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Reed canary grass straw as a substrate in soilless cultivation of strawberry

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ABSTRACT

The aim of this study was to evaluate whether ground reed canary grass (*Phalaris arundinacea*) straw (RC) could be used to replace peat for short production cycle greenhouse crops. Characteristics of RC, peat, mixture of RC + peat (50% + 50%), and coir were determined and the performance of strawberry (*Fragaria* × *ananassa* cv. Elsanta) on these substrates was evaluated. Water holding capacity of RC was low in comparison to peat and coir, but could probably be improved by decreasing its particle size in processing. The buffering capacity of RC was similar to coir, but clearly lower than in peat. Because of similar reactions to addition of base, liming recommendation of RC would probably be approximately the same as for peat. The C-to-N ratio was 60 in coir, 41 in peat, 23 in RC, and 29 in the mixture of RC + peat. High concentration of inorganic N in RC was rapidly consumed by the microbial activity in the incubation experiment. Vegetative growth of the strawberry plants was the most vigorous in peat, but the total yield, berry size, and sugar to acid ratio in berries were similar in all the substrates. In conclusion, ground reed canary grass may be used to replace peat or coir in soilless culture of strawberry. However, due to its low water holding capacity, irrigation regime has to be adjusted accordingly.

1. Introduction

About 40 million m^3 of peat is used annually world-wide in horticultural production (Myllylä, 2005). Schmilewski (2009) reported that in Finland 1 million m^3 of growing media constituents were used in 2005 and 89% of that was peat. Also in Germany, peat dominated growing media market in 2005 with 93% (8.5 million m^3) share of all constituents (Schmilewski, 2009). In the UK, the annual use of peat as growing medium has been roughly 2.5 million m^3 from 1993 to 2005 (Robertson, 1993; Schmilewski, 2009). Global concern of use of peat has been raised because of its ecological unsustainability (Carlile and Coules, 2013; Gruda, 2012; Raviv, 2013; Vaughn et al., 2011). In principle, peat is renewable material, but it has a very slow regrowth rate and it is often called slowly-renewable material (Gruda, 2012; Raviv, 2013). Moreover, its harvest is causing destruction of mires and wetlands. In 2006 EU Commission adopted a thematic strategy for soil protection (EU, 2006), where decline of organic matter (soil carbon stock) and biodiversity were regarded as serious threats to soils of Europe. In England, where the trend against use of peat may be the strongest, there is a plan to reduce and phase out the horticultural use of peat by 2020 in amateur gardening and by 2030 in professional horticulture (DEFRA, 2011). Recently, availability of peat has been poor partly due to unfavourable weather conditions for peat mining and partly due to restrictive permission policies. Consequently, the price for peat has risen. These reasons call upon alternatives for peat as a substrate in soilless culture.

Many renewable materials to be used as growing media have been researched during the past several decades. Most of them are agricultural and industrial by-products such as coconut (*Cocos nucifera*) coir, grape (*Vitis vinifera*) bagasse, composted cork and pine (*Pinus taeda*) bark. Coir, grape bagasse and composted cork are already widely used as ecologically sustainable alternatives for peat in strawberry cultivation (López-Medina, 2002). Pine bark has not only performed well as substrate of strawberry, but also in production of ornamental crops and in nursery industry (Cantliffe et al., 2007). However, coir has been the most potential organic alternative to peat in soilless culture, mainly due to its good water retention and aeration characteristics (Ayesha et al., 2011; Cantliffe et al., 2007; Recamales et al., 2007), and is becoming into major use both in pot plant and nursery production, and in greenhouse vegetable production. It is considered ecologically sustainable as

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growing medium constituent mainly because it is renewable industrial waste-product for which no other use is found (Lieten et al., 2004; Meerow, 1994; Noguera et al., 2000).

Altland (2010) has studied the use of processed biofuel crops including switchgrass (*Panicum virgatum*), willow (*Salix* spp.), corn (*Zea mays*) stover, and giant miscanthus (*Miscanthus* × *giganteus*) as nursery substrates. Although plant growth was satisfactory in all these substrates, their chemical and physical properties need to be modified. Typically, air space is too high and container capacity too low in this kind of materials. Ground miscanthus straw could be used to replace up to 80% of pine bark in container substrate (Altland and Locke, 2011). Switchgrass could be successfully used as a substrate for short production-cycle woody crops, such as rose, when ground fine enough and amended with peat moss (Altland and Krause, 2009).

A growing medium should primarily have a balanced and stable porosity to provide enough air and water to the roots and physically support the crop. Adequate water uptake of crop requires high water holding capacity (WHC) in the medium. Aeration and WHC are affected by the ratio of air capacity to water volume, which are mainly dependent on the particle size distribution of the growing medium (Abad et al., 2005; Fornes et al., 2003). Total porosity of substrate is an important factor in WHC and aeration, because it determines the total pore space that can be filled by air and water. Besides these physical characteristics a premier substrate should have high cation exchange capacity (CEC) (Vaughn et al., 2011), although inert growing media, e.g. rockwool is commonly used in greenhouse production by tightly controlled fertilizer regimes. Peat as a growing medium has all these required characteristics, although compression and water repellency of peat may be problems. In long-term cultivation of heavily irrigated crops, compression can decrease aeration so dramatically that the substrate becomes waterlogged (Cantliffe et al., 2003; Heiskanen, 1995). The ideal growing medium would have the favourable characteristics of peat, but it should also have better re-wettability and capacity to conserve high air-filled porosity.

In Finland, peat is by far the material most commonly used in greenhouse and nursery production. A few Finnish growers also use imported coconut coir in production. Obviously, there is a need to develop an ecological and sustainable, locally produced substrate to be used as a growing medium. Cultivation of reed canary grass (*Phalaris arundinacea*) increased in Finland in the 2010s and was extended up to 20,000 ha particularly on areas where peat excavation had come to the end. It was considered a promising fuel in power plants, and projects elucidating its cultivation were carried out (e.g. Pahkala et al., 2008). Reed canary grass has also been shown to reduce greenhouse gas emissions from abandoned peat mining areas (Mander et al., 2012). However, due to its low energy density and technical problems it is not used in energy production any more. Attempts to utilize reed canary grass for making pulp and paper (Saijonkari-Pahkala, 2001; Pahkala et al., 2008) and for bioethanol (Kallioinen et al., 2012) have also been carried out. New uses for this crop suitable for marginal lands are still needed.

The aim of this study was to evaluate whether ground reed canary grass straw could be used to replace peat in short production-cycle greenhouse crops. Performance of this material was evaluated in soilless culture of strawberry (*Fragaria* × *ananassa* Duch.) in comparison to peat and coir.

2. Materials and methods

2.1. The substrate characteristics

Plant fibre substrate was produced by Kiteen Mato ja Multa Oy (Kitee, Finland). Reed canary grass (*P. arundinacea*) (RC) was cut in spring, baled, and stored outdoors in 0.5-m high clamps until it was ground by passing baled straw through a hammer mill and through a 3-cm screen. RC is cut in early spring, after it has shed the seeds during winter. In the experiment, RC substrate was compared to coco coir (Cocos-Lanka Holland B. V., Netherlands) and peat (Kekkilä A2 White 630 W, Kekkilä, Tuusula, Finland). In addition, a substrate mix with 50% RC and 50% peat by volume was included. The peat had been limed to pH 5.5 and fertilized (N-P-K 14-4-20, 0.9 kg/m^3), whereas RC and coir were not limed nor fertilized. Limed and fertilized peat served as a control treatment being a standard substrate used by the strawberry growers.

Chemical properties of the substrates were determined by Eurofins Viljavuuspalvelu Oy (Mikkeli, Finland). Electrical conductivity (EC) and pH were measured in the soil:water suspension (1:2.5 v/v). Macronutrients Ca, K, Mg, P, and S were extracted with a 0.5 M acetic acid – 0.5 M ammonium acetate solution (pH 4.65), which is used in soil testing in Finland.

To determine water holding capacity (WHC) the substrates were first dried at 70 °C for 1 d. Then a 10-g sample of each dried substrate, in four replicates, was placed in a funnel plugged with a stopper and lined with a filter paper. Ample water was added and the samples were incubated in the funnels for 3 d. The stoppers were removed from the funnels and water was allowed to drain by gravity for 1 d. The moist substrates were weighed, and the amount of water retained in the substrate was calculated as percentage of substrate dry weight. This simple approach gives a rough estimate of the WHC even though it does not give information about the pore size distribution and availability of water, which will be studied later in more detail.

The pH-buffering capacity was determined by adding sulphuric acid (H_2SO_4) to decrease, or calcium hydroxide ($Ca(OH)_2$) to increase the pH of the substrate. After incubation, pH in substrate samples was determined. There were seven pH treatments in three replications, as follows:

1. 27 mEq (14 ml 1 M) H_2SO_4
2. 18 mEq (9.333 ml 1 M) H_2SO_4
3. 9 mEq (4.666 ml 1 M) H_2SO_4
4. Control
5. 13.5 mEq (0.5 g) $Ca(OH)_2$
6. 27 mEq (1 g) $Ca(OH)_2$
7. 40.5 mEq (1.5 g) $Ca(OH)_2$

First, the 500-ml substrate samples in containers were watered into equal moisture contents. Then, H_2SO_4 solution and solid $Ca(OH)_2$ were added and stirred. The pH in the leachate of the substrates was measured with a pH meter (pH/mv Meter Ultra-Basic, Denver Instrument, Göttingen, Germany) in the beginning of the experiment and after two and four weeks of incubation. The leachate was obtained by pressing by hand from the substrate samples.

The concentrations of total nitrogen (N) and carbon (C) were determined with a C/N-analyser (Vario Elementar Max C/N, German Technology, Germany) in four replicates of 1 g samples, which were dried at 50 °C for 1 d and sieved and crushed. C-to-N-ratios of each substrate were calculated.

Mineralization of N was monitored in an incubation experiment, where the 500-ml substrate samples were kept moist in containers at 20 °C for 8 weeks. Water was added to the substrates to keep them in approximately the same moisture content as they would be during standard cultivation. Containers were kept in the dark to prevent growth of algae that would consume mineralized N. In the beginning and in 2-week intervals samples (containers) were removed and placed into a freezer (−20 °C). In total, 80 samples (four treatments in four replicates and five sampling times) were