Journal of Scientific Agriculture 2018,2: 62-65
doi: 10.25081/jsa.2018.v2.860
http://updatepublishing.com/journals/index.php/jsa

ISSN: 2184-0261

REVIEW ARTICLE

SUITABLE SUBSTRATE FOR OPTIMAL CROP GROWTH UNDER PROTECTED FARMS–AN ASSESSMENT

AMARESH SARKAR[*], MRINMOY MAJUMDER

Department of Civil Engineering, National Institute of Technology, Agartala, PIN-799046, Tripura, India

ABSTRACT

An attempt has been made in this paper, to review crop growing substrates for protected farms. Optimal substrate type and volume for different crops cultivar is different. Substrate selection is a critical factor for optimal production of high-quality vegetables. Crop root orientation and depth determine the type and volume of substrate required which is very important for optimal crop growth and maximum profit. Growing crops on substrates in protected skyscrapers would not only mitigate the need for more land, it produces growing space vertically.

Keywords: Substrate, Nutrient solution, Controlled environment agriculture

INTRODUCTION

Food need is increasing globally as the inhabitants are increasing. Protected farming is a popular technique for growing vegetables all seasons regardless of location and climate. The most innovative technology for plants growing in greenhouses is growing plants in mineral substrates such as rock wool, vermiculite, perlite, zeolite, ceramic and others. The origin of substrates is different, some of them are of natural origin while others are produced artificially [26, 8]. They also differ in their physical, chemical, and biological properties. Therefore, substrate selection is one of the most important factors affecting plant growth and development in the greenhouse and influencing vegetable quality ([15]. Protected farming is a cleaner, safer, method than open field agriculture and an eco-friendly way to grow premium produce in a location where weather, or soil, is not optimal [18]. Growing crops in a multi-story protected farm in an urban area would mitigate the need for land and transportation cost. Protected farming allows growing of locally demandable crops to and decreases greenhouse gas emissions [10]. Crop diseases and soil erosion are less in protected farms compared with open field agriculture [13]. Increasing use of urban protected culture may be a partial solution to increasing population. Growing crops under open-field conditions produce major challenges, most importantly is decreased land. Enhancing agricultural productivity is necessary and food production will need to be doubled by 2050 [1]. Globally, available per-capita cropland is about 0.23 ha but is shrinking. Climate change is expected to harmfully impact on food production [19]. Protected farm structure can also be constructed on non-cultivable soil and urban roof-tops [21]. The amount of solar radiation, which provides the energy to evaporate moisture from the substrate and the plant, is the major factor. Other important factors include air temperature, wind speed, and humidity level [11]. The plant canopy size and shape influences light absorption, reflection, and the rate at which water evaporates from the soil. Leaf architecture affects the transpiration rate from individual leaves. Rooting depths vary with crop species and may be affected by compaction or hardpans which may exist. Rooting depth determines the volume of soil from which the crop can draw water and is important when determining to what depth the soil must be wetted when irrigating [24]. The initial investment in constructing a protected farm is high but crop yield is higher compared to open field agriculture. The benefits of Controlled Environment Agriculture (CEA) over Open Field Agriculture (OPA) in conditions of crop growth, nutrient need, land area need and water need are in fig. 1 [20]. Scientific American supports multi-layered protected farms as a solution to the problem of a growing population and a dwindling world food supply [2].

Crop yield under controlled environment farming is much higher than the open field farming [7]. Cultivation of crops on protected farms has been practicing commercially by Go Green Agriculture, California; Good Life Farms, Indiana, USA; Thanet Earth farm, Kent, Britain [5]. Nearly all leafy vegetables are grown fast protected farms [16]. An attempt has been made in this paper to review substrates

Received 07 November 2017; Accepted 08 February 2018

*Corresponding Author

Amaresh Sarkar

Department of Civil Engineering, National Institute of Technology, Agartala, PIN-799046, Tripura, India

Email: amaresh.sarkar@gmail.com

for optimal crop growth yield under protected farms.

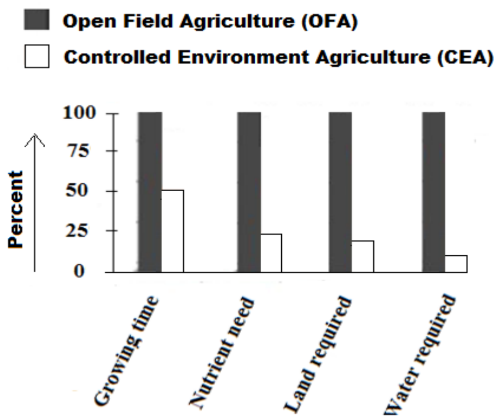

Fig. 1: Percent of savings between crop productions with CEA over OFA

MATERIALS

In order to serve as a suitable replacement for soil, the substrate must be capable of supporting the root system and holding moisture and nutrients. It should be inert, free of insects and diseases, and not easily broken down. Also, the substrate should allow adequate aeration of the roots and have good drainage qualities [17]. Plants need sufficient access to oxygen in the air in order to grow and take up water and nutrients. Poor drainage can lead to decreased growth, stunting, wilting, and discoloration of the leaves and, in the worst cases, drowning [17]. Economically and practically, there are many problems inherent in creating a multi-layered protected farm [17]. Various substrates suitable for growing various crops are classified in fig. 2.

An inadequate water supply is the most limiting factor to plant growth. Water deficiencies can cause the plant to spend all its available energy on developing an extensive root system, the result being a small, stunted shoot. For this reason, it is important that the substrate media should be flooded, and subsequently drained, one to three times daily or as often as necessary to keep the roots moist [17]. Sample appearance of eight different types of substrate viz., coir (coco-fiber), rock wool, vermiculite, perlite, peat, biochar, sawdust and clay pebbles commonly used in protected farming are shown in fig. 3 to 10 respectively.

RESULTS

The optimal substrate for different crops is different. Coco coir is an organic plant material that has neutral pH value. It breaks down and decomposes very slowly. Coco coir holds 50% moisture and allows for good aeration to the roots. Coco fiber comes in two forms, coco coir (fiber), and coco chips; both made from coconut husks, the only difference in the particle size [4]. Rockwool is one of the most common growing media's used in a hydroponics system. Rockwool is a sterile, porous, non-degradable medium that is composed primarily of granite and/or limestone [4]. Perlite is mainly composed of minerals that are subjected to very high heat to form like popcorn shape and becomes very lightweight, porous and absorbent. Perlite has very lightweight and tends to float. It has a neutral pH value and excellent wicking action. Perlite can be used directly or after mixed with other types of the substrate depends upon the type of crop cultivar to be grown [4]. Vermiculite is a silicate mineral that is like perlite, expands when exposed to high heat. As a growing media, vermiculite is quite similar to perlite except that it has a relatively high cation-exchange capacity. Vermiculite has very lightweight and tends to float [4]. Expanded round clay pebbles are often used in hydroponic systems as substrate. Clay pebbles are porous and lightweight that increases aeration to the plant's root systems. Clay pebbles provide improved drainage systems which help in maintaining the health of the crop root systems [4]. Biochar is obtained from the carbonization process of biomass in an oxygen-limited environment. Biochar is soil enhancer that holds carbon higher content and makes the soil more fertile [4]. The pH value, porosity (%) and water holding capacity (%) of the eight different substrates are shown in table 1.

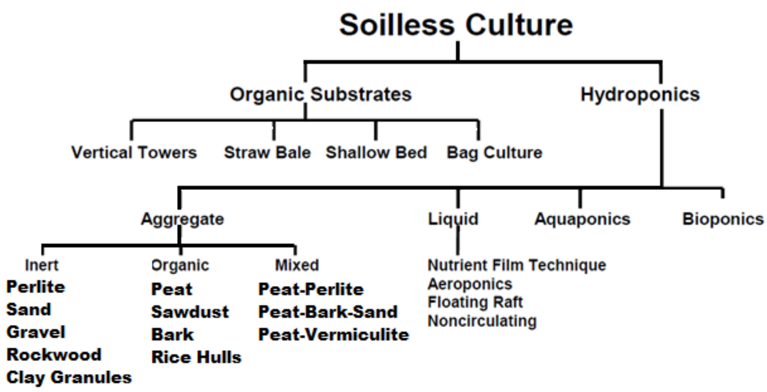

Fig. 2: Classification of soilless agriculture

Fig. 3: Coco-Fiber

Fig. 4: Rockwool

Fig. 5: Vermiculite

Fig. 6: Perlite

Fig. 7: Peat

Fig. 8: Bio-char

Fig. 9: Sawdust

Fig. 10: Clay Pebbles

Table 1: Ph-value, porosity (%) and water holding capacity (%) of eight different substrates

Substrate	Ph Value	Porosity (%)	Water holding capacity (%)	Suitable crops
Coir (Coco-Fiber)	5.5–6.8 [27]	80 [9]	40 [9]	Cucumber
Rockwool	7.0–8.0 [27]	96 [9]	91 [9]	Potato
Vermiculite	6.0-7.2 [27]	80 [14]	70 [14]	Cucumber, Tomato, capsicum
Perlite	6.5-7.5 [27]	75 [9]	40 [9]	Cucumber, Tomato, capsicum
Peat	3.0-7.3 [27]	94 [14]	77 [14]	Tomato, capsicum
Biochar	6–10 [27]	40-75 [28]	25% to 56% [6]	Tomato, capsicum
Sawdust	5.03 to 5.89 [29]	40-50% [3]	65% [3]	Tomato, capsicum
Clay Pebbles	7.0 [12]	70 [12]	18% [12]	Potato

The initial investment and operating cost on substrate under protected farm is high but the crop yield higher compared with open field farming. The average crop yield per plant under protected farming is found to be tomato 5.75 kg [23], capsicum 0.79 kg [23], lettuce 1 kg [25], cucumbers 6.75 [23] and spinach 0.3 kg [22]. Selection of optimal substrate in a protected farm helps protected crop grower for getting optimal crop yield and profits. Growing food within cities at the doorstep of the consumers eliminates the need for transport, therefore reducing greenhouse gas emissions. Mostly, leafy vegetables are growing fast on substrates under protected farms.

CONCLUSION

Protected farms are the fastest growing sector of agriculture. Selection of optimal substrate for a particular crop plays an important role in optimal crop yield under a protected farm. The substrate for optimal crop growth must be inert and free of insects, should allow adequate aeration of the roots and water drainage system. Substrate selection depends upon the type of crop cultivar to be grown under protected farms. Commonly used substrates are coir (coco-fiber), rock wool, vermiculite, perlite, peat, biochar, sawdust and clay pebbles etc. This study is expected to help protected farmer for appropriate selection of substrate for optimal crop yield.

AUTHOR'S CONTRIBUTIONS

Authors contributed equally to the overall study and manuscript preparation and approved the final version of the manuscript for publication.

REFERENCES

1. Alexandratos, N. and J. Bruinsma. World agriculture towards 2030/2050:The 2012 revision, Agricultural Development Economics, Working paper No. 12-03. Food and Agriculture Organization, Rome. 2012
2. Anonymous, Off-grid-world. Vertical Farm. 2012, updated on 7th May 2016.
3. Anonymous. Greentrees Hydroponics. Rockwool, Green trees Hydroponics, California, USA. 1992, updated on 22nd May, 2017.
4. Anonymous. Growing Mediums and Hydroponics, Home Hydro Systems, 2017, updated on 28th January, 2017.
5. Anonymous. Meet some growers. American Hydroponics Inc., Arcata, CA, 2015, updated on 28th January, 2016.
6. Anthony, M. How Biochar Improves Soil–Stability And Affinity, Wakefield Biochar, Columbia, USA, 2017, updated on 28th January, 2017.
7. Banerjee, C., and Adenaeuer, L. Up, Up and Away! The economics of vertical farming. Journal of Agricultural Studies, 2014:2, 40-60.
8. Bhat, N. R., Suleiman, M. S., Thomas, B., Lekha, V. S., George, P., and Ali, I. S. Growing substrates for organic lettuce production in Kuwait. World Journal of Agricultural Sciences, 2013. 9: p. 143-147.
9. Buechel T. Greenhouse Herb and Vegetable Production–Part 4/4–Growing Media, 2016, updated on 19th June, 2017.
10. Despommier, D. The rise of vertical farms. Scientific American, 2009. 301: p. 80-87.
11. Garrison, S. Best Management Practices for Irrigating Vegetables, Extension Specialist in Vegetable Crops, by Rutgers Cooperative Extension, New Jersey Agricultural Experiment Station, Rutgers, The State University of New Jersey. 2002
12. GBC India. Light Expanded Clay Aggregate, Ahmedabad, India, 2017, updated on 22nd May, 2017.
13. Han, G. Growing Up. Massachusetts Academy of Math and Science. The Scientia Review. 2009, updated on 22nd January, 2015.
14. Jacques D. and Walden R. A review of the major growing media components, Sun Gro Horticulture, Agawam, USA, 2005, updated on 28th January, 2016).
15. Jankauskiene, J., Brazaityte, A., and Viskelis, P. Effect of Different Growing Substrates on Physiological Processes, Productivity and Quality of Tomato in Soilless Culture. In Soilless Culture-Use of Substrates for the Production of Quality Horticultural Crops. InTech. 2015.
16. Jensen H. M., Hydroponics Worldwide–A Technical Overview. Univ. Arizona. School of Agriculture. Tucson, Arizona 85721, 2013, updated on 28th January, 2016.
17. Kessler J. Raymond, Williams J. David and Howe Robyn. Alabama Cooperative Extension System, ANR-1151, Hydroponics for Home Gardeners, Auburn University, 2006, updated on 14th May, 2016.
18. MAFES. Commercial Horticulture**.** Mississippi Agricultural and Forestry Experiment Station (MAFES), Mississippi State University Extension Service, Stoneville, MS, 2010 updated on 28th January, 2016.
19. Mellino, C. World's largest 'vegetable factory' revolutionizes indoor farming. Transforming green. Eco-Watch, Bengaluru, India, 2015, updated on 28th January, 2016.
20. Meyers, G. Cityscape farms: Soilless farming. Green Building Elements, 2010, updated on 22th January, 2016.
21. MIT. Urban agriculture mission, Feeding the world. Massachusetts Institute of Technology (MIT), Cambridge, MA, 2014, updated on 28th January, 2016.
22. Pena J. G., Greenhouse Vegetable Production Economic Considerations, Marketing, and Financing, Texas Cooperative Extension, 2005 updated on 28th January, 2016.
23. Rajasekar M., Arumugam T. and Ramesh Kumar S. Influence of weather and growing environment on vegetable growth and yield, Journal of Horticulture and Forestry, 2013, 5: p. 160-167, November,
24. Steven, C. Hydroponics as an agricultural production system, Issue 63. Practical Hydroponics and Green Houses. Global form for Innovation in Agriculture. Wanneroo, CA, 2002, updated on 22nd January, 2016.
25. Valenzuela H., Kratky B., Cho J. Crop Production Guidelines, University of Hawaii. CTAHR, 2011, updated on 28th January, 2016.
26. Verdonck, O. D., De Vleeschauwer, D., and De Boodt, M. The influence of the substrate to plant growth. In Symposium on Substrates in Horticulture other than Soils in Situ, 1981, 126:p. 251-258).
27. Wilfried, B., Remi, N. W., Nebambi, L., Alison, H., Nicolás, C., Cherubino, L., Stefania, D. P. and Muien, Q. Good agricultural practices for greenhouse vegetable crops: principles for mediterranean climate areas (No. 217). FAO of the United Nations. 2013.
28. Brechner, M. and Both A. J. Hydroponic Lettuce Handbook. Controlled Environment Agriculture, 2014, updated on 22nd January, 2014.
29. Tu, C. M. "Use of sawdust for soil pH amendments." Communications in Soil Science and Plant Analysis, 1995, 26 (19-20), p. 3175-3180.