How growing media have an impact on feeding a growing population

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Growing on Grodan systems can help shorten fresh produce supply chains through flexible production systems which have no need for fertile soils and can be located anywhere.

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March 2016

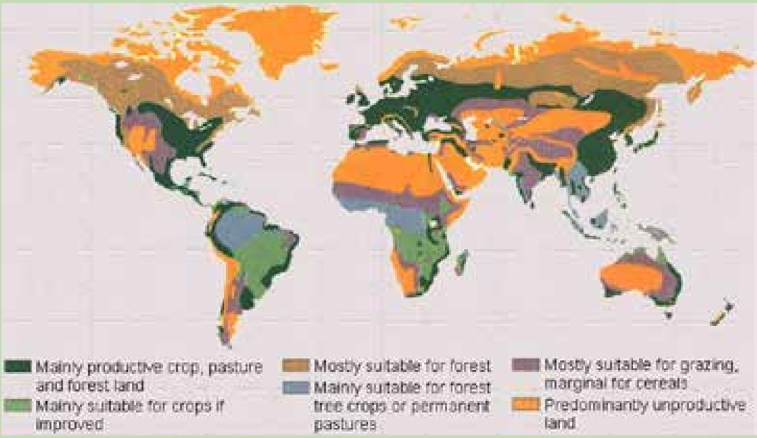


Figure 1.0
Much of the land in developing countries is not suited to rainfed agriculture, but of the potentially productive land, only about one-third is cultivated. The scale of the map does not allow some important cropland areas, for example in West Africa, to be shown. Also, land shown as mainly suitable for one use may well be suited for other uses (source: http://www.fao.org/docrep/u8480e/U8480E0e.htm#Cultivated areas and gross reserves).

Introduction

World population is expected to grow another 1 billion in just 12 years, and reaching 9 billion people in 2050, creating unprecedented demand for food, and hence agricultural land. To keep up with population and economic growth, food production should increase by 70% by 2050 (Glenn *et al.*, 2015). This ever-increasing demand for food will be accompanied by a continual decrease in arable land area due to climatic change, urbanization, and industrialization. The International Rice Research Institute (IRRI) currently estimates that 1 ha of cultivable land is lost every 7.7 s (http://irri.org/). A large part of the total earth land surface is characterised as predominantly unproductive land and only a small proportion is 'mainly productive crop, pasture and forest land' (Fig. 1). 1.6 billion hectares of land are currently used to grow crops, whereas 25 percent of the earth's lands are degraded (ICTSD, 2011).

Much of the current degraded land worldwide is lost to erosion and human activities, and it is difficult and expensive to exploit new land for agricultural use (Godfray *et al.* 2010). Degrading of land is caused by erosion (wind and water), salinization and desertification. Other reasons for the loss of arable land are urbanization and the rise of sea levels. More than 800 million hectares of land throughout the world are salt affected (FAO, 2008). Of the 1500 million ha of land farmed by dryland agriculture, 32 million ha (2%) are affected by salinity to varying degrees. Of the current 230 million ha of irrigated land, 45 million ha (20%) are salt affected. Irrigated land accounts for only 15% of total cultivated land, but because irrigated land has at least twice the productivity of rainfed land, it produces one third of the world's food (Munns and Tester, 2008).

The increased scarcity of land and the growing demand for food assert the need for more efficient land use allocation and innovation in agriculture (Lambin and Meyfroidt, 2011). Globally, more people live in urban areas than in rural areas, with 54 per cent of the world's population residing in urban areas in 2014. In 1950, 30 per cent of the world's population was urban, and by 2050, 66 per cent of the world's population is projected to be urban (United Nations, 2014). This strong worldwide urbanisation also puts a demand for producing vegetables in close proximity of the consumers. Europe's second largest city is Berlin. It has 3.45 million inhabitants (Wikipedia. 2016). These inhabitants consume annually 85.6 million kg tomatoes (based on 24.8 kg per capita as an average for Germany; Hortidaily, 2014). To produce such an amount of tomatoes 324 ha of German glasshouses is needed, since in Germany 265 ha of glasshouses is producing 70 million kg of tomatoes yearly (26.4 kg m-2; Garming *et al.*, 2014). Berlin occupies 89,100 ha (Wikipedia, 2016) so about 0.4% of this area would be needed for tomato production in greenhouses.

Figure 1.0
Vertical farming; soilless cultivation, no fertile soil is needed

With agricultural land becoming more scarce and the need for producing closer to or even in the cities to shorten the supply chain (Despommier, 2013), not always the best soil can be chosen for producing crops. When grown on substrate the quality of underlying soil is not a consideration, since plants do not root in the underlying soil; water and nutrients are delivered directly to the crop via the substrate. Substrate cultures can even take place without soil, e.g. on concrete floors in buildings (Fig. 2)

Question

Is there scientific proof that growing on substrates vs growing in soil requires less land area for equivalent production level and is therefore more efficient ?

Introduction

Soilless cultivation systems, e.g. cultivation on mineral wool, allow for a much more accurate control of the root environment (e.g. water and nutrient availability, EC, pH, oxygen availability, root temperature) compared to cultivation in soil. This is expected to result in higher yields per unit land area. Typically, 1 m^2 of tomato greenhouse with a rooting depth of 30 cm would represent 300 l of rooting volume per m^2, whereas for a mineral wool substrate cultivation this would be only 14 l (Sonneveld, 2000). This lower volume is a main reason making the substrate root environment easier to control than the soil. There will be about 8 times more fertilisers required for changing the concentration in the soil (substrate) solution in the upper layer of a soil than in a mineral wool substrate system (Sonneveld, 2000). Hence, substrate culture represents a much more controllable system. Other reasons for expected higher yields in soilless cultivation systems are: (1) roots are isolated from soil-borne pests and diseases, and (2) often in soilless cultivation systems the greenhouse soil is covered with white plastic foil, which reflects light thus increasing crop light interception and potential production.

Soilless cultivation systems can largely contribute to the necessary increase in food production, as cultivation on substrate enables that crops are produced on non-arable land (not fit for farming), e.g. poor soils and contaminated soils (i.e., high heavy metal or salinity levels). At least 20% of all irrigated lands are salt affected with some estimates being as high as 50% (Vijayvargiya and Kumar, 2011).

Yield in soilless and conventional soil-based systems

Hussain *et al.* (2014) reported yields 10-20 times higher in hydroponics compared to the agricultural average yields (Table 1). Hence one can anticipate a much reduced required land area needed for hydroponic production.

Crop	Hydroponic (ton/ha)	Agricultural average (ton/ha)	Hydroponic/ Agricultural
Wheat	5.5	0.7	8
Oats	3.5	1	3.5
Rice	14	1	14
Maize	9	1.7	5
Soybean	1.7	0.7	2.5
Beet root	23	10	2.3
Cabbage	20.5	15	1.4
Peas	16	2.3	7.0
Tomato	450	19	24
Cauliflower	34	14.2	2.4
Lettuce	24	10	2.4
Cucumber	32	8	4

Table 1.0
Yields in hydroponic systems (cultivation on substrates) compared with average agricultural yields obtained in soil (based on Singh and Singh (2012))

Olle *et al.* (2012) concluded from their literature review that the yield of various vegetables tends to be higher for plants grown in various growing media compared to those grown in soil indicating that the growing media could meet plant demands better than the soil.

Abak and Celikel (1994) conducted experiments in Turkey and they reported 15% (statistically significant) higher tomato yields on mineral wool compared to soil. These authors obtained, averaged over two years, 23.3 kg m^{-2} on mineral wool, whereas soil-based cultivation yielded 20 kg m^{-2}.

Barbosa *et al.* (2015) compared the land requirements of hydroponics with those of conventional agriculture by example of lettuce production in Yuma, Arizona, USA. Data were obtained from crop budgets and governmental agricultural statistics, and contrasted with theoretical data for hydroponic lettuce production derived by using engineering equations populated with literature values. Annual yields of lettuce per greenhouse unit (815 m^2) were 41 ± 6.1 kg m^{-2} whereas conventional production yielded 3.9 ± 0.21 kg m^{-2}. Hydroponics therefore offered 11 ± 1.7 times higher yields.

Guler *et al.* (1995) compared sweet melon production on mineral wool with production in soil in Chania, Greece. Growth on mineral wool substrate resulted in a yield of 8.3 kg m^{-2}, whereas production in soil yielded 6.1 kg m^{-2} (Fig. 3). This 36% higher yield on mineral wool substrate resulted from higher average fruit weights: 1031 g $fruit^{-1}$ on mineral wool, and 734 g $fruit^{-1}$ on soil.

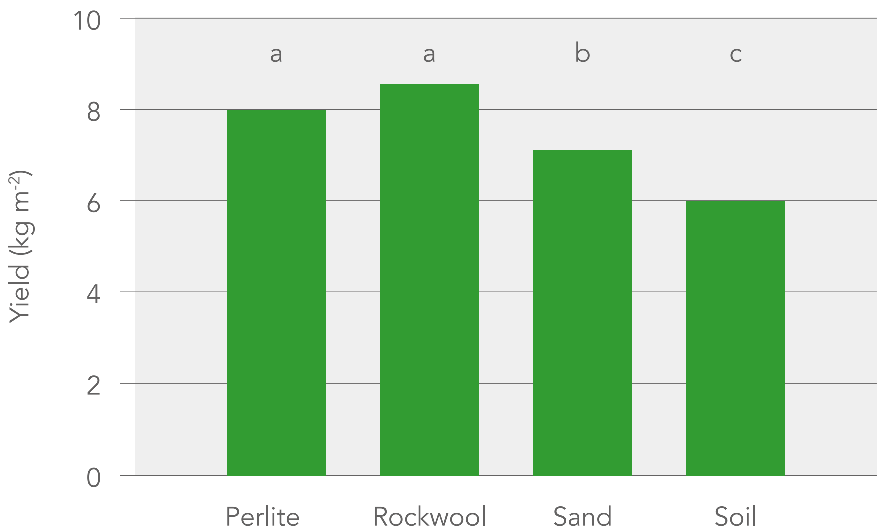


Figure 3.0
Sweet melon yield, averaged over 2 years, grown on 3 different substrates (perlite, mineral wool and sand) or in a conventional soil-based system (different letters indicate significant differences; Guler et al., 1995).

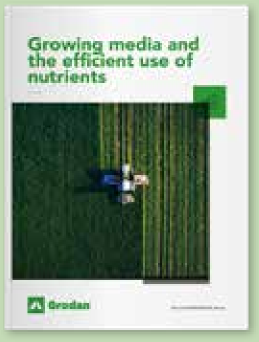
36%
On mineral wool substrate

Conclusive summary

In relation to the question on land requirement for an equivalent production level and comparison between soilless cultivation and growing in soils, the literature review demonstrates that:

- Yield per unit land area in soilless cultivation (substrates like mineral wool and NFT systems) is potentially much higher than in soil-based (conventional) systems. Reported yield improvements vary between 15 and 40%, However, yields can be as much as 10 to 20 times higher, when comparing soil-based cultivation in the field, with soilless cultivation in greenhouses.
- When grown on substrates there are no specific requirements for soil quality since the growing system is separated from the soil. Hence, land unfit for soil-based production (poor soils and contaminated soils, i.e., high heavy metal or salinity levels), or land infected with soil-born diseases can be used for production of vegetables and ornamentals on substrates. The soil quality is irrelevant for soilless cultivation systems and production can even take place where there is no soil (e.g. on concrete floors in buildings; city farming, vertical farming). This means that soilless cultivation is a way to bring food to the city.

More whitepapers



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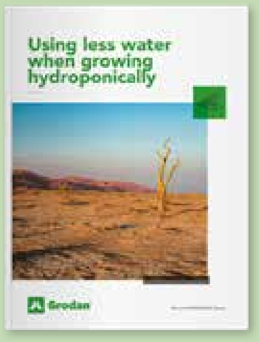

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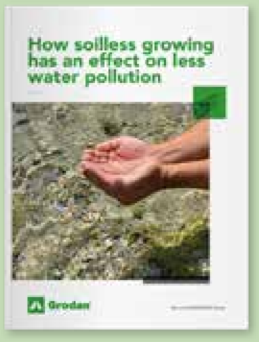

How soilless growing has an effect on less water pollution

Download them here **www.grodan.com/sustainable**

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Grodan supplies innovative, sustainable mineral wool substrate applications for professional horticulture, based on the Precision Growing principle. These applications are used for the growing of vegetables and flowers, such as tomatoes, cucumbers, capsicums, aubergines, roses and gerberas. Grodan supplies stone wool substrates in combination with customized advice and innovative tools to support growers with Precision Growing. This facilitates sustainable production of healthy, safe and delicious fresh produce for consumers.

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