlings. The plant's height measures revealed that, after two months from transplanting, both the substrate and fertiliser had a key role. CONTROL plants grew faster than the other ones. And CONTROL, PO3 and PO1 showed decreasing values clearly, respectively (Figure 50).

Regarding, fertilisers, DCM® and STR treatments showed higher values than no fertilised only in the alternative substrates (PO1 and PO3), showing that these growing media should be amended to have acceptable plant growth.
The floral stems measures indicate a decreasing value with CONTROL, PO3 and PO1 substrate, while STR had higher amount than no fertilised treatments.

Figure 50. Representative plants of lavender for each treatment at the end of the experiment.

Figure 51 shows the water release curve of the growing media used in the experiment. It can be checked the differences between the media in the water retention at low matric potential. CONTROL substrate (based on peat) retains much water than PO3 and PO1. Particularly, PO1 was too coarse in particle diameters and for this reason it water retention properties are weak. PO3 substrate presented an intermediate approach.

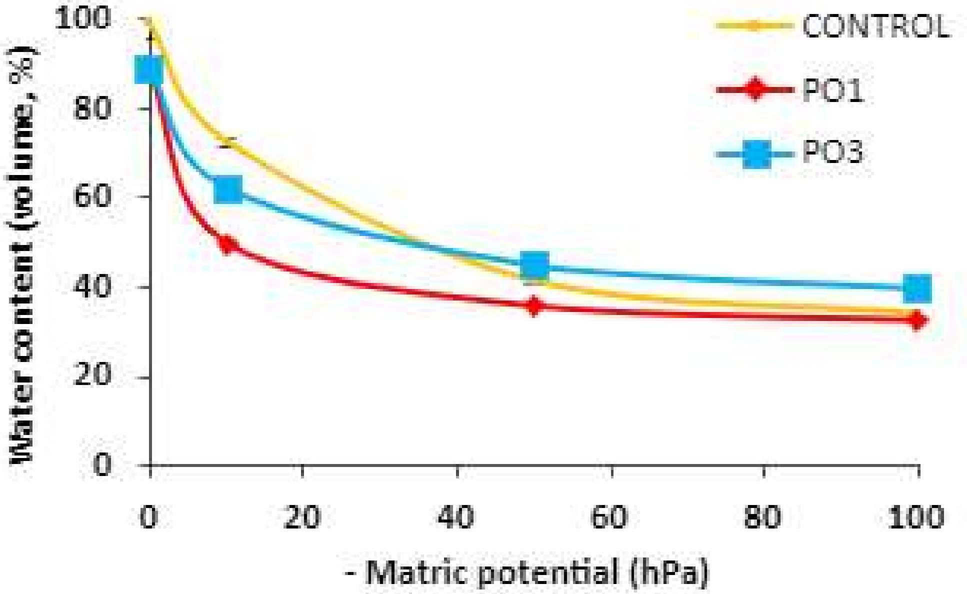


Figure 51. Water retention of the different substrates used in the experiment. (CONTROL: Control substrate based on peat.)

All the leachate's chemical parameters measured, pH was higher in the alternative substrates than in the CONTROL one, while electrical conductivity showed lower values in PO1. Both N-NO_3^- and N-NH_4^+ concentration and N total loss were higher in CONTROL leachates, especially in the beginning of the assay. However, both P concentration and total amount, were higher in PO3 substrate. The release of nitrates in the control substrate should be an issue to deal with, even in organic agriculture. The principle of prevention (fertilisation with adjusted doses) should be applied and the diagnosis of the rhizosphere fertility should be assessed, too (Cáceres and Marfà, 2013). The groundwater in several areas in Europe are polluted for livestock or agricultural practices. For nursery production, the CLEANLEACH® system has been proposed to recycle and to clean up (at the end) leachates (Cáceres et al., 2017; Cleanleach - YouTube.)

The final results of this study will be published in the next months.

5 Conclusions and future research needs

5.1 Conclusions

5.1.1 Specific conclusions

In Turkey: It was concluded that the olive saplings grown in compost (0% peat) performed as well as those grown in "PEAT+ treatment (40% peat)". A very promising result was the 100% peat free mature compost made from 70% of chopped olive pruning materials, and otherwise locally available materials. In this experiment animal manure consumption was reduced as 2% (in volume) in composting procedure, while the general manure has been using approximately 40-50% in compost piles. It probably promising start for vegan compost production.

In Catalonia/Spain IRTA, very clear and conclusive results were obtained. Organic certified commercial peat performed very well compared to the alternative substrates but, under the Mediterranean climate, the release of N through leachates was considerable. Totally alternative growing medium based on Mediterranean forest biomass and horse manure had acceptable plant growth when the proportion of N-rich material (horse manure) was enough; the use of struvite which can be obtained elsewhere in wastewater treatment plants could be an alternative to commercial fertilisers as P was available for plant growth, but the dose should be adjusted.

In Catalonia/Spain EAM. Composts performed very well as growing media in seedling production of horticultural plants in Mediterranean conditions, even better than peat. Mixtures with 20% extruded materials also had a similar response as peat (substrates with higher proportion of extruded material were discarded). The salinity level of composts materials did not hinder seedlings emergency and growth. In the other hand, initial fertility of substrates, referring to the nitrate initial concentration, is related with its final growth, so fertility is an important limiting factor.

In UK: Composted woodchip performed very well as a growing media in module plugs for vegetable transplants and this is a material that could be produced with low inputs on-farm from local materials. This is, however, a lengthy process and so growers would need to plan well ahead and dedicate time the production. Dilution of the compost with un-composted extruded wood fibres was not effective due to immobilisation of nitrogen although this could possibly overcome by feeding. Un-composted extruded fibres did not replace vermiculite as an addition to the composted woodchips. In fact the trials shows limited advantage of adding any vermiculite.

5.1.2 General conclusions

The trend for producing local (or on-farm) compost, upscaling/standardisation of the composting experiences.

The different crisis in raw materials, growing media, energy, transport problems, crisis and other issues related to invasive species would trend to find peat alternatives locally. The project has come across several of these different crisis.

- Compost produced carefully (well matured) and locally could be appropriate materials to replace peat to a certain extent; selection of appropriate raw materials is important.

- Experiences have been done at intermediate scale. On-farm composting is, then, a feasible way to produce high quality compost.
- The procedure for each location should be replicated and standardised in order to have homogeneous compost from well-known and homogeneous raw materials.

Selection of materials and conditions

- Woody materials are appropriate as a raw material
- Extrusion can be an effective method for transforming and defibre wood, but N starvation should be taken into account and must be managed (fertilisation or microorganism addition)
- Composted woody materials mixed with other raw materials with no excessive N can be used, but the experiments should be developed taking into account the fertility of the material
- The management of the growing conditions (agronomic practices including N fertilisation and microorganisms addition) should be considered during the use of the peat alternatives.

Need to widespread of the experiences

- The most successful trials and results should be replicated using other species and under commercial conditions (in general) in order to have more consistent results for a specific material and local condition.

5.1.3 Future research needs

In Turkey: Fresh fibre material from olive pruning materials as well as other fruit trees annually accumulate in large amounts in the country. Thus, “extruded fibre production” of these artificial horticultural organic material or “composting” them in a shorter time (<8 months) should be considered and scientifically searched scientifically. Additionally, the usage of animal manure during composting of the plant residues can be totally replaced different materials to eliminate materials sourcing from animal production.

In IRTA. It is important to increase the knowledge on the use of such materials for other species for organic horticulture (and other crops). In these experiments it is necessary for the inclusion of sources of variation dealing with fertilisers, as the growth in containerised production is linked to water and nutrient management. Aspects of microbiology should be also investigated to gain deeper insight into the mechanisms of nutrient availability.

In UK: More work is needed to study the effect of the composting process to see how it can be accelerated by the addition of materials other than woodchip without compromising the performance of the finished product. A particular problem for growers is to produce peat free ‘blocking media’ that is cohesive enough to be used without containerisation. For commercial and practical reasons not all growers will be able to produce their own media and so the processing must be capable of being up-scaled to manufacture a marketable product.

In EAM. Further experiments with compost as growing media using fertigation could be helpful for enhancing its results and maybe highlight other media issues in comparison with other substrates, as far as fertigation is a helpful tool for controlling the production cycle by producers, being able to speed the process when required.

General “Future needs” considering scientific, technical and environmental aspects

Raw materials

Homogeneous and locally available by-products should be selected (intermediate or low pH, low electrical conductivity) in order to have appropriate inputs materials.

Extruded materials could have impact for their use as a fibrous ingredient, but the management of starvation when used should be ensured, thus studied.

Composting

Scientific knowledge on long composting oriented to produce growing media should be promoted. This knowledge should be linked to the agronomic use of the final materials.

Culture management

The management of the production system (water, fertiliser and microbiology) with alternative growing media it is key to ensure the plant growth. Further studies should be performed in commercial nurseries to build on the results of the project.

Environmental, health and economic issues

Last, but not least: Different aspects should be considered dealing with peat replacement in order to ensure the sustainability of the use of the local alternatives: composting performance (preventive measures if emissions or leachates are formed), culture (nutrients leaching, water management), human health (possible dust in compost, gases, pathogen microorganisms) and economic issues.

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