LIFE AGRISED, LIFE17 ENV/IT/000269

"Use of dredged sediments for creating innovative growing media and technosols for plant nursery and soil rehabilitation"

Guideline

In-pot plant growing using compost-based substrates

Index

Introduction

The production of plants in containers is now a widely used technique in ornamental outdoor nurseries (conifers, flowering and evergreen shrubs, medicinal and aromatic plants, small trees), for flowering species and, in the context of fruit nurseries, citrus and olive plant production. This technique has a series of characteristics, most of which are positive, that substantially differentiate it from the traditional farming on the ground; they can be summarized here:

- a delicate operation such as transplanting is eliminated which, even if well done, still causes a certain shock for the plants.
- the use of artificial substrates allows greater uniformity and better control of production.
- most of the cultivation operations can be mechanized and the plants, easy to handle, can be moved to the nursery, sold or prepared for shipment at any time.
- better integration with advanced propagation techniques (eg micropropagation) which require a growth phase in a container.
- the plants can be managed over a very long period of time (basically, only the coldest periods and the hot and drought ones must be avoided) thus freeing the producer and the buyer from the constraint of strictly respecting the transplant or planting periods dwelling for

plants produced in the ground (particularly if with bare roots).

While considering all this, it is necessary to remember that plants grown in containers have, of course, a reduced volume of substrate that can be explored from their roots, as well as limited is the availability of water and nutritional elements to allow satisfactory growth. This means that the advantages listed above are accompanied by some problematic aspects requiring careful monitoring by the nursery growers. Among these aspects we remember:

- the organization of the nursery must be structured to allow for precise and timely interventions (irrigation, fertilization). Above all, irrigation systems today require a level of precision agriculture.

- repotting to rebalance the roots / substrate ratio at least in part are mandatory and frequent (difficult to go beyond a vegetation cycle)

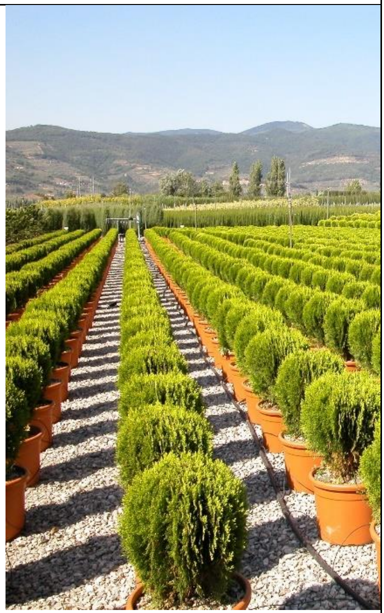
- plants are more subject to thermal excesses (winter and, above all, summer) at the root level, as the pot is unable to provide the protective effect that the soil can give.

It therefore follows that the substrate itself becomes one of the central element of the production process: over the years, starting initially from very coarse substrates (normal field soil was also used), we have gradually tried to assemble substrates that were increasingly suitable and calibrated for the growth and development of plants.

Physico-chemical characteristics of components for nursery substrates

The physical characteristics of a growing substrate should help the roots support and anchoring, retain water and make it available to the plant, allow gas exchange between the roots and the atmosphere outside the substrate, containing thermal changes, the absence of seeds, plant and animal parasites, a structure with a good porosity, up to 75% consisting of 42% from the liquid phase and 33% from the gaseous one (Nelson, 2003; Tesi , 2008). According to Aendekerk et al. (2000) the total porosity should be between 85 and 95%. The percentages of porosity can vary between 40-60% for the liquid phase and between 15-35% for the gaseous one (Pimpini, 2004). Other authors indicate the 10-20% range as ideal for porosity (Bunt, 1988; Jenkins and Jarrell, 1989). In addition to this, the structure must be stable and remain stable over time, resisting compaction, volume reduction (no more than 30%) during the dehydration phase, to avoid causing root breakage (Pimpini, 2004) . From the porosity it is possible to calculate the apparent density (or apparent weight) which corresponds to the volume occupied by the solid particles of the substrate plus the empty spaces: to facilitate the management of the substrate, the apparent porosity should assume low values (Reed, 1996). The optimal apparent weight for container cultivation varies between 60 and 250 kg /m^3 (Pozzi and Valagussa, 2009). This factor is of primary importance for adult crops, while it assumes secondary importance in the case of small honeycomb containers. The high water retention capacity consists in maintaining adequate humidity for the crop, which allows to reduce irrigation interventions; however, it must not be excessive in order not to cause problems of radical asphyxia. To avoid this occurrence, especially in tall containers, the drainage components of the substrate must be increased (Pimpini, 2004). After irrigation, 10-20% of the substrate volume should be filled with air. The water content should be as high as possible provided the porosity and density of the substrate are adequate (Nelson, 2003). The insulating power of the substrate is closely related to the water holding capacity, but is also influenced by the color and thermal conductivity of the material. Organic substrates of dark color, for example, undergo a lower thermal excursion than those of a sandy nature (Pimpini, 2004). The ideal chemical characteristics of a substrate are as follows: being a nutrient reserve (Nelson, 2003), having a high cation exchange capacity, a pH suitable for a large number of species, preferably subacid, and a good buffering power. The cation exchange capacity (CEC) allows us to know the need to bring all the essential nutrients to the plant right from the start of the crop (Thesis, 2008). The CEC is defined by the sum of exchangeable cations that the substrate can hold per unit of weight. It is expressed in milliequivalents per 100 cm^3. A suitable value is between 6-15 me /cm^3.

Growing areas in container nurseries

Plants just after repotting	**Plant during cultivation**
	

The pH, which is the measure of the hydrogen ions present in the substrate, regulates the availability of all the essential nutrients for the plant (Reed, 1996). The pH should be subacid with a minimum of 5.2 to 6.3 (Bunt, 1988). The buffering power allows to keep the pH constant and close to the optimum required by the plant. It would not make sense to establish the pH at the beginning of cultivation if it then varies due to irrigation and fertilization (Tesi, 2008). The formulation of a correct cultivation substrate is based on the choice of materials that allow to have all these characteristics. The materials can be of organic or mineral origin, deriving from processing waste or other human activities, and of industrial origin. The characteristic that we always try to obtain is the stability of the substrate over time. A brief review of the main components of a modern nursery substrate is carried out below.

Main components of a substrate for ornamental plant nurseries

Peat

Peat was and still is the most widespread organic component of substrates. It is a fossil vegetable material deriving from the decomposition of the remains of herbaceous plants stratified after their death in swampy environments. It can be found in deep layers even several meters and the typical natural environments where peat is found are the cold and humid areas of the countries of Northern and Eastern Europe and of North America and Canada (Pandini, 2004). The area that has a surface layer of peat accumulated over time is called a peat bog. There are various types of peat bogs: there are tropical ones widespread in many equatorial and tropical areas where intense rainfall combined with poor drainage favor the initiation of peat formation processes; then there are the low or swampy ones that are formed in low areas or lake basins, widespread all over the world: they represent the first stages of formation of high peat bogs; there are mountain ones, consisting of a continuous layer covering the underlying mineral layer. Finally, we have the high bogs that develop on previous low bogs and form deposits with a convex profile that can also rise above the ground level. While the first three are not used for the preparation of substrates due to their non-homogeneous characteristics, due to the presence of several plant species that have contributed to the formation of the peat bog, the high bogs, being made up almost exclusively of sphagnum trees, and with a high constancy of characteristics, represent the best source for the extraction of peat to use for cultivation substrates (Cattivello and Zaccheo, 2009). The pH of raised bogs is between 3.0 and 3.5. They can be divided commercially based on color: brown or black peat are the most degraded, blond ones are less degraded and are located at a greater height, closer to the surface (Pandini, 2004). In nurseries, blond peat is used almost exclusively, thanks to their good structural stability with a porosity of 75-90%: this allows for aeration, high water absorption and retention capacity (Tesi, 2008). The buffering power of peat grows as the degree of decomposition increases. It can be added with different materials to increase the buffering capacity, but to avoid excessive fluctuations in pH it is necessary to use peat with a good physical structure (Cattivello, 2010).

Coco mix

Coconut mixes (coco fiber and coir dust) have been introduced as a component of substrates for ornamental nurseries quite recently. In horticulture and floriculture for soilless cultivation it is very common, for example, for the cut flower rose. This material is used pure or in a mixture and represents one of the most interesting alternatives to the use of peat, having very similar physico-chemical characteristics (Table 1). Coir is a waste material derived from the processing of coconut. The production process involves the collection, transport to the factory, crushing of the mesocarps in a sort of hammer mill, following which a series of processing by-products are obtained. The long fibers are eliminated and used for other purposes, such as the manufacture of ropes and mats, while the residues, composed of short and medium fibers and other material, undergo a sieving process that has the purpose of separating most of the dust from the residual fiber. The result is a product that is generally referred to as "coir dust", ie coconut fiber in powder form. After sieving, the latter is dried, packaged in bags or compacted into briquettes or compressed loaves.

The final product is in some cases characterized by an excessive content of soluble salts due to the cultivation of the coconut palm in places close to the sea. The level of soluble salts is probably the main limiting factor: too high a

salinity and in particular an excessive concentration of sodium chloride can in fact lead to crop failures depending on the species cultivated, the stage of development of the plant and the cultivation technique used. Several experiments have been carried out in recent years on coir dust, in order to characterize its physico-chemical properties and verify its behavior in cultivation.
In the bibliography there are discordant results, sometimes justified by the heterogeneity of the material, which assumes different properties in relation to factors such as the origin of the product and the size of the fibers. The experiences carried out on ornamental shrubs at various research centers led to responses that encourage the use of this raw material, especially in relation to its excellent physical characteristics. It should be remembered that coconut-based substrates are now mostly obtained from combinations of shredded walnut husk ("coir dust") mentioned above with variable percentages of coconut fiber, added to give better drainage. This material has a fairly neutral reaction and, excluding the case of acidophilic plants, replaces peat well enough in substrates for container crops.

Table 1 - Some physical and chemical characteristics of materials used for the preparation of cultivation substrates.

Parameter	Ideal substrate	Sphagnum peat	Compost	Wood fiber	Coir dust
Apparent density (kg/L)	0,15 – 0,60	0,07–0,30	0,30-0,40	0,12-0,13	0,08 – 0,10
Total porosity (% vol.)	>85	>90	>80	>90	>90
Available air (% vol.)	20-30	15 - 40	20 - 30	45 – 50	10 - 20
Available water (% vol.)	25-40	25 – 30	10 - 20	15 - 20	20 - 25
pH	4,5-6,0	2,5 – 3,5	7,0 – 8,0	6,0 – 6,5	5,5 – 7,0
Electric conducibility (mS/cm)	<2,0	0,20–0,60	1,5 – 3,0	0,60-0,80	0,20 – 0,50

Wood fiber

Wood fibers are ligno-cellulosic materials obtained as a by-product of the wood industry, which produces up to 50-70% of wood waste. The production of wood fiber requires a mechanical (defibration) and thermal (steam treatment under pressure up to high temperatures) process which causes a decomposition of the starting material. Depending on the technologies used, natural pigments are then added to color the substrate and / or mineral elements to stimulate microbial degradation. Following a stabilization and homogenization process, the final product obtained can be used as it is or mixed (up to 30-80%) with peat, coconut fiber, composted soil improvers, bark. Wood fibers are characterized by high porosity and capacity values for the air, which determines a reduced water retention; these characteristics oblige the plant growers to an optimization of irrigationshifts. Among the most relevant chemical properties we find the neutral or subacid pH, the reduced supply of soluble mineral elements and, consequently, the low electrical conductivity (EC). It is also important to underline the high C/N ratio of the raw material, which can cause nitrogen immobilization phenomena by the microorganisms present and a reduction in the availability of this nutritional element for the plant under cultivation. Manufacturing industries stabilize the commercial product by adding nitrogen compounds.

Coir dust	Rice husk	Wood fiber
		

Rice husk

The husk is a by-product of rice processing, consisting of the husks that surround the kernel of the cereal. The use in the horticultural field has been experimented in the production of mixtures of different raw materials, after a preliminary sterilization process of the raw product. Generally, the percentage of husk within a substrate should be around 20-30% by volume. To be used, this residue from rice processing must first be composted and subsequently sterilized to eliminate any parasites (Pimpini, 2004). Sterilization is not necessary in the case of parboiled husks; Parboiling is a hydrothermal treatment that causes physico-chemical transformations of the rice grain and determines its sterilization: it is performed by soaking the paddy, then steamed and finally dried (Baldoni and Giardini, 2001). Following this process, it can be used as it is to form substrates. This material guarantees good softness and high air capacity (Pandini, 2004).

Compost

Compost is the product of a transformation, called aerobic bioconversion, which can be carried out through various production processes and promoted by microorganisms present in the materials to be composted (biomass); such materials can be of different nature: urban waste, purification sludge, industrial or agricultural waste. Because of this extreme heterogeneity of both the biomasses and the production processes used, the term compost generally includes very different products, with very variable physical and chemical characteristics.

To regulate their production, the legislator has framed composted soil improvers in the legislation on fertilizers (DL 75/2010), bringing them back into three different categories and defining for each of them the agronomic and hygienic-environmental parameters to be verified and the respective quality limits:

1) composted green soil improver, obtained following the controlled transformation and stabilization process of green organic residues (waste from the maintenance of

ornamental greenery, crop residues, plant material in general);

2) mixed composted soil improver, obtained starting not only from vegetable waste but also from the organic fraction deriving from solid urban residues, waste of animal origin, waste from agro-industrial activities, wastewater and sludge;

3) peaty compound soil conditioner, which is the mixture of peat with green and / or mixed composted soil conditioner.

While introducing the fundamental distinction between green composted soil conditioner and mixed composted soil conditioner, within each single category the final products can show different characteristics from an agronomic point of view. This fact has contributed to a bad reputation of the compost, since in some cases it did not determine a good cultivation result, or even caused serious damage to the container crops on which it was used; thus, its use is mostly limited to that of organic soil improver.

In horticultural crops, especially the potted ones, where the volume of substrate in which the plant spends its entire crop cycle is extremely small, it is therefore essential to deepen the knowledge of the physico-chemical characteristics of the product that is intended to be used in order to correctly evaluate its potential, establish the percentage (of the product) in the mixture and adapt the cultivation technique in order to optimize production performance. Furthermore, the compost used must comply with certain characteristics and conditions that do not compromise the health of the crops, such as the absence of phytotoxicity and vital seeds and the reduced presence of heavy metals.

From a chemical point of view, compost generally have a pH that varies from neutral to sub-alkalinity and a salinity between 1.5 and 3.0 mS / cm (Table 1); the organic substance content is generally lower than that of peat. Compliance with the legal parameters is a guarantee of quality and good production results, if the user is aware of it and is able to adapt the cultivation techniques to the type of substrate used.

With regard to the physical properties, it is more complex to establish common characteristics of the compost which in fact depend on the type of waste material used, its origin and the screening process that the final product has undergone. In general, compost has a high porosity and a good water retention capacity.

In recent years a new type of compost, called "quality compost", has been introduced, with interesting characteristics and a better success in nursery use, too. This product, obtained with biomass selected at the source and through a controlled aerobic bioconversion process, meets the standards established by law. The biomass used can be "green" waste (pruning, mowing, foliage) possibly integrated with other wood-cellulosic materials (shavings, boxes, pallets) and / or highly fermentable matrices, such as food waste or processing of agroindustry, biological sludge or the organic fraction of municipal solid waste (FORSU).

Pumice

There are various types of pumice in nature that differ greatly in their chemical properties and utility. However, silicon dioxide is the main component. Pumice stone can be used in horticulture since, thanks to its particular structure, it is able to improve the water balance of the growing substrate, ensuring air circulation and oxygenation. Pumice is an effusive magmatic rock mainly formed through explosive eruptions. The fast cooling of the rock favors the formation of expanded alveolar minerals. It is therefore a very light rock with a very high porosity; for this reason, it is the only rock that can float in water (with volumes greater than 5-7 cubic centimeters). One of the main components of this magmatic rock is silica; other accessory minerals can be calcite and zeolite; the darker colored pumices contain a good dose of iron. Thanks to its characteristics, pumice can be used in agriculture and horticulture as an ingredient for soils and cultivation substrates due to its considerable porosity but also to a certain water retention and slow release of liquids. It is an absolutely natural and ecological product (pH 7-8) and it favors the development and well-being of plants. Due to its particular structure, pumice cannot be completely saturated, thus guaranteeing the presence of air and other fundamental gases. Porosity and permeability are fundamental characteristics to ensure gas exchange and the right presence of water within the growing substrate, favoring the optimal activity of the roots.

Mineral components to be used in nursery substrates

Coarse-grained pumice	**Small-grained pumice**	**Lapillus**
		

It can have a beneficial action even in heavy soils allowing water and air to penetrate, and it can also be added to compost to improve its transformation and final characteristics (about 2-3% of the total volume). The compost, once transformed, can also be sieved for a pumice reuse. The pumice that is found inside the compost during the transformation and maturation process will be rich in useful bacteria and microorganisms. On the market there are different types of pumice depending on the various uses, it will therefore be necessary to make sure that it is pumice produced for horticulture. There are different grain sizes: from sands (0-3 mm) to grits (from 2-4 mm for the finer grits to 12-25 mm for the larger grits). It can be used in varying proportions in growing media or in the preparation of soil for sowing, transplanting, growing in pots and cuttings to improve the water balance or to lighten the substrate. Excellent in horticulture, it improves the characteristics of the substrate and promotes aerobic conditions around the root system. It also finds applications in turf, improving drainage in cases of excess humidity; in this regard it can be placed on the bottom of the pots as a draining base (3-5 cm thick layer, depending on the size of the containers). It is very resistant over time, cannot be compacted or even washed away, and can be used for mulching or as a mineral soil improver. Being composed in a good percentage of silicon, it brings the benefits and advantages of this element; if well used, it can prevent the formation of unwanted mold and algae. Very similar material is lapillus, also a volcanic rock used in horticulture. Lapilli and pumice have similar characteristics, with the difference that the former originated from a magma with a lower silica content and a lower number of internal cavities (though larger than the pumice). This determines a greater macroporosity; for this reason, lapillus has a structure denser than pumice, and thanks to the type of magma from which it was generated it can guarantee the availability of useful and usable microelements by plants.

Environmental implications related to the use of substrates for potted plants cultivation

In recent years there has been a growing attention of people to environmental issues. In fact, the relationship between business and the environment has been progressively changing, from a concept in which the environment is seen as a container of resources to be exploited without grasping an intrinsic economically quantifiable value, to a vision of the environment as a real "productive factor". Moreover, the growing interest of public opinion towards environmental protection is orienting the economic system and therefore individual companies towards a more sustainable management of their activities. This new scenario entrusts individual companies with a decisive role in identifying their environmental criticalities relating to process and / or product standards. It is, in fact, the company that through a process of continuous improvement and self-control must demonstrate to the so-called interested parties or stakeholders (public opinion, public authorities, customers, suppliers) its commitment to the environment, also exploiting it in communication terms. The horticultural sector is no exception to this logic, also taking into account that due to the high intensity of cultivation and the not always rational management of resources (in particular as regards water, fertilizers and pesticides) and company waste (eg. production waste), this production sector is held responsible for a non-negligible environmental impact, not always mitigated by the indisputable positive effects produced, such as the requalification of the landscape and the absorption of CO_2. In this perspective, the question of substrates for pot crops must be considered. Potted plant production, born in the United States in the second half of the 1950s, after having tested different components (including the same agricultural soil) for the repotting of the plants, have come to identify a combination of components which are then optimal for this kind of ornamental nursery production. It is therefore for this reason that now most of the substrates consist, in general, of a mineral fraction (very often pumice, sometimes lapilli) and an organic fraction, peat. The latter has been the main component of substrates for years, having ideal characteristics for a cultivation substrate: it is light, homogeneous, very porous, relatively stable, safe from a phytopathological point of view, it generally has an acid pH, which however it can be easily fixed. These characteristics have made it suitable for the cultivation of almost all plant species. If we take into consideration what the ornamental container nurseries considered for years the most classic of substrates, the peat-pumice mixture, and we make a careful analysis of the environmental implications deriving from the use of these components, we can easily realize what the extent of the problem is, especially as regards peat.

Basic components for the classic nursery substrate

Peat	Pumice
	

Starting from the peat production phase, we immediately see that the extraction from peatlands requires considerable use of machinery contributing to CO_2 emissions; once extracted, this must then be transported over great distances, from the production place to the area of use (if we consider Lithuania as a peat production area and Pistoia as an area using it, we are talking about a journey of about 2000 km by truck). Finally, once it reaches its destination, the peat must be sorted, handled, processed, with a further increase in CO_2 emissions before ending up inside the container. It should also be taken into account that once extracted the peat itself undergoes oxidative processes that release an additional fraction of CO_2 into the air. In addition, the increasing exploitation of peat bogs, largely due to the increase over the years in demand from the nursery sector for container production, has now highlighted its limits in terms of product availability. Like all non-renewable energy sources on our planet, in fact, peatlands are running out. Although this happens more slowly than for other exhaustible energy sources, it is beginning to be considered a problem, to the point that various countries (e.g. Germany) have long since implemented policies to protect these particular environments, preventing further exploitation.

Partly the same considerations can be done for pumice, a volcanic rock extracted in quarries located between lower Tuscany and upper Lazio, and which are then transported to the areas of greatest demand, after being ground to the required grain size. Therefore, pumice has the same environmental problems defined for peat: a supply chain that causes CO_2 emissions in the extraction phase, in the processing phase and finally for the transport phase; however, it should be specified that the emission level of the pumice chain is somewhat lower than the equivalent level of the peat chain.

From the combination of the above considerations, the need to explore other types of materials to evaluate their "usability" as components for nursery substrates clearly emerged; as is logical, since the central theme remained environmental sustainability, the utmost attention was paid to materials that were processing waste, from the nursery chain as from other production chains, or in any case recycled materials (e.g. sediments), in a general logic of replacing extraction materials (peat, pumice) with re-use materials. In this perspective, it is clear that the introduction of coconut fiber was the first important step of the nursery sector towards that much desired goal of reducing the environmental impact, even if it should be emphasized that the distant origin of this material (and the consequent transport to our production districts), make this product a "half solution" and not yet a full and total answer to those questions that the need for greater respect for the environment requires.

Experiences of using composted materials for the production of container plants

In this chapter experiences carried out in our Department in the recent past will be reported. As part of the experiments carried out in the nursery sector, the search for alternative substrates has, in fact, always been absolutely central, producing over time a series of data and experiences of undoubted value.

Humus derived from bovine manure

This research was carried out in 2011, using a product consisting of manure and fermented vegetable materials deriving from a controlled supply chain, subjected to a period of composting. This humus (as defined by the manufacturer) was added to the substrate in increasing percentages, replacing the standard organic fraction, i.e. peat. The comparative treatments have been summarized in the diagram below:

Substrate	Pumice	Peat	Humus
Control (A)	50	50	
Humus 1	50	35	15
Humus 2	50	15	35
Humus 3	50	--	50

Values are expressed as a percentage of the volume

Young one-year-old plants of photinia (*Photinia x fraseri*) and lentage (*Viburnum tinus*), very common species in the local nursery landscape, both characterized by good adaptability to development conditions, were used. At the start of the experimentation, they were repotted in a medium-small container (16 Ø) with the prepared mixes and enriched with a controlled release fertilizer, at the rate of 2 g / l of substrate.

From the results obtained, it was possible to note that the use of this humus in the substrate for the breeding of Fotinia and Viburnum plants had highlighted some problems. Going into the details of the results, it can be seen that the differences between the different treatments were significant from the first survey, and generally showed a good adaptation of the viburnum to the presence of humus up to the threshold of 35% (thesis H2), while the H3 thesis, characterized by an organic fraction entirely attributable to composted humus, immediately showed significantly lower development performance. Photinia, on the other hand, was more sensitive, with a significantly lower development of all the theses with humus (thesis H2-H3-H4) compared to the control thesis (A)

Table 2 - Maximum height detected on two dates on a sample of 6 plants of *Photinia x fraseri* and *Viburnum tinus*

	VIBURNUM TINUS				**PHOTINIA x FRASERI**			
Substrates	15-set		16-nov		15-set		16-nov	
A	**44,50**	a	**46,83**	a	**91,00**	a	**107,00**	a
H2	**43,33**	a	**46,67**	a	**84,00**	ab	**89,67**	b
H3	**41,00**	a	**44,50**	ab	**67,17**	b	**88,67**	b
H4	**36,83**	b	**40,83**	b	**69,50**	b	**78,50**	b

As regards the development measured in terms of dry matter produced, the results are shown in the tables below. The viburnum confirmed a good adaptability with humus levels of 15% (H2 thesis), while the growth values were lower in the H3 and H4 theses. Even more clear is the result with photinia, where the differences between the control thesis and the others were really significant, as can also be seen from the total dry weight alone. It is however interesting to note that these different growth performances did not influence the distribution of growth between the crown and roots, or the degree of hydration of the plants, both of which are always not significant for both viburnum and photinia, which leads to to exclude a physiological imbalance of the plants in the experimentation.

Table 3 - Accumulation (g) and dry matter partitioning in Viburnum tinus plants (6 plants)

Sub.	**Tot FW**		**Leaf DW**		**Shoot DW**		**Root DW**		**Tot DW**		**DW /FW**		**Shoot.**	
A	155,19	a	26,18	a	15,85	a	22,40	ab	64,42	a	0,417	ns	1,889	ns
H2	153,42	a	25,88	a	15,60	a	22,89	a	64,36	a	0,426		1,841	
H3	103,92	b	19,35	b	9,75	b	14,90	c	44,00	b	0,428		1,985	
H4	119,94	b	23,66	a	12,55	a	18,00	bc	54,21	ab	0,453		2,034	

Table 4 – Accumulation (g) and dry matter partitioning in Photinia x fraseri (6 plants)

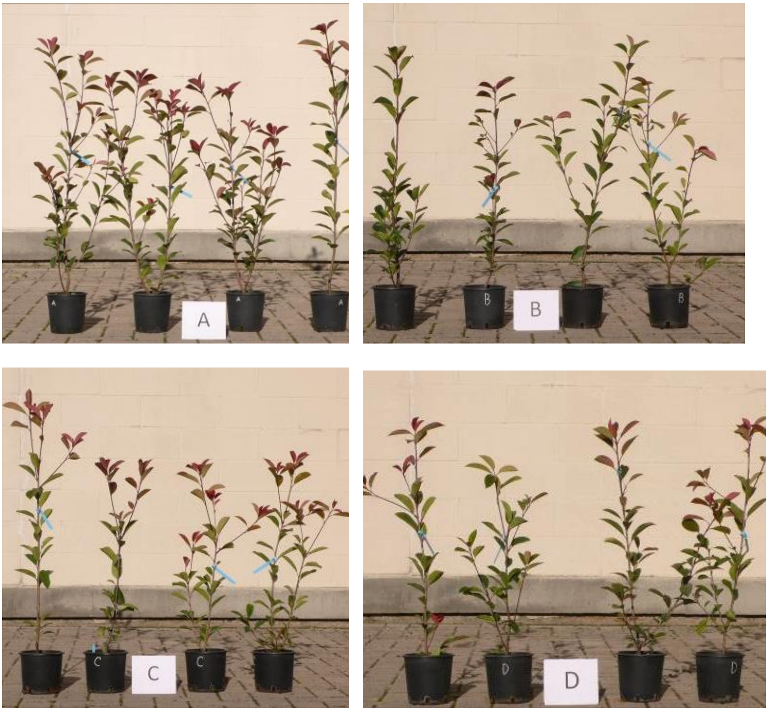
Sub.	**Tot FW**		**Leaf DW**		**Shoot DW**		**Root DW**		**Tot DW**		**DW /FW**		**Shoot/Root**	
A	184,94	a	28,70	a	44,85	a	22,10	a	95,65	a	0,518	ns	3,381	ns
B	107,66	b	19,49	b	27,05	b	13,53	b	60,07	ab	0,559		3,629	
C	79,76	b	14,77	b	18,21	c	9,51	b	42,49	c	0,533		3,500	
D	86,82	b	16,99	b	18,36	c	10,64	b	45,99	bc	0,537		3,415	

The results are accompanied by photos (below) taken at the end of the research on both species, giving confirmation both of the good adaptability of Viburnum to a medium-low concentration of humus (thesis H2), and of the sensitivity of photinia, clearly more vigorous in the control thesis.

It is not easy to explain the results obtained, which are clearly partial, given that they refer to a single year of experimentation on only two ornamental species. It is conceivable that the addition of this humus, a fine "granulometry" product, replacing the blond peat, a much coarser component from a physical point of view, has altered the physical characteristics of the substrate, contributing, in the cultivation conditions applied, negatively to the final result. The shortness of the cultivation cycle (less than 6 months), on the other hand, could be read as a further reason for the non-response (positive) of this organic matrix which, being a composted soil improver enriched with a microbial consortium selected on the microbiological component , should carry out an activating action (phytostimulant) on soils and / or substrates, but probably in longer times than those foreseen by a container cultivation cycle, which never exceeds, at most, 8-10 months.

Figure. 1 – *Viburnum Tinus* plants compared at the end of the experimentation

Figure. 2 – *Photinia x fraserii* plants compared at the end of the experimentation



Waste product from the coffee and mushroom supply chain

In the search for alternative materials to the classic components of nursery substrates, we had the opportunity to test a very particular material, namely a composted product resulting from a waste from two previous production chains. In particular, it was planned to try an exhausted product used as a substrate for the cultivation of mushrooms, in turn obtained from coffee grounds used in normal bars. For this purpose, in collaboration with a nursery company in Pistoia and with the Funghi Espresso company, a comparison was made between the "classic" substrate based on peat and pumice and one or more substrates, possibly also consisting of coco, and added of a composted organic soil improver of the origin described above. It was therefore possible to verify the effects of adding this soil improver in different proportions to the substrate, in order to evaluate its performance, and to identify a mixture of recycled components (coconut, composted matter) capable of representing an alternative, ecologically sustainable, to the classic nursery substrates based on the use of extraction material (peat, pumice).

Plants used in the growing trials

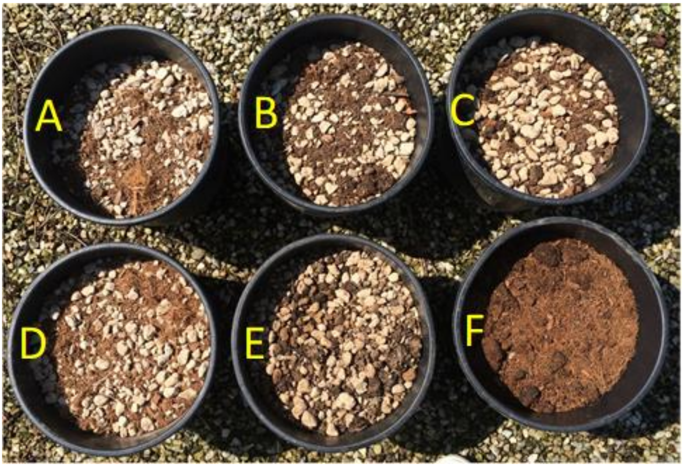
Plants of two outdoor ornamental species were used, *Photinia x fraseri* and *Prunus lusitanica*, both 2 years old grown in 16Ø pots. At the start of the experimentation, they were repotted into a medium container (24Ø) with the substrates prepared according to the table below. The substrates were enriched with a controlled release fertilizer, added according to the quantities indicated by the standard protocols of use (Nutricote 5g / l). As for coconut, a mixture of coconut fiber and coconut husk was used, in the percentage currently commonly used in nurseries (70:30 fiber: husk). It was planned to use 15 plants for each mix being compared.

Sub	**Peat**	**Pumice**	**Coconut**	**Compost**
A	50	50	--	--
B	30	50	--	20
C	--	50	30	20
D	--	50	50	--
E	--	50	--	50
F			50	50

** Values are expressed as a percentage of the volume*

The plants, placed in the nursery according to an experimental design in blocks in order to minimize any experimental errors, were subjected to continuous monitoring, with periodic measurements of growth in height, and growth analysis on plants in containers. From a visual comparison, the plants did not show differences between the various theses, an observation reinforced by the months of continuous observations in the nursery: the glance of the picture of plants highlighted the homogeneity of the same for the entire duration of the season. In particular, *Prunus lusitanica* showed a better ability to adapt to the increasing percentages of the coffee substrate, not only tolerating them but showing a certain benefit from the introduction of the soil under test upon visual examination.

Substrates used in the growing trials



With regard to the real growth of plants, evaluated through the accumulation of dry matter, there were no statistically significant differences among the different mixes, although a certain tendency to some state of suffering in thesis D was detected in photinia. Prunus provided more “compact” data, the various theses showed very similar growth averages. The PS / PF ratio, which indicates the hydration status of the plants, was similar between the various theses in both species, while the only sign of a possible effect due to the addition of this compost is found in the canopy / Roots (C / R), which in photinia was higher in the theses compared to the control, perhaps indicating a non-optimal condition for root development.

Table 5: Growth, DW/FW and Shoot/Root ratio in Photinia plants

Photinia x fraseri	Dry Weight (g)	DW/FW	Shoot/Root
Starting DW	63.41	0.4	1.2
A	625.2 ns	0.4	1.1
B	427.1	0.3	1.5
C	603.2	0.4	1.2
D	523.9	0.4	1.4
E	436.3	0.4	1.4
F	561.7	0.4	1.5

Table 6: Growth, DW/FW and Shoot/Root ratio in Prunus Lusitanica plants

Prunus lusitanica	Dry Weight (g)	DW/FW	Shoot/Root
Starting DW	119.2	0.4	0.7
A	441.9 ns	0.3	0.8
B	334.7	0.3	0.9
C	350.5	0.3	1.0
D	423.2	0.3	0.8
E	510.1	0.3	0.9
F	449.7	0.3	0.8

In conclusion, it is possible to affirm the matrices under investigation, at the concentrations tested, have shown a certain potential if used for the cultivation of plants in containers. It should be emphasized that the preparation of this coffee-based product was carried out by hand, which made it difficult to disassemble the macro-aggregates in the product mass. It is likely that a further refinement of the matrix, with longer and more accurate composting processes, passages in shredding machines, can result in a product with better chemical-physical characteristics. On the other hand, the nature of the waste used is very particular because it derives from the recycling of an exhausted substrate of mushroom growing, in turn obtained from waste from the coffee supply chain. Its use in a cultivation cycle therefore represents its "third life" as a productive factor, and this is undoubtedly its main strength. Some alternative applications, such as the use as a soil improver in the open field, could certainly provide ideas for new research. At present, container cultivation would require a more processed product or it is possible to think about its use in high-volume pots, where plants coming from the open ground are usually re-cultivated.

Cultivation experiences in the LIFE - Agrised project

The Agrised project, having planned a phase of experimentation in the nursery with products derived from the co-composting of green waste and river sediments, represented a precious opportunity to broaden the framework of knowledge on the prospects for the use of waste materials in nursery substrates. Before commenting on the technical results of the experiment, a word on the matrices used.

Green Waste – The nursery companies, with their activities, naturally produce a series of waste, scraps and / or by-products that are managed in different ways. One of these categories of waste / by-products is represented by "vegetable waste", a definition which refers to a variety of materials, including dried or unsaleable plants, exhausted mixes and pruning residues. The prevalence of one or more of these materials is linked to the type of nursery farm (Recchia et al., 2013); infact in the farms that have mainly open field crops, the matrix of the waste is mostly represented by dry plants and pruning, while for those in which the cultivation in containers prevails the substrates are of great importance. In a production area as big as Pistoia nursery district, the size of the problem can be quantified at around 20,000 tons / year of waste produced (Marzialetti, 2008). With regard to these materials, nursery companies found themselves faced with the prospect of their alternative management to costly disposal as company waste; it is in this perspective that the idea of obtaining a composted material starting from different matrices, which can be reused as a component of substrates in companies, came to maturity, while evaluating the environmental implications of this operation.

Dredged sediments – Among the components that could find an application in a compost suitable for the cultivation of plants in containers are the sediments found through the dredging of rivers, a resource that is little or not used and in excess which, generally, is disposed of in landfills as waste. In Europe, the periodic dredging of river stretches and ports, necessary to avoid flooding and hydrogeological instability, produces about 200 million m^3 of sediments per year (Bortone et al. 2004). The possible use as a compostable matrix for a cultivation substrate would therefore represent an effective method of disposal of these dredges which, otherwise, are destined to be disposed of as waste, with the costs and impacts associated with it. The biggest problem related to the use of these materials may be contamination by various substances that they may present, especially if the dredged mud comes from navigable canals, ports or locations close to them. In fact, several studies have found consistent accumulations of heavy metals, especially zinc (Zn), copper (Cu) and lead (Pb), followed by chromium (Cr), nickel (Ni) arsenic (Ar), and other organic molecules (Hashim et al., 2018), despite the fact that it has been demonstrated that the composting process can contribute to a certain degree to the phytoremediation of these sediments (Mattei et al., 2016).

Cultivation Trials – The components described above, vegetable waste and sediments, were mixed in two different locations (in Pistoia and in the Czech Republic), to form different mixes as shown below:

Treatment	Green Waste	Dredged sediment	Peat:Pumice
1	--	--	100
2	75	25	--
3	50	50	--
4	25	75	--
5	37,5	12,5	50
6	25	25	50
7	12,5	37,5	50

At the end of the co-composting process, the mixes obtained, added with fertilizer, were used as a cultivation substrate both as they are (theses 2, 3 and 4) and further mixed with the classic peat substrate: pumice (1: 1) commonly used in ornamental nurseries. The latter operation was decided after having characterized the 3 product mixes from a physical-chemical point of view; the result was an excessive density, a sub-alkaline pH and a fairly high salinity. In all, six mixes were tested in the Czech Republic (the three compost fertilized + the three compost mixed with peat / pumice); while in Pistoia there were nine (the three fertilized compost + three compost mixed with peat / pumice + three compost mixed with pith / coconut fiber). The cultivation evidence was based on two very common species, often used in our research:

Viburnum Tinus, *Photinia × Fraseri* “Red Robin”. The plants were evaluated in relation to both a standard peat / pumice (50:50) and a coir pith / coir fiber (70:30) mix. The cultivation conditions are those normally carried out by the nurseryman. That is, repotting from a 3Lt container to a 9.5Lt, drip irrigation, slow release fertilizer 12 months in the substrate (4gr / LT). In the Czech Republic only one cycle of cultivation with spring potting was carried out, while in Pistoia two: the first with autumn potting and the second in spring.

Cultivation area with Fotinia and Viburnum plants distributed among the various treatments

From all the results obtained with these 3 mixes and with the other preparations with peat / pumice or coco, it clearly emerges a considerable potential of these alternative substrates to be used in the normal production cycle of ornamental shrubs. Since the first autumn repotting, in October, it was possible to notice that the plants, both in Italy and in the Czech Republic, showed a very good condition compared to the plants repotted in the control substrate, regardless of the mix used. As evidence of what has been said, you can see below a photo after 4 months from repotting in Pistoia in which you can clearly see a beautiful flowering of all the viburnum plants just before the start of the growing season in March. This first impression was confirmed throughout the season: the development of photinia and viburnum plants, was always rather homogeneous between the various theses, the plants did not show any symptoms of suffering.

Flowering of photinia plants potted with compost-based substrates

This also emerged clearly from the ecophysiological analysis carried out on them (photosynthesis, stomatal conductance, chlorophyll measurement), which highlighted a completely normal condition for the plants of the various treatments under comparison, without any significant state of stress. At the end of the season a photographic survey was carried out, after which the plants were measured (height), and a sample of these was subjected to the calculation of the accumulated dry matter.

Table 7- Growth measures (height, dry matter) and Shoot/Root and DW/FW ratios in Photinia plants

		Fresh weight (kg)			Dry weight (Kg)				
Treatm.	Height	Canopy	Roots	Total	Canopy	Roots	Totale	Shoot/Root	DW/FW
1	150,67	1,42	0,44	1,86	0,71	0,16	0,88	3,27	0,47
2	128,67	1,08	0,37	1,45	0,53	0,17	0,70	2,89	0,48
3	136,00	1,17	0,35	1,52	0,59	0,19	0,78	3,36	0,51
4	140,67	1,12	0,28	1,40	0,57	0,16	0,73	3,97	0,52
5	124,00	1,11	0,34	1,45	0,55	0,18	0,73	3,32	0,51
6	131,00	1,71	0,39	2,11	0,85	0,18	1,03	4,35	0,49
7	136,00	1,01	0,24	1,25	0,55	0,14	0,69	4,18	0,55

Table 8 - Growth measures (height, dry matter) and Shoot/Root and DW/FW ratios in Viburnum plants

		Fresh weight (kg)			Dry weight (Kg)				
Treatm.	Height	Canopy	Roots	Total	Canopy	Roots	Totale	Shoot/Root	DW/FW
1	80,67	0,93	0,40	1,33	0,51	0,15	0,66	2,35	0,49
2	78,33	0,86	0,29	1,14	0,49	0,13	0,62	2,99	0,54
3	77,33	0,69	0,20	0,89	0,41	0,11	0,52	3,49	0,59
4	85,67	0,79	0,25	1,04	0,46	0,16	0,62	3,16	0,60
5	83,33	0,62	0,17	0,78	0,34	0,10	0,45	3,67	0,57
6	82,33	0,84	0,23	1,07	0,43	0,13	0,55	3,70	0,52
7	80,33	0,65	0,21	0,85	0,36	0,13	0,49	3,15	0,57

Final considerations on the use of composted materials in nursery substrates

After having presented the general problem of nursery substrates, centered on the need to make them more environmentally friendly, and having reviewed some of the most common components and others that could be introduced for the aforementioned purposes, some experiences have been illustrated in this regard at the our Department in recent years, to finally come to formulate a series of final considerations about the potential and problems inherent in the use of composted materials in the potted plants production process.

- Despite a widespread mistrust among professionals, there do not seem to be any elements that would absolutely advise against the use of these matrices in nursery substrates; on the contrary, interesting potentials have been seen, which clearly indicate their applicability, particularly under certain conditions, considered below.

- It is very important that the components chosen to be composted are well prepared, and then subjected in advance to adequate grinding and possible screening, so that the resulting product does not alter the physical characteristics of the substrate, which are essential for a positive result of the subsequent cultivation phase.

- The composting process must certainly be developed in relation to the matrices used at the entrance. In the case of Agrised, for example, although positive results have been obtained in the degradation of pollutants present within the dredged sediments, certain values, both in one product and in the other, have shown how these processes must be studied and calibrated carefully in order to fully comply with the limit values imposed by the laws of the various countries and to be able to produce compost of a quality that can be used commercially as well as beyond simple experimentation.

- The central issue in the prospect of a possible use of these materials remains the percentage of use in the substrates used for the common cultivation practice. The experiences made in the past have generally identified a limit threshold between 20 and 30% depending on the case, but the experiences conducted in AGRISED, where 100% mixes were used with however interesting results, allow us to glimpse well-developed fields of application more extensive than previously envisaged.

- An aspect that emerged in previous experiences with respect to AGRISED is that of the size of the plants grown with substrates characterized by the presence of composted matrices. Generally, it is considered appropriate to avoid the cultivation of young, small plants with these types of substrates, reserving them for plants of greater size and age which, other factors being equal (species, cultivation conditions), are generally less sensitive to the not always optimal physicochemicals characteristics of such alternative materials.

- Due to what has been said above on the percentages of use and on the age of the plants in cultivation, it could be suggested to avoid composted products in the first year of life of the plants, to go to 10% in the second year, to 20% in the third year, and reach 30-40% for large plants, almost always plants grown in the ground and placed in large containers only in the last period of production, not long before the sale.

- Another point that could suggest the use of these matrices lies in the simple consideration that the permanence of the plants in the cultivation substrates covers a relatively short period of time: it goes from 6-7 months of a growing season, up to 18-24 months if the plants remain in the same container for two vegetative seasons. After these periods, most of the plants, if they are not sold, become waste and therefore eliminated. This means that we do not have to expect negative side effects due to long stays of the roots in sub-optimal growing mixes.

It is clear, to conclude, that the very nature of the composted matrices (a river sediment and vegetable waste), of variable origin, makes it difficult to be able to provide exact and repeatable use protocols. Although the body of knowledge acquired up to now is becoming increasingly larger and articulated, any indication that can be given on the commercial use of these composted materials in the nursery sector cannot ignore a preliminary phase of fine-tuning the main steps preceding their use in the nursery sector: analysis of the matrices used, pre-composting processing, monitoring of the composting itself.

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