Scientia Horticulturae 235 (2018) 205–213

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Short communication

Cascading use of *Miscanthus* as growing substrate in soilless cultivation of vegetables (tomatoes, cucumbers) and subsequent direct combustion

Thorsten Kraska[a,*], Barbara Kleinschmidt[b], Jan Weinand[b], Ralf Pude[a,b]

[a] Field Lab Campus Klein-Altendorf, Faculty of Agriculture, University of Bonn, Campus Klein-Altendorf 1, 53359 Rheinbach, Germany
[b] Institute of Crop Science and Resource Conservation, Faculty of Agriculture, University of Bonn, Klein-Altendorf 2, 53359 Rheinbach, Germany

ARTICLE INFO

Keywords:
Miscanthus
Vegetable production
Sustainable
Renewable
Direct combustion
Cascade utilization
Tomato
Cucumber
Growing substrate
Resource efficiency

ABSTRACT

The demand for sustainable and environment friendly growing media as alternatives for peat or inorganic substrates like Rockwool for vegetable production in the greenhouse is increasing. At the same time growing media have to meet the requirements of the growers with respect to crop performance (yield, product quality) and consistent supply of high quality raw material. In this study we tested *Miscanthus* shreds, chips and fibers as alternative organic growing substrate for Rockwool in soilless cultivation of mini cucumbers and tomatoes as primary use under practical conditions. Following vegetable production we evaluate the combustion quality of the used growing substrate for a secondary use as solid fuel. Cucumbers and tomatoes grown on the different *Miscanthus* substrates obtained comparable cumulative yields to Rockwool. Additionally tested plant traits (single fruit length, diameter and weight for cucumbers; plant growth and total soluble solids for tomatoes) were not affected. Gross calorific values of *Miscanthus* shreds and chips were almost the same after using them as growing substrate compared to the original material. In contrast, the value for fibers decreased significantly. Ash contents were higher in comparison to the original feedstock but were still below 7% for shreds and chips. Ash content of fibers increased to over 10% after primary use as growing medium. In conclusion, *Miscanthus* is a promising sustainable and renewable alternative to Rockwool in soilless cultivation of vegetables and can be used in a cascade with subsequent direct combustion and reuse of the ash.

1. Introduction

Greenhouse production area is increasing worldwide. In Germany it reached in 2016 over 1.200 ha including 337 ha tomatoes and 201 ha cucumbers among the three main cultivated crops (Destatis, 2017). In The Netherlands under glass production area was 1775 ha for tomatoes and 540 ha for cucumbers in 2016 (CBS, 2017). The reasons for greenhouse cultivation are obvious. It is possible to optimize all limiting environmental factors as well as cultivation parameters such as growing medium. For this Rockwool as an inorganic and inert substrate is widely used in soilless cultivation of vegetables like tomato or cucumber. It is offered as ready-to-use Rockwool slabs wrapped in polyethylene bags (Savvas et al., 2013), in which crop management is reliable and easy to handle. The physical and chemical properties are well defined. Water, air and nutrient supply could be controlled and optimized (Gruda et al., 2013). It is virtually free of soil-borne pathogens (De Swaef et al., 2012). Beside these obvious advantages as growing medium it comes with the shortcomings that manufacturing has a high energy demand to melt basaltic rock at high temperatures of 1500 °C and additives have to be added to achieve the desired properties (Bussel and McKennie, 2004; Gruda et al., 2013). A negative impact from various emissions has to be considered (Pluimers et al., 2000; Antón et al., 2012) and although it can be re-used to some extent (Peet and Welles, 2005), lack of acceptable secondary uses makes recycling and disposal of Rockwool necessary which are regarded to be unsustainable (Bussel and McKennie, 2004; Papadopoulos et al., 2008). Alternative organic growing media components have been tested widely (see Maher et al., 2008; Gruda et al., 2013; Barrett et al., 2016 for reviews). In their thorough and critical review on achieving environmentally sustainable growing media Barrett et al. (2016) scrutinize the underlying drivers for raw material selection with regard to performance, economy, and ecology. One conclusion they draw is that a successful substrate must perform under practical conditions and constraints equal or better as a commercial available standard to be accepted by growers. They suggested that any new material should be tested in a commercial context before conducting detailed studies on the performance. One promising sustainable alternative could be *Miscanthus*. *Miscanthus* shreds and fibers have been used by Mac Cártaigh et al. (1997) as potting medium for

* Corresponding author.
E-mail address: kraska@uni-bonn.de (T. Kraska).

https://doi.org/10.1016/j.scienta.2017.11.032
Received 24 July 2017; Received in revised form 5 November 2017; Accepted 29 November 2017

Table 1
Summary of experimental and growing parameters (further details are given in Supplements A and B).

	cucumbers	tomatoes
Variety	Khassib	Lyterno
Sowing	Rockwool plugs	Rockwool plugs
Pre-cultivation	Rockwool cubes	Rockwool cubes
Transplanting on day	23	28
plants/slab	2	2
Growing media tested	Rockwool *Miscanthus* shreds	Rockwool *Miscanthus* shreds *Miscanthus* chips *Miscanthus* fibers
Days of cultivation on tested substrate	90	143
1st Harvest on day	42	112
Last Harvest on day	97	168
Harvest frequency	1–4 times per week (details given in supplement B)	Once per week
Watering	Drip Irrigation every hour (130 mL/plant) and an additional irrigation after reaching a light sum of 30 kLux; one dripper per plant	
Fertigation	Standard nutrient solution containing required macro and micro nutrients (details given in supplement A) EC = 2.0 mS cm^{-1}	EC = 2.5–2.8 mS cm^{-1}
Temperatures (min-max)	20–30 °C	20–30 °C

shrub species, while Altland and Locke (2011) have used it in mixtures with sphagnum peat moss and pine bark for potting media. Two other perennial grasses, Switchgrass and reed canary grass, have been successfully tested without further amendments as potting media for woody crops (Altland and Krause, 2009) and strawberries (Kuisma et al., 2014). Moreover, Clemmensen (2004) showed that composted *Miscanthus* had a high air filled porosity and oxygen diffusion which would be favorable for soilless cultivation. Beside this general suitability of perennial grasses as a growing medium, *Miscanthus* can be grown in an ecological and economic sustainable manner and is one of the most productive land plants in temperate climate (Heaton et al., 2010). While the quality of *Miscanthus* as primary renewable resource depends on climatic factors and genetic background it can be managed through agronomic practice especially fertilization and harvest time though (Iqbal et al., 2015). It is considered to be a low-input crop providing ecosystem services like CO_2 mitigation or biodiversity (Emmerling and Pude, 2017). Thus as a primary resource could fulfill the criteria laid down by Barrett et al. (2016) for organic substrate concerning availability, ecology and economic. So far *Miscanthus* is mainly used as a solid fuel to produce heat energy (Lewandowski et al., 2016) and has not been tested as a stand-alone medium in soilless vegetable production.

Based on knowledge from literature we hypothesized that both uses of *Miscanthus* as growing media and solid fuel could be combined in a cascading manner to increase resource efficiency as it has been proposed earlier (Kraska et al., 2015). First, we tested *Miscanthus* as standalone organic growing media in soilless cultivation of tomatoes and cucumbers in the greenhouse. Secondly, we studied, if a subsequent use of *Miscanthus* for direct combustion is feasible. With these two main objectives the emphasis of this study was not on the physical or chemical characteristics of the raw material, but on its (1) general suitability as a potential growing medium to cultivate cucumbers and tomatoes under practical conditions in the greenhouse with just minimal processing and (2) its combustion quality as a subsequent secondary. As control and standard for crop performance we used Rockwool for better comparison with other studies.

2. Materials & methods

In a first experiment *Miscanthus* shreds were tested as growing medium for cucumbers (*Cucumis sativus* L.). In a 2nd experiment beside *Miscanthus* shreds, chips and fibers were used in tomatoes (*Solanum lycopersicum* L.) to test the effect of different processing on plant performance and combustion quality. In both experiments Rockwool was used as standard growth medium in soilless culture. Plants were cultivated according to common management practice for cucumbers and tomatoes grown on Rockwool, including automated watering and fertigation. Experimental details are summarized in Table 1. Information on fertigation and details on experimental time lines are given in Supplement A and B.

Experiment 1: Mini cucumbers (variety 'Khassib RZ F1', Rijk Zwaan) were sown into Rockwool plugs, cultivated on Rockwool cubes until the 4-leaf stage. 23 days after sowing two plants were transplanted on commercial growbags containing Rockwool (Grodan Top Master) or *Miscanthus* shreds. Eight slabs with *Miscanthus* were randomly placed on the four inner trough rows of a greenhouse (area of 224 m^2 with 6 rows, 240 slabs with 2 plants on each slab) where cucumbers were cultivated on Rockwool under practical conditions. Maintaining of cucumber was conducted weekly including removing discolored leaves. Neighboring Rockwool slabs were used as control. All growbags were thoroughly watered for two days before two cucumber plants were placed on each slab. First harvest was 19 days after transplanting. Cucumbers were harvested 2–4 times a week over a period of nine harvest weeks. Harvested cucumbers (number of fruits and weight) were pooled by week for each plant. Beside yield parameters, bulk density, caloric value, and ash content of *Miscanthus* before and after use were measured.

Experiment 2: Tomatoes (variety 'Lyterno RZ F1', Rijk Zwaan) were sown into Rockwool plugs and cultivated on Rockwool cubes. 28 days after sowing two plants were placed on each growbags containing Rockwool or three differently processed *Miscanthus* substrates. Plants were cultivated in 'leaning and lowering' system according to common management practice for greenhouse tomatoes. Each truss was pruned to seven fruits and pollinated by humble bees. First harvest was 84 days after transplanting. Tomatoes were harvested once each week over a period of nine weeks. Due to limited availability of processed *Miscanthus* the number of replicates was seven growbags for chips and four for fibers instead of eight growbags resulting in maximum number of 16 plants (Rockwool, *Miscanthus* shreds). Beside cumulative fruit yield plant growth and total soluble solids (TSS) were estimated and as