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Phytoremediated marine sediments as suitable peat-free growing media for production of red robin photinia (*Photinia x fraseri*)

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HIGHLIGHTS

- Phytoremediated marine were used as peat-free growing media for growing red robin photinia plants.
- Environmental impact related to the use of sediments-common peat-based growing were compared by LCA.
- Plants grown on fertilized sediments were comparable to those grown on peat-based growing media.
- The LCA showed a lower C footprint of plants grown on sediment-than peat-based growing media.

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ABSTRACT

Sediments dredged by an industrial port, slightly contaminated by heavy metals and petroleoum hydrocarbons, were phytoremediated and used as peat-free growing media for the red robin photinia (*Photinia* x *fraseri* L.). Plants were grown on sediment only (S), sediment mixed with composted pruning residues (S + PR), sediment fertilized with controlled release fertilizers (S + F) and peat-based growing media as control (C). Plant elongation and dry weight, leaf contents of chlorophyll, malondialdehyde (MDA), macronutrients and heavy metals were determined at the end of one growing season. Environmental impact related to the use of sediment-based as compared to peat-based growing media was assessed by the Life Cycle Analysis (LCA). Sediment-based growing media presented significantly higher bulk density, pH and electrical conductivity values, lower C and N contents, and significantly higher total and available P. Red robin photinia grown on S + F growing media showed morphological and chemical parameters similar to those of control plants (C), whereas plants grown on S and S + PR showed lower growth. Leaf concentration of nutrients and heavy metals varied depending on the considered element and growing media, but were all within the common values for ornamental plants, whereas the highest MDA concentrations were found in plants grown on traditional growing media. The LCA indicated the use of sediments as growing media reduced the C footprint of ornamental plant production and the contribute of growing media to the environmental impact per produced plant. We concluded that sediments phytoremediation and use in plant nursery is a practical alternative re-use option for dredged sediments.

1. Introduction

High grade ornamental plant production in containers requires growing media that generally contain peat and palm fiber and coir pith, mixed with pumice or perlite to improve porosity and

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stability, and fertilized to reach adequate levels of nutrients. It was estimated that in the European Union (EU) about 40 million m^3 of growing media are produced every year (Altmann, 2008), and peat is currently still the prime raw material for professional growing media (Schmilewski, 2009; Ceglie et al., 2015). Palm coir fiber and pith are by-products of the coconut processing that are increasingly used as ingredients of growing media thank to its suitable pH value (between 5 and 7), good physical stability and water retention properties, and is widely avaialable on the market. In recent years increasing conflicts of peat extraction and use with EU environmental Directives such as Environmental Impact Assessment Directive (92/43/EC), Habitats Directive (Natura 2000), Birds Directive (Directive 2009/147/EC), are emerging. This urges the plant nursery sector to search for alternative peat-free growing media and soil improvers. Also pumice and perlite, other key ingredient of peat-based growing media, are non-renewable resource and high impact materials, respectively, and their use must be progressively reduced in the future. Palm coir fiber- and pith-based growing media also have high environmental impact related to high initial salinity and transportation, as they produced mainly along the South-East India and Sri-Lanka coasts, and require long shipment distances for EU producers.

Regardless of the large research efforts to reduce peat in growing media (e.g. Abad et al., 2001; Garcia Gomez et al., 2002), by replacing them with various plant residues and organic wastes (Garcia Gomez et al., 2002; Hernandez Apaolaza et al., 2005), the materials tested so far have shown limited potentials mainly due to variability of the original materials, adverse physico-chemical properties and sanitary problems, particularly in the use of composted biosolids (Abad et al., 2001; De Lucia et al., 2013).

Sediments from the coastal, riverine and lacustrine environments of developed Countries are regularly dredged to guarantee the free navigation and docking activities, to prevent flooding events, and control water contamination caused by the release of pollutant accumulated into bottom sediments. Management of dredged sediments is a major environmental issue in worldwide, as they are generally considered as waste materials, although the major international Conventions (e.g. Barcelona Convention, 1995) have suggested to reuse the dredged sediments to the maximum extent. The amount of dredged sediments in Western Europe is in the order of 100–200 million tonnes per year (Bortone et al., 2004). In Europe, currently none of the EU environmental Directives deal specifically with dredged material, but three main Directives have a direct or indirect impact on sediment management (Fig. 1): the Water Framework Directive (2000/60/EC), the Waste Framework Directive (75/442/EEC, 91/156/EEC), and the Habitat Directive (92/43/EEC). The recent changes in the EU and national legislation on sediment management, have progressively supported the re-use of unpolluted or remediation and re-use of dredged sediments. In fact, Europe must face large-scale remediation of sediments in many river basins impacted by historical contamination, and there is growing concern to fulfill the European Water Framework Directive (SedNet, 2003).

Ornamental plant production is among the most remunerative agricultural sectors, with an estimate annual gross production in the EU of ca. 20 millions of Euros, and a slightly increasing demand in the last 20 years (European Commission, 2015). Most ornamental plants are produced in containers, and demand for growing media will also likely increase in the future. Therefore, the use of alternative peat-free growing media, constituted by locally available low impact materials, is an interesting option to prevent limitations and losses of value for the production of ornamental plants. In a previous study, we showed that phytoremediation conducted using *Paspalum vaginatum*, *Spartium junceum* and *Tamarix gallica* could be a technique for reclaiming dredged marine sediments and allow them for a safe use as growing media for several ornamental plants (Mattei et al., 2017). However, while the phytoremediation degraded the total petroleum-derived hydrocarbons by more than 50%, the total heavy metal concentrations were not significantly decreased (Masciandaro et al., 2014), but stabilized into recalcitrant forms (Doni et al., 2015). We hypothesized that phytoremediated sediments, although containing significantly higher concentrations of heavy metals than peat, could be optimized to allow the production of ornamental plants of comparable grade as plants grown on traditional peat-based growing media, and reduce the environmental impact of plant nursery production, with no increase of metal mobility during the plant growth. We tested our hypothesis growing 'Red Robin' photinia plants (*Photinia* x *Fraseri*), a plant of prime interest for the Italian ornamental plant market, on either phytoremediated sediments or traditional peat-based growing media. The environmental impact of the photinia production on sediment- or peat-based growing media was evaluated by the Life Cycle Analysis (LCA). The LCA is a widely accepted procedure for assessing the impact of productive process involving various activities, and is considered a key decision support tool, increasingly used for assessing the environmental performances of products throughout their whole life cycle, identifying differences among different systems in terms of resource consumption and environmental impacts (Cellura et al., 2012). Recent applications of the LCA to the plant nursery sector has allowed to assess the relatively high

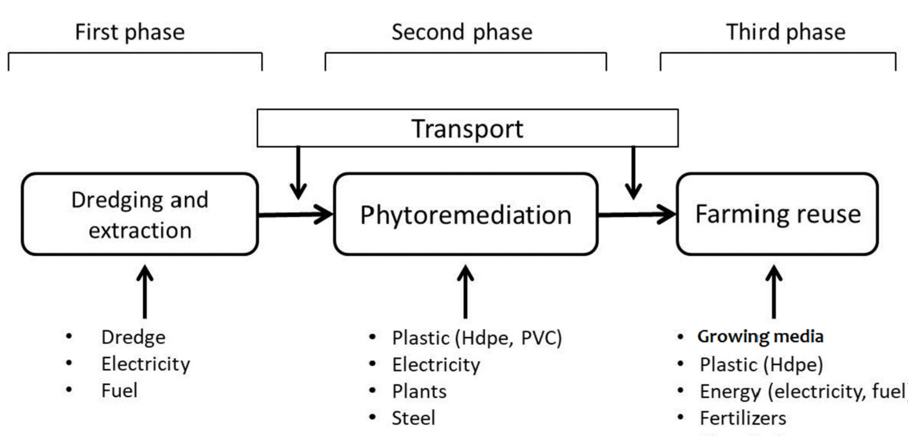

Fig. 1. LCA system diagram of the considered materials and processes in for the experiment of the Red Robin photinia production on sediment- and peat-based growing media.