Asian Journal of Crop Science

ISSN 1994-7879

OPEN ACCESS Asian Journal of Crop Science

ISSN 1994-7879
DOI: 10.3923/ajcs.2018.1.9

Review Article
Soilless Media Culture-A Propitious Auxiliary for Crop Production

[1]Amjad Farhan Ashraf Farhan, [1]Abd. Jamil Zakaria, [2]Prof Nashriyah Mat and [2]Khamsah Suryati Mohd

[1]Faculty of Agriculture Production and Food Innovation Research Institute (AGROPOLIS), Universiti Sultan Zainal Abidin, 22200 Besut Terengganu, Malaysia
[2]Faculty of Bioresource and Food Industry, Universiti Sultan Zainal Abidin, 22200 Besut Terengganu, Malaysia

Abstract
Soil-based cultivation is presently confronting dire challenges to the lack of land availability, massive escalation rate of industrialization and intense urbanization. Land-related agriculture is at stake due to irrepressible climate vicissitudes, relentless soil degradation, unbefitting management practices and other adversative effects. The settings are further exacerbated by the increment in population with respect to diminutive land availability to cultivate. Hence, soilless media culture would make ways as an auspicious auxiliary in current pressing scenario. Proper management practices and technological advancements can utterly exploit the soilless substrates effectively and efficiently. Optimization of yield pertaining to incorporation of soilless media can also result in superior quality and growth performance in relevance to less agricultural inputs being consumed.

Key words: Soilless culture, burnt rice husk, peat moss, coir dust, perlite, vermiculite

Received: October 04, 2017 Accepted: December 01, 2017 Published: December 15, 2017

Citation: Amjad Farhan Ashraf Farhan, Abd. Jamil Zakaria, Prof Nashriyah Mat and Khamsah Suryati Mohd, 2018. Soilless media culture-a propitious auxiliary for crop production. Asian J. Crop Sci., 10: 1-9.

Corresponding Author: Amjad Farhan Ashraf Farhan, Faculty of Agriculture Production and Food Innovation Research Institute (AGROPOLIS), Universiti Sultan Zainal Abidin, 22200 Besut Terengganu, Malaysia

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Soil formation was influenced from different kinds of parent materials, time, biotic factors, topography and climate in which soil would be made up of approximately 40-50% of minerals, 0-10% of organic matter content, flora and fauna, macroscopic and microscopic organism as well as around 50% of pore space mainly from air and water[1]. Inside the soil, there are massive colonies of phylogenetic groups of bacteria in a universally scattered manner and somehow ample in existence[2]. It was comprised of organic matter content, mineral matter, some pore space, water, air, life forms as well as vast presence of micro-organism and macro-organism[3]. Soil is also the typically most profound growing media being conventionally exploited as planting medium for plants[4]. Horizons in soil are also presented to segregate the minerals and organic constituents as well as the disparate parent materials in morphology, depth, physical, chemical and biological characteristics[5]. Other than that, animals and plants are directly or indirectly highly dependent on soil for nutrients and support[6]. Taxonomically, soil is also renowned to be assortment of natural bodies of the earth's superficial, whether amended by man or earthly materials, encompassing living matter and supporting plant progression[7]. The dynamic relationship it possesses would make it central for plant to thrive amicably within its surrounding environment. Healthy soil with sufficient organic matter content, humic acids, humin and fulvic acids can prearrange decent condition to sustain growing plants with advanced yield and superior growth[8]. It was also made up of around 40-80% of sand, silt and clay which the diverse presence of these components with different extents could result in dissimilar characteristics and textures[9]. The settings are further exacerbated by the increment in population with respect to diminutive land availability to cultivate. Hence the objective of study was that soilless media culture would make ways as an auspicious auxiliary.

Soil degradation and compaction: Intensive and unrestrained exploitation of soil had been a foremost problem to the proliferation of plants and its environment[10]. Disturbed lands had been found to inhibit soil microbial functional diversity such as lower metabolic diversity and carbon-mineralization in comparison to undisturbed lands[11]. Naturally, soils are resilient yet it can be inclined to relentless deterioration through soil formation and unfitting cultural practices[12]. Degradation of soil can lead to mechanical resistance via its soil matrix to the root in which it can obstruct its progress especially when the root pressure was overwhelmed in a way that it could lead to a decline in root length and root elongation rate[13]. Other than that, the occurrence of compaction can breed undesirable outcomes such as reduced crop yields, deprived state of plant growth, constrained plant root growth and lesser nutrient uptake[14,15]. This is why careful forecasting and administration of soil were obligatory in order to avert the possibility of reduced yield and productivity mainly instigated through soil compaction[16]. Physical properties of soil could also be altered by means of compaction in which it would consequence to the change of soil porosity, soil textures and water holding capacity[17-20].

Prominent challenges and confrontational effects in soil management had arisen due to modernization of civilization, which direct to diminishing scale of land availability for cultivation, apart from rapid industrialization and colossal urbanization projects worldwide[4]. The effects are going to get worse as soil was also prone to degeneration in its quality particularly under climatic circumstances and irrepressible manner of conventional farming in which it could further interrupt plant growth performance[21-23]. Although, it was assumed to be a rather intricate interaction, there was actually a threshold of soil bulk density in which it could resist root penetration to the point that it could be utterly immobilized[24]. Penetration resistance given by the soil would surely impact root zone and water movement mainly during primary growth[25]. There are few primary soil physical properties that could affect the blossoming of plants which would include heat capacity, soil strength, water holding capacity, soil texture, hydraulic conductivity and soil structure[26]. This can be further seen through its texture that could somehow define the bulkiness, pore size and mechanical resistance that the soil could offer[27]. The mechanical resistance from the soil was also found out to be highly interrelated to the root elongation and crop yield[28]. The hydrostatic pressure (turgor) of the seedlings must also be ensured to be appropriate in order to overwhelm internal restraints imposed by the surrounding media[29]. Several studies had also indicated detrimental outcomes due to soil compaction pertaining to the growth of plants[30-32]. Unhealthy and unreserved practices of utilizing available land may lead to infertile and less productive land such as highly degraded soil and BRIS soil. These soils have high temperature and dry condition contributed to its excessively low water holding capacity and low organic matter content which would make it suitable only to few crops and has higher overall costs for cultivation[33,34]. Hence, the application of soilless media culture in crop cultivation would greatly benefit the farmers and consumers alike as well as providing an alternative to the usage of problematic soils and its additional cost of inputs.

Soilless media: Soilless media can be in the form of substrates originated from peat moss, bark, coir, compost, rice hulls, vermiculite and perlite[35]. This soilless culture is a mainstream practice in developing countries as normal ground soils are typically discontented in usage for crop production[12]. Hence, the rudimentary characteristics of good soilless media would be easy to acquire, economical, abundant in nature, light weight, possess upright chemical properties and has a satisfactory water retention capabilities[36]. The quality of the growing media must also be greatly maintained to ensure good growth of seedlings[37]. This was because sustainable production of ornamental flower and other crops would need to compensate decent growing media with sufficient water holding capacity and aeration[38,39]. The most common incorporated soilless media are coir-dust based substrates and sphagnum peat in which it is among the most preferred and commercialized primary media[40]. This was because it is occasionally acknowledged as substrates or growth media with the most prominent crop production mechanisms for containerized or raised beds with restricted volumes and was appropriate for continuous supply of nutrients through fertilization[41-43]. Plants cultivated in soilless culture naturally tend to have smaller root-system volume than those in soil culture yet the root density of soilless grown plants was more complex[44]. This technique of cultivation has also no need to adhere itself to traditional technique of using soil in crop production which may cut some of the input costs[45]. Current trends of growing seedlings, plant proliferation and production of ornamental plants are also immensely dependent on soilless substrates especially in containerized planting as it would ensure overall good plant proliferation and growth performance[46-48].

Coir dust: Coir dust also acknowledged as cocopeat, is customarily extracted from coconut husk in the form of fiber as an agricultural by-product[49]. This coir dust was usually made into potting mix, yet careful attention was required to ensure the porosity of media was not compromised due to deprived state of aeration as well as lower metabolic energy required for seed germination[12,50]. This is because the interrelation in between air and water within the context of media porosity was very precarious to plant growth[51,52]. On the other hand, optimum water retention is compulsory as water discrepancy would momentously inflicts substantial reductions in crop yield as it was greatly inclined to the abridged leaf carbon fixation and general growth inhibition[53].

Coconut coir dust has also adequate physical and chemical properties, making it an apt soilless media for growing plants[54]. Coir products usually obligate to extraordinary K contents yet low in calcium, hence it necessitates incorporation of calcium in order to improve the media[55]. It was also further elaborated that coir-based products has pH value of approximately six, making liming practices a bit improper due to the probabilities of pH exceeding optimum level yet gypsum might be a salvation to both lack of calcium and sulfur. It was also stated that this byproduct of coconut industry would also embrace prodigious significance as an alternative to peat moss pertaining to soilless media application[56]. However, coconut coir is also known to express complications regarding its high salinity yet its mixtures are noteworthy as an environment friendly substitute for peat substances in containerized planting[57,58].

Diverse coir dust origins would also obligate significantly unalike physical and chemical properties[59]. However, this growing media was promising as a replacement for the diminishing scale of sphagnum peat[60]. Both coir and peat based substrate would have different water retention especially if it was mingled with other media yet coir dust is acknowledged as a prominent growing media with relation to decent pH, electrical conductivity and other chemical characteristics making it being incorporated widely in crop cultivation[48,61-63]. Its good characteristics would somehow contribute to a greater employment of cocopeat especially in growing crops with satisfactory value in the tropics[64,65].

Burnt rice husk: Biochar has a remarkable potential to act as a substitute for the incorporation of manure and compost as it could preserve the carbon's stability inside the soil[66]. It had also been found that there was a microbial immobilization in biochar which may contribute in retaining nitrogen inside soil from being leached[67]. This may be due to the higher availability of carbon that had led to the stimulation of microbial activity which resulted in greater nitrogen demand, higher immobilization rate and the recycling of NO_3. The example can be seen from the incorporated charcoal which was done by the natives in Amazonia which had facilitated to the formation of a rich dark soil called Terra Preta or Dark Earth[68]. In several researches, it was found that nitrogen content inside the charcoal was determined at 0.67 and 1.09%, respectively[69]. The persistency of the charcoal had also contributed to the stability of the Terra Preta in which the land can still be intensively cultivated until now due to its high fertility. The application of fly ash and rice husk ash had also elevated the soil properties via plummeting the soil bulk density, enriched organic carbon content, nutrients, soil pH as well as rice yield[70].

Additionally, it was found that the cation exchange capacity (CEC) can be further improved by 50% by the incorporation of charcoal[71]. Other than that, it had also been demonstrated that rice husk and rice husk ash had the capabilities in eradicating heavy metals[72]. Biochar incorporation as soil amendment is utterly favorable in diminishing the bulk density, soil strength, exchangeable Al and soluble Fe, escalating the soil water content, porosity, soil pH, cation exchange capacity (CEC) as well as exchangeable K and Ca[73]. Rice husks were considered as one of the agricultural waste products in which its existence was somehow abundant in the tropical countries comprising of Indonesia, Thailand and Malaysia[74]. In fact, the existence of Terra Preta had proven that even the unfertile soil could also be converted into fertile soil with the aid of the charcoal[75]. Hence, it is wise to fully utilize the abundance availability of rice husk charcoal as it is also a by-product that exists in enormous extents that could lead to environmental pollution[76].

Peat moss: In recent decades, peat substrates had accomplished itself as the foremost components with well-known characteristics of retaining water in greater capacity than most of other soilless potting media[77,78]. This naturally existing and organic soil conditioner can also regulate air and moisture for area neighboring the plant roots, making it a superlative and prized constituents for both horticulture and floriculture industry[79]. Soil amendments and top dressing from peat was also a common practice in gardens and nurseries, particularly contributed by its characteristics to embrace water like a sponge and deliberately emancipating it to the environment when the adjoining soil dries[80].

Sphagnum peat moss had remained a typical growing media for many years, hence there was some expressed distress on this non-renewable resource[56,81]. Peat moss is the most mainstream constituent in nursery and greenhouse mixes for containerized planting media whereby it was usually incorporated to amplify water retention and plummeting the media total weight[82,83]. In the environments, materialization and buildup of carbon-rich peat deposits can be perceived up to ten meters thick due to its net primary production that exceeded decomposition[84]. Upright characteristics of peat moss such as low bulk density, structural stability, low pH, little nutrient and nitrogen immobilization as well as structural stability had given it special attention as apposite horticultural growing medium[85]. However, care should be taken in its over-utilization as peat mosses are very indispensable to the ecosystems where they usually thrive particularly at wetlands.

Sand: Sand is one of the mainstream soilless media incorporated in agriculture despite its infertility and incompatibility for cultivation[86]. It was usually mixed with different kinds of soil and media to a befitting ratio whereby it could offer decent quality of growing media without the need to compromise drainage as well as water and nutrient retention capabilities[87]. Gas diffusion, water retention and air within pore space are reliant on particle size and pores of the media[52,88]. The colonization of *G. intraradices* and infectious propagules was also found to be 40-50% higher in sand than those plants grown in other media[89]. Other than that, majority of standard mixed medium would feature fine sand or concrete sand with sphagnum peat or coconut coir to uplift its properties[90]. Sand is also particularly convenient for plants that necessitate growing media with loose soil and dry environment due to its competencies in not retaining much moisture as well as alleviating the porosity of planting medium[4,91]. It was usually emanates in the form of silica which is the heaviest material for growth media, inert, incompressible and assuring less exchange capacity and water retention[92]. It was also found that sandy soil also had the greatest pH and lowest exchangeable acidity and Al among other type of soils[93].

Perlite: Perlite is typically combined with other soilless media in order to attain promising results in crop germination[94]. This gleaming-like volcanic rock will expand itself under rapid controlled heating in which it would retain its lightweight aggregation, low bulk density, chemically inert in many environment, exceptional as filter aids and fillers for numerous as well as expansive in its used mainly in plant cultivation[95,96]. In terms of input costs, perlite is also cheaper than the rockwool and has been incorporated around the world for agricultural productions[97]. The comparisons in between rockwool and perlite pertaining to the cultivation of soilless melon (*Cucumismelo reticulatus*) had also been found to be indifferent[98]. Other than that, perlite is widely known originated from mined mineral that was crushed and then expanded under high temperature[99]. It was also able to simulate decent properties similar to rockwool especially in tomato (*Lypersicon esculentum*) cultivation[100].

Additionally, this siliceous material has closed-cell structure so that water would only adhere to its surface, without absorbing it making perlite well drained and lightweight[101]. It also encompasses decent porosity due to its foam-like cellular structure, good thermal capabilities, low density and quite cheap in its production cost[102]. This soilless media had also demonstrated itself to be superior to polystyrene bead as an additive in growing media due to its elevated moisture retention capabilities[103,6]. The presence of water in perlite will be released gradually at relatively low tension, which would make it to possess good drainage and aeration at the rhizosphere[104]. The incorporation of perlite is rather a mainstream practice in nursery propagation and greenhouse growing media[83]. It was also established that the practice of coarse-grade perlite and pine bark in the production of beit alpha cucumber had shown to lead to a greater degree of leachate in comparison to the medium-grade perlite[105].

Vermiculite: Vermiculite is preferable due to its low moisture retention yet it could still uphold greater amount of water than perlite which can lead to the optimization of plant germination[106]. It was found that vermiculite had slightly better effective cation exchange capacity (ECEC) and exchangeable calcium than peat[107]. Vermiculite is typically neutral in pH, possess decent water holding capacity as well as containing little amounts of magnesium and potassium[101]. This soilless media was also known to be porous due to its foam-like cellular structure, with decent characteristics such as upright thermal stability, low moisture retention, low density and relatively cheap in cost[102]. The heating process had contributed to its sterilization, nimble in weight, decent buffering capacities, good water retention as well as having relatively good cation exchange capacity[108]. Vermiculite is quite related to perlite from the point that both originate as mined minerals that were heated to a finished product, yet perlite was incorporated to increase drainage whereas vermiculite was used to retain water and positive-charged nutrients such as potassium, calcium and magnesium[83].

CONCLUSION

Crop production by means of soilless culture is promptly successfully in both momentum and acceptance in agricultural sectors. The amassed popularity and positive trends across the globe can be especially grasped in commercial crop productions contributed from the dearth of arable land and population increment. Demand on horticultural products is certainly on a rise and the technology of exploiting soilless substrate and its management practices is currently being refined to its fullest extent. Conversely, the bottleneck to proper practice and culture is being thwarted by the lack of knowledge and awareness of public pertaining to soilless crop production. Access to state-of-the-art technology and precision farming is still rather reserved for developing countries and the startup expenditure would somehow be enormous and extravagant. Hence, appropriate employment of soilless media in agriculture is mandatory specifically to its availability, suitability and expenditure in order to make it efficacious and feasible.

SIGNIFICANCE STATEMENT

This study addressed the issues of current diminishing trends of available soil fits for cultivation. Thus, this study will aid in determining the benefits and suitability of soilless media culture as an alternative to soil-based cultivation.

REFERENCES

1. CASFS., 2016. Soils and soil physical properties. Center of Agroecology and Sustainable Food System, USA.
2. Davis, K.E., S.J. Joseph and P.H. Janssen, 2005. Effects of growth medium, inoculum size and incubation time on culturability and isolation of soil bacteria. Applied Environ. Microbiol., 71: 826-834.
3. FAO., 2006. Plant nutrition for food security: Soil fertility and crop production. Food and Agriculture Organization of the United Nations, Rome, Italy.
4. Hussain, A., K. Iqbal, S. Aziem, P. Mahato and A.K. Negi, 2014. A review on the science of growing crops without soil (soilless culture): A novel alternative for growing crops. Int. J. Agric. Crop Sci., 7: 833-842.
5. Jenny, H., 1994. Factors of Soil Formation: A System of Quantitative Pedology. Dover Publications, New York.
6. McDaniel, P.A., A.L. Falen and M.A. Fosberg, 2012. Soils and Environment: A Land and Homestic Evaluation Handbook and Training Guide. University of Idaho, CALS Publications, USA.
7. NRCS., 2006. Soils-fundamental concept. Natural Resources Conservation Service, USA.
8. Pettit, R.E., 2004. Organic matter, humus, humate, humic acid, fulvic acid and humin: Their importance in soil fertility and plant health. http://www.humates. com/pdf/ORGANICMATTERPettit.pdf
9. USGS., 2011. What's in my soil? United States Geological Survey, Science Education Handout, March 2011. https://education.usgs.gov/lessons/soil.pdf
10. Ayers, P.D., 1987. Moisture and density effects on soil shear strength parameters for coarse grained soils. Trans. ASABE, 31: 1282-1287.
11. Alia, A.H.N.A., S. Tosiah, Z.Z. Norziana, Z.A. Jamil and M.M. Radzali, 2013. Characterization of soil microbial functional diversity in Pulau Tekak Besar, Tasik Kenyir. J. Trop. Agric. Food Sci., 41: 95-108.
12. Baiyeri, K.P. and B.N. Mbah, 2006. Effects of soilless and soil-based nursery media on seedling emergence, growth and response to water stress of African breadfruit (*Treculia Africana* Decne). Afr. J. Biotechnol., 5: 1405-1410.

13. Bennie, A.T.P. and R. du T. Burger, 1988. Penetration resistance of fine sandy apedal soils as affected by relative bulk density, water content and texture. S. Afr. J. Plant Soil, 5: 5-10.
14. Bowen, H.D., 1981. Alleviating Mechanical Impedance. In: Modifying the Root Environment to Reduce Crop Stress, Arkin, G.F. and H.M. Taylor (Eds.), American Society for Agricultural Engineers (ASAE), St. Joseph, MI., pp: 21-57.
15. Carr, M.K.V. and S.M. Dodds, 1983. Some effects of soil compaction on root growth and water use of lettuce. Exp. Agric., 19: 117-130.
16. Daddow, R.L. and G.E. Warrington, 1983. Growth-limiting soil bulk densities as influenced by soil texture. Watershed Systems Development Group, USDA Forest Service, USA.
17. Froehlich, H.A., 1979. Soil compaction from logging equipment: Effects on growth of young ponderosa pine. J. Soil Water Conserv., 34: 276-278.
18. Glinski, J. and J. Lipiec, 1990. Soil Physical Conditions and Plant Roots. CRC Press, Boca Raton, Florida.
19. Hayashi, Y., K.I. Kosugi and T. Mizuyama, 2009. Soil water retention curves characterization of a natural forested hillslope using a scaling technique based on a lognormal pore-size distribution. Soil Sci. Soc. Am. J., 73: 55-64.
20. Henderson, C., A. Levett and D. Lisle, 1988. The effects of soil water content and bulk density on the compactibility and soil penetration resistance of some Western Australian sandy soils. Soil Res., 26: 391-400.
21. Iovieno, P., L. Morra, A. Leone, L. Pagano and A. Alfani, 2009. Effect of organic and mineral fertilizers on soil respiration and enzyme activities of two Mediterranean horticultural soils. Biol. Fertil. Soils, 45: 555-561.
22. Ishaq, M., M. Ibrahim, A. Hassan, M. Saeed and R. Lal, 2001. Subsoil compaction effects on crops in Punjab, Pakistan: II. Root growth and nutrient uptake of wheat and sorghum. Soil Tillage Res., 60: 153-161.
23. Lull, H.W., 1959. Soil Compaction on Forest and Range Lands. Forest Service, U.S. Department of Agriculture, USA., Pages: 33.
24. Ocanell, D.J., 1975. The measurement of apparent specific gravity of soils and its relationship to mechanical composition and plant root growth. In: Soil physical condition and crop production. MAFF Technol. Bull., 29: 298-313.
25. Pabin, J., J. Lipiec, S. Włodek, A. Biskupski and A. Kaus, 1998. Critical soil bulk density and strength f or pea seedling root growth as related to other soil factors. Soil Tillage Res., 46: 203-208.
26. Van Quang, P., P.E. Jansson and L. van Khoa, 2012. Soil penetration resistance and its dependence on soil moisture and age of the raised-beds in the Mekong Delta, Vietnam. Int. J. Eng. Res. Dev., 4: 84-93.
27. Schuurman, J.J., 1965. Influence of soil density on root development and growth of oats. Plant Soil, 22: 352-374.
28. Stelluti, M., M. Maiorana and D. de Giorgio, 1998. Multivariate approach to evaluate the penetrometer resistance in different tillage systems. Soil Tillage Res., 46: 145-151.
29. Taylor, H.M., G.M. Roberson and J.J. Parker, 1966. Soil strength-root penetration relations for medium- to coarse-textured soil materials. Soil Sci., 102: 18-22.
30. Veihmeyer, F.J. and A.H. Hendrickson, 1948. Soil density and root penetration. Soil Sci., 65: 487-494.
31. Wert, S. and B.R. Thomas, 1981. Effects of skid roads on diameter, height and volume growth in Douglas-fir. Soil Sci. Soc. Am. J., 45: 629-632.
32. Wilshire, H.G., J.K. Nakata, S. Shipley and K. Prestegaard, 1978. Impacts of vehicles on natural terrain at seven sites in the San Francisco Bay area. Environ. Geol., 2: 295-319.
33. Mustapha, Z., N. Mat, R. Othman and A.J. Zakaria, 2017. Growth of BRIS soil bacteria in organic material and potassium nitrate. Proceedings of the 5th International Conference on Chemical, Agricultural, Biological and Environmental Sciences, April 18-19, 2017, Kyoto, Japan, pp: 6-11.
34. Mustapha, Z., N. Mat, R. Othman and A.J. Zakaria, 2017. Quantification of BRIS soil bacteria at tembila, besut terengganu. AGRIVITA J. Agric. Sci., 39: 252-256.
35. Aquatrols, 2009. Understanding media surfactants for use in soilless media. http://s3.amazonaws. com/aquatrols/2009121 4131635.pdf
36. Chang, C.P. and S.M. Lin, 2007. The formation and growing properties of poly (Ethylene terephthalate) fiber growing media after thermo-oxidative treatment. Mater. Sci. Eng.: A, 457: 127-131.
37. Corti, C., L. Crippa, P.L. Genevini and M. Centemero, 1998. Compost use in plant nurseries: Hydrological and physicochemical characteristics. Compost Sci. Util., 6: 35-45.
38. Dresboll, D.B., 2010. Effect of growing media composition, compaction and periods of anoxia on the quality and keeping quality of potted roses (*Rosa* sp.). Scient. Horticult., 126: 56-63.
39. Erstad, J.L. and H.R. Gislerod, 1994. Water uptake of cuttings and stem pieces as affected by different anaerobic conditions in the rooting medium. Scient. Horticult., 58: 151-160.
40. Evans, M.R. and J.K. Iles, 1997. Growth of *Viburnum dentatum* and *Syringa*×*prestoniae* 'Donald Wyman' in *Sphagnum* peat and coir dust-based substrates. J. Environ. Horticult., 15: 156-159.
41. Ingram, D.L., 2014. Understanding soilless media test results and their implications on nursery and greenhouse crop management: Report No. HO-112. Agriculture and Natural Resources, UK.
42. Macz, O., E.T. Paparozzi and W.W. Stroup, 2001. Effect of nitrogen and sulfur applications on pot chrysanthemum production and postharvest performance. I. Leaf nitrogen and sulfur concentrations. J. Plant Nutr., 24: 111-129.

43. Mohd Aziz, R., Z. AbdJamil, S.A.H. Armizatul, I.M. Noh, H. Hafiz and A.R. Norahshekin, 2011. Effects of root zone cooling using water chilling system on plant physiological responses and fruit yield of tomato var. Baccarat under greenhouse condition. Proc. Trans. Malaysian Soc. Plant Physiol., Vol. 19.
44. Raviv, M. and H. Lieth, 2008. Soilless Sulture: Theory and Practice. Elsevier Science, USA.
45. Sabahy, A., A. Bahnasawy, S. Ali and Z. El-Haddad, 2014. Physical and chemical properties of some soilless media. https://pdfs.semanticscholar.org/ea15/d9776c35ef8e1da809e9320dfeac4949427c.pdf
46. Sahin, U., O. Anapali and S. Ercisli, 2002. Physico-chemical and physical properties of some substrates used in horticulture. Die Gartenbauwissenschaft, 67: 55-60.
47. Sahin, U., S. Ors, S. Ercisli, O. Anapali and A. Esitken, 2005. Effect of pumice amendment on physical soil properties and strawberry plant growth. J. Central Eur. Agric., 6: 361-366.
48. Wilson, S.B., P.J. Stoffella and D.A. Graetz, 2001. Use of compost as a media amendment for containerized production of two subtropical perennials. J. Environ. Hortic., 19: 37-42.
49. Abad, M., P. Noguera, R. Puchades, A. Maquieira and V. Noguera, 2002. Physico-chemical and chemical properties of some coconut coir dusts for use as a peat substitute for containerised ornamental plants. Bioresour. Technol., 82: 241-245.
50. Henry, D., 1982. Palm seed germination study. Proc. Florida State Hortic. Soc., 95: 256-257.
51. Bruckner, U., 1997. Physical properties of different potting media and substrate mixtures-especially air-and water capacity. Acta Hort., 450: 263-270.
52. Caron, J. and V.N. Nkongolo, 1999. Aeration in growing media: Recent developments. Acta Hort., 481: 545-552.
53. Chaves, M.M. and M.M. Oliveira, 2004. Mechanisms underlying plant resilience to water deficits: Prospects for water-saving agriculture. J. Exp. Bot., 55: 2365-2384.
54. Evans, M.R., S. Konduru and R.H. Stamps, 1996. Source variation in physical and chemical properties of coconut coir dust. HortScience, 31: 965-967.
55. Handreck, K. and N. Black, 2002. Growing Media for Ornamental Plants and Turf. University of New South Wales Press, Sydney, Australia.
56. Holman, J., B. Bugbee and J. Chard, 2005. A comparison of coconut coir and sphagnum peat as soil-less media components for plant growth: Report. Hydroponics/Soilless Media, USA.
57. Ma, Y.B. and D.G. Nichols, 2004. Phytotoxicity and detoxification of fresh coir dust and coconut shell. Commun. Soil Sci. Plant Anal., 35: 205-218.
58. Meerow, A.W., 1994. Growth of two subtropical ornamentals using coir (coconut mesocarp pith) as a peat substitute. Hortic. Sci., 29: 1484-1486.
59. Radjagukguk, B. and O. Soeseno, 1984. A comparative study of peats and other media for containerized forest tree seedlings. Acta Hortic., 150: 449-458.
60. Shanmugasundaram, R., T. Jeyalakshmi, S.S. Mohan, M. Saravanan, A. Goparaju and B. Murthy, 2014. Coco peat-An alternative artificial soil ingredient for the earthworm toxicity testing. J. Toxicol. Environ. Health Sci., 6: 5-12.
61. Wira, A.B., Z. Abd Jamil and S.A.H. Armizatul, 2011. Effect of K-fertigation levels on tomato sap and plant performance. Trans. Malay. Soc. Plant Physiol., 19: 21-24.
62. Wira, A.B., I.M. Razi and Z.A. Jamil, 2011. Composts as additives in coconut coir dust culture for growing rockmelon (*Cucumis melo* L.). J. Trop. Agric. Food Sci., 39: 229-237.
63. Awang, Y., A.S. Shaharom, R.B. Mohamad and A. Selamat, 2009. Chemical and physical characteristics of cocopeat-based media mixtures and their effects on the growth and development of *Celosia cristata*. Am. J. Agric. Biol. Sci., 4: 63-71.
64. Yahya, A., H. Safie and S. Kahar, 1997. Properties of cocopeat-based growing media and their effects on two annual ornamentals. J. Trop. Agric. Food Sci., 25: 151-157.
65. Yahya, A., H. Safie and M.S. Mokhlas, 1999. Growth and flowering responses of potted chrysanthemums in a coir dust-based medium to different rates of controlled-release fertilizer. J. Trop. Agric. Food Sci., 27: 39-46.
66. Baldock, J.A. and R.J. Smernik, 2002. Chemical composition and bioavailability of thermally altered *Pinus resinosa* (Red pine) wood. Org. Geochem., 33: 1093-1109.
67. Bengtsson, G., P. Bengtson and K.F. Mansson, 2003. Gross nitrogen mineralization-, immobilization- and nitrification rates as a function of soil C/N ratio and microbial activity. Soil Biol. Biochem., 35: 143-154.
68. Denevan, W.M., 1996. A bluff model of riverine settlement in prehistoric Amazonia. Ann. Assoc. Am. Geogr., 86: 654-681.
69. Eckmeier, E., M. Rosch, O. Ehrmann, M.W. Schmidt, W. Schier and R. Gerlach, 2007. Conversion of biomass to charcoal and the carbon mass balance from a slash-and-burn experiment in a temperate deciduous forest. Holocene, 17: 539-542.
70. Karmakar, S., B.N. Mitra and B.C. Gosh, 2009. Influence of industrial solid waste on soil-plant interaction in rice under acid Lateritic soils. Proceedings of the World of Coal Ash (WOCA) Conference, May 4-7, 2009, Lexington, USA., pp: 1-13.
71. Lehmann, J., J.P. da Silva, Jr., C. Steiner, T. Nehls, W. Zech and B. Glaser, 2003. Nutrient availability and leaching in an archaeological anthrosol and a ferralsol of the central amazon basin: Fertilizer, manure and charcoal amendments. Plant Soil, 249: 343-357.
72. Mahvi, A.H., N. Alavi and A. Maleki, 2005. Application of rice husk and its ash in cadmium removal from aqueous solution. Pak. J. Biol. Sci., 8: 721-725.

73. Masulili, A., W.H. Utomo and M.S. Syechfani, 2010. Rice husk biochar for rice based cropping system in acid soil 1. The characteristics of rice husk biochar and its influence on the properties of acid sulfate soils and rice growth in West Kalimantan, Indonesia. J. Agric. Sci., 2: 39-47.
74. Muntohar, A.S., 2004. Utilization of uncontrolled burnt rice husk ash in soil improvement. Civil Eng. Dimension, 4: 100-105.
75. Steiner, C., W.G. Teixeira, J. Lehmann, T. Nehls, J.L.V. de Macedo, W.E.H. Blum and W. Zech, 2007. Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil. Plant Soil, 291: 275-290.
76. Theeba, M., R.T. Bachmann, Z.I. Illani, M. Zulkefli, M.H.A. Husni and A.W. Samsuri, 2012. Characterization of local mill rice husk charcoal and its effect on compost properties. Malay. J. Soil Sci., 16: 89-102.
77. Alexander, P.D., N.C. Bragg, R. Meade, G. Padelopoulos and O. Watts, 2008. Peat in horticulture and conservation: The UK response to a changing world. Mires Peat, 3: 1-10.
78. Boelter, D.H., 1968. Important physical properties of peat materials. U.S. Department of Agriculture, USA. https://www.nrs.fs.fed.us/pubs/jrnl/1968/nc_1 968_boelter _001.pdf
79. CSPMA., 2015. Industrial social responsibility report. Canadian Sphagnum Peat Moss Association, Canada.
80. Chalker-Scott, L., 2015. The myth of permanent peatlands. Washington State University, Washington, USA.
81. Whyman, S., K. Slade and K. Childerhouse, 2009. Catalogue of sphagnum peat mosses in amgueddfa cymru-national museum wales. https://museum.wales/media/14447/Sp hagnum-Catalogue-Analysis.pdf
82. Joosten, J.H.J., 1995. The golden flow: The changing world of international peat trade. Regional variation and conservation of mire ecosystems. Gunneria, 70: 269-292.
83. Robbins, J.A. and M.R. Evans, 1914. Greenhouse and nursery series: Growing media for container production in a greenhouse or nursery. Part I-components and mixes. Agriculture and Natural Resources. https://www.uaex. edu/publications/PDF/FSA-6097.pdf
84. Rydin, H. and J. Jeglum, 2006. The Biology of Peatlands. Oxford University Press, England .
85. Schmilewski, G., 2008. The role of peat in assuring the quality of growing media. Mires Peat, 3: 1-8.
86. Ang, L.H., 1994. Problems and prospects of afforestation on sandy tin tailings in Peninsular Malaysia. J. Trop. For. Sci., 1: 87-105.
87. Barker, D.G., T. Pfaff, D. Moreau, E. Groves and S. Ruffel *et al*., 2006. Growing *M. truncatula*: Choice of Substrates and Growth Conditions. In: The *Medicago trunca*-Tula Handbook. Mathesius, U., E.P. Journet and L.W. Sumner (Eds.)., Samuel Roberts Noble Foundation, Ardmore, OK.
88. Caron, J.A., L.M.B. Rivie`re and G.B. Guillemain, 2005. Gas diffusion and air-filled porosity: Effect of some oversize fragments in growing media. Can. J. Soil Sci., 85: 57-65.
89. Gaur, A. and A. Adholeya, 2000. Effects of the particle size of soil-less substrates upon AM fungus inoculum production. Mycorrhiza, 10: 43-48.
90. Havis, J.R. and W.W. Hamilton, 1981. Physical properties of container media. Ornamentals Northwest Arch., 5: 7-8.
91. Indriyani, N.L.P., S. Hadiati and A. Soemargono, 2011. The effect of planting medium on the growth of Pineapple seedling. J. Agric. Biol. Sci., 6: 43-48.
92. Spomer, L.A., W.L. Berry and T.W. Tibbitts, 1997. Plant Culture in Solid Media. In: Plant Growth Chamber Handbook, Langhans, R.W. and T.W. Tibbitts (Eds.)., Chapter 7. Iowa State University, Ames, IA., pp: 105-118.
93. Zhao, Y.G., G.L. Zhang, Z. Wen-Jun and Z.T. Gong, 2005. Soil characteristics and crop suitability of sandy soils in Hainan, China. Proceedings of the Management of Tropical Sandy Soils for Sustainable Agriculture: A Holistic Approach for Sustainable Development of Problem Soils in the Tropics, November 27-December 2, 2005, Khon Kaen, Thailand, pp: 49-53.
94. Atiyeh, R.M., C.A. Edwards, S. Subler and J.D. Metzger, 2000. Earthworm-processed organic wastes as components of horticultural potting media for growing marigold and vegetable seedlings. Compost Sci. Utilization, 8: 215-223.
95. Chesterman, C.W., 1975. Industrial Rocks and Minerals. 4th Edn., Port City Press, USA.
96. Ercisli, S., U. Sahin, A. Esitken and O. Anapali, 2005. Effects of some growing media on the growth of strawberry cvs. 'Camarosa' and 'Fern'. Acta Agrobot., 58: 185-181.
97. Grillas, S., M. Lucas, E. Bardopoulou, S. Sarafopoulos and M. Voulgari, 2001. Perlite based soilless culture systems: Current commercial applications and prospects. Acta Hortic., 548: 105-114.
98. Guler, H.G., C. Olympios and D. Gerasopoulos, 1995. The effect of the substrate on the fruit quality of hydroponically grown melons (*Cucumis melo*, L). Acta Hortic., 379: 261-266.
99. Hochmuth, G.J. and R.C. Hochmuth, 2016. Keys to successful tomato and cucumber production in perlite media. University of Florida, Institute of Food and Agricultural Science, USA.

100. Jensen, M.H., 2002. Controlled environment agriculture in deserts, tropics and temperate regions: A world review. Acta Hortic., 578: 19-25.
101. Landis, T.D., D.F. Jacobs, K.M. Wilkinson and T. Luna, 2014. Growing Media. In: Tropical Nursery Manual: A Guide to Starting and Operating a Nursery for Native and Traditional Plants, Wilkinson, K.M., T.D. Landis, D.L. Haase, B.F. Daley and R.K Dumroese (Eds.)., U.S. Department of Agriculture, Forest Service, USA.
102. Li, R.G., J.Q. Zhu, W.B. Zhou, X.M. Cheng and Y.Y. Li, 2015. The Adsorption Performance of Sodium Nitrate for Vermiculite, Perlite and Ceramsite. In: Material Science and Environmental Engineering: Proceedings of the 3rd Annual 2015 International Conference on Material Science and Environmental Engineering (ICMSEE2015, Wuhan, Hubei, China, 5-6 June 2015), Chen, P. (Ed.)., CRC Press, China, pp: 159-162.
103. Matkin, O.A., 2005. Comparative growth studies Perlite vs. Polystyrene media. The Perlite Institute Incorporation, California, USA.
104. Ors, S. and O. Anapali, 2010. Effect of soil addition on physical properties of perlite based media and strawberry cv. Camarosa plant growth. Scient. Res. Essays, 5: 3430-3433.
105. Shaw, N.L., D.J. Cantliffe, J. Funes and C. Shine III, 2004. Successful beit alpha cucumber production in the greenhouse using pine bark as an alternative soilless media. HortTechnology, 14: 289-294.
106. Arenas, M., C.S. Vavrina, J.A. Cornell, E.A. Hanlon and G.J. Hochmuth, 2002. Coir as an alternative to peat in media for tomato transplant production. HortScience, 37: 309-312.
107. Headlee, W.L., C.E. Brewer and R.B. Hall, 2014. Biochar as a substitute for vermiculite in potting mix for hybrid poplar. Bioenergy Res., 7: 120-131.
108. Resh, H.M., 2012. Hydroponic Food Production: A Definitive Guidebook for the Advanced Home Gardener and the Commercial Hydroponic Grower. 7th Edn., CRC Press, USA., ISBN: 9781439878675, Pages: 560.