Vol. 14(1), pp. 10-15, January-March 2022
DOI: 10.5897/JHF2021.0684
Article Number: 578504D68920
ISSN: 2006-9782

http://www.academicjournals.org/JHF

ACADEMIC JOURNALS
expand your knowledge

Journal of Horticulture and Forestry

Full Length Research Paper

Suitability of sand amended with carbonized rice husks and goat manure as a growing medium

Nkurunziza Ephrem[1*], Samuel Nyalala[1] and Umuhoza Karemera Noëlla Josiane[2]

[1]Department of Crops, Horticulture and Soils, Egerton University, P. O. Box 536-20115, Egerton, Kenya.
[2]Department of Crop Sciences, University of Rwanda/College of Agriculture, Animal Sciences and Veterinary Medicine, Rwanda.

Received 17 December, 2021; Accepted 24 February, 2022

A laboratory experiment was conducted at Rwanda Agriculture and Animal Resources Development Board (RAB). The study determined a suitable and alternative growing medium to peat moss as an unaffordable medium to Rwandan farmers and soil-based growing media which produce low quality transplants. Growing media were formulated from sand (S) amended with carbonized rice husks (CRH) and goat manure (GM) and peat moss (PM). Nine treatments were formed and applied in a completely randomized design (CRD) with four replications. The growing media were analysed for physical and chemical properties including bulk density (BD) and total porosity (Po), organic matter (OM), organic carbon (OC), total nitrogen (TN), phosphorous, potassium, pH and electrical conductivity (EC). Data obtained were subjected to analysis of variance and means were separated using HSD test at *p*≤ 0.05. The results revealed that there were significant differences among the formulated growing media but not in the pH. T_5, T_6, T_7, T_8 and T_9 resulted in good physical and chemical properties as growing media for crop production.

Key words: Sand, peat moss, goat manure, topsoil and carbonized rice husks.

INTRODUCTION

A growing medium is a substance through which plant roots grow, extract water and nutrients (Landis et al., 1990). Growing medium is made from mixtures of components which provide water, air, nutrients and support to plants (Robbins and Evans, 2011). The soil-based growing medium usually results in reduced productivity of the crop (Baiyeri and Mbah, 2006) since natural soils are associated with imbalance of microorganisms, water and air, nutrition, variability and weeds leading to seedling stress exposure (Landis et al., 1990). The soilless media (organic or inorganic) improve crop yields over soil-based because they increase and easily optimize rates of water, nutrient, and oxygen transport (Blok et al., 2017). The use of organic media is advantageous as they are naturally sourced, cost effective in comparison to inorganic substrates and provide additional nutrients to the crop (Raviv et al., 2002). However, they are biologically unstable as they degrade over time leading to compaction and reduced aeration for plant roots (Olle et al., 2012). Common organic substrates include compost, coconut coir, peat moss, bark, rice hulls or sawdust, which are locally available materials that are lightweight, have high water-holding capacity and CEC, and some contain limited

*Corresponding author. E-mail: nkurunzizaephrem@gmail.com. Tel. +250 785355631.

quantities of mineral nutrients (Landis et al., 1990). Peat moss is widely used due to its ideal physical and chemical characteristics (Asaduzzaman et al., 2015). However, it is an expensive material to small scale farmers especially in developing countries (Kuisma et al., 2014) and its use has severe environmental implications because it is a non-renewable resource (Maher et al., 2008). In addition, its extraction releases sequestered carbon, destroys natural habitats and degrades the quality of groundwater (Dunn and Freeman, 2011) while sand improves the bulky density and aeration of the growing medium (Raviv et al., 2002). Carbonized rice husks improve soil properties by enhancing soil water and nutrient retention, carbon sequestration, greenhouse gas emission reduction and boosting crop yield (Oladele et al., 2019). Goat manure on the other hand has essential elements required for plant growth including N, P, K, Ca and Mg (Mowa et al., 2018). The use of peat moss is limited because it is expensive and unavailable to most farmers in Rwanda as a developing country (Kuisma et al., 2014). Consequently, most Rwandan farmers use field soils as growing medium for producing transplants and result in poor quality because the natural soils are associated with soil-borne pests and diseases, water, air and nutrients imbalance (Baiyeri and Mbah, 2006). Therefore, the formulation of an alternative growing medium from a mixture of sand amended with carbonized rice husks and goat manure as locally available substrate should be a response of unaffordability of peat moss. The objective of this study was to determine the suitable and alternative growing media to peat moss and soil-based growing media for quality transplants production for Rwandan farmers. We hypothesized that the mixture goat manure and carbonized rice husks with sand substrates will result in growing medium with better levels of chemical and physical properties required for production of quality transplants.

MATERIALS AND METHODS

Study site

The study was conducted at Rwanda Agriculture and Animal Resources Development Board (RAB), Rubona Station/ Southern province in Analytical Laboratory for Soil, Plant and Water Analysis. The station is located in Rubona village, Kiruhura Cell, Rusatira Sector, Huye District of Southern province, on longitude of 029°46’475’’E, latitude of 02°29’327’’S and at an altitude of 1727 m above sea level. The average annual rainfall and temperature are 1039 mm and 19°C, respectively (Ndayambaje et al., 2013).

Preparation of carbonized rice husks

Carbonization of the rice husks was done outdoor with the following materials: a round holed (1 cm diameter) tin of 10L volume and holed (1cm diameter) metal chimney of 25 cm in diameter, dried eucalyptus firewood, shovel, natural water, and watering can, candle and match box. The firewood was filled in the tin and chimney was fixed to the top of the tin. Fire was set on the woods inside the tin, and the rice husks were piled around the tin until half of the chimney was covered. As the rice husks next to the tin were turning black, they were frequently turned over to prevent them from complete burning to ash until all were carbonized. After carbonization, water was immediately sprinkled over the entire pile using watering can to avoid continuous burning (Sarian, 2008). Thereafter, the CRH was broken up into small pieces by hands to increase the chance of water and nutrient-holding capacity.

Collection and preparation of peat moss, sand and goat manure

Peatmoss was purchased from Holland Greentech-Rwanda. Goat manure was prepared from goat droppings collected from loafing shed located around the Rwanda-Israel Horticulture Centre of Excellence (HC^{o}E). Thereafter, they were air-dried until a constant weight was reached and then ground using a mortar. Sand was collected from Rusine river and sieved with 2mm sieve to get medium to coarse sand. Thereafter, the obtained sand was washed to flush out any salt content and then air- dried to remove any water that remained. Topsoil was collected in a field located around the experimental site using diagonal sampling method to obtain a composite sample. Thereafter, the sample was air-dried for one week and then subjected to oven sterilization.

Formulation of the growing media

Carbonized rice husks, goat manure, topsoil, sand and peat moss were applied either alone or in combination at different ratios to formulate the growing media for the experiment. The following media were formulated: T_1; Peat moss as a positive control, T_2; Sand 100%, T_3; Top Soil + Goat Manure 70: 30%, T_4; Sand + Goat Manure + Carbonized Rice Husks 50: 50: 0%, T_5; Sand + Goat Manure + Carbonized Rice Husk 50: 40: 10%, T_6; sand + goat manure + Carbonized Rice Husk 50: 30: 20%, T_7; sand+ goat manure + Carbonized Rice Husk 50: 20: 30%, T_8; sand+ goat manure + Carbonized Rice Husk 50: 10: 40% and T_9; sand+ goat manure + Carbonized Rice 50: 0: 50%. All media were sterilized by drying them using an oven at 120^{o}C for 2days.

Characterization of the growing media

Physical characterization

Bulky density was determined by inserting into the medium a 5 cm diameter thin-sheet metal tube of a known weight (W1) and volume (V) of 5 cm^3. The medium was excavated around the tube and the medium beneath the tube bottom cut. Excess medium substrates from the tube ends were removed using a knife and then dried at 105^{o}C for 2 days and weighed to get W2. Bulk density was calculated using the formula (g/cm^3) = (W2 g - W1 g)/ V (cm^3) as described by Anderson and Ingram (1993). The total porosity was measured using the formula:

$$Po = 1 - (qb/qs) \quad (1)$$

where *q*b and *q*s are bulky density and particle density in percentage respectively (Baruah and Barthakur, 1998).

Chemical characterization

pH was measured on 2.5:1 soil water suspension while EC of the saturated paste extract was measured to determine the level of salinity as described by (Okalebo et al., 2002). Total nitrogen was calculated using the formula:

% N in soil sample = (A-B) × 0.1×v×100 / 1000 × W × al (2)

where A = volume of the titre HCl for the blank, B = volume of the titre HCl for the sample, V = final volume of the digestion, W = weight of the sample taken and al = aliquot of the solution taken for analysis (Okalebo et al., 2002).

Total phosphorus was determined using ascorbic acid as described by (Okalebo et al., 2002) with the following formula:

P in sample (%) = C ×V× f/ W (3)

where C = the corrected concentration of P in the sample, V = volume of the digest, f = dilution factor, W = weight of the sample. The potassium content of the growing medium was determined using the procedure of flame photometry as described by Okalebo et al. (2002).

Organic matter (OM) was calculated after ash content determination using the formula:

ash (%) = [(W3 - W1) / (W2 - W1)] x 100 and organic matter (%) = 100 - ash% (4)

where W1 = the weight of the empty, dry crucible containing growing medium, W2 = the weight of the dry crucible containing growing medium and W3 = the weight of the dry crucible containing growing medium following ignition. W3 - W1 = weight of the ash (Okalebo et al., 2002). The organic carbon (OC) was calculated using the formula; OC (%) = T × 0.2 × 0.3/sample weight (g) (5) where T is the titre (Okalebo et al., 2002).

Data analysis

To determine the effects of the substrate mixtures on physical and chemical properties of the formulated growing media, analysis of variance (ANOVA) was carried out; and the means for significantly different treatments were separated using Tukey's honestly significant difference test at $p \leq 0.05$. The data analysis was carried out using the Statistical Analysis System package, SAS software version 9.2 (SAS Institute, 2010). The statistical model fitted for this experiment was:

$$y_{ij} = \mu + T_i + \varepsilon_{ij}$$

where ***Yij***= overall observation, μ= overall mean, T_i = effect due to treatment, ε_{ij} = A random error associated with the response from the ***j***th sample of the ***i***th treatment, ***i***: 1, 2, 3, 4, 5, 6, 7, 8 and 9.

RESULTS

Physical characterization

The substrate mixtures used in this study significantly ($p \leq 0.05$) influenced the physical properties of the formulated growing media. Peat moss alone indicated the highest porosity of 90% followed by T_3, T_6 and T_7. However, its bulky density value of 0.09g/cm3 was the lowest followed by T_3, T_4, T_5, T_6, T_7, T_8 and T_9 which were not significantly different. Sand alone showed the highest bulky density of 1.53g/cm3 and the lowest value of porosity (42.42%) followed by T_6 (48.49%) and T_4 (56.28%). While treatments T_3, T_5 and T_7 were similar in the physical properties, Treatments T_8 and T_9 showed no significant difference in both bulky density and total porosity parameters (Figure 1).

Chemical characterization

Substrates used revealed significant differences in chemical properties of the growing media formulated from them. Peat moss had the lowest pH value of 5.8 while the values of the other treatments were not significantly different. The highest EC was observed in T_4 (4.78mS/cm) followed by T_3 (3.92mS/cm). Sand alone showed the lowest value of 0.33 mS/cm followed by T_9 (0.71mS/cm). Peatmoss showed the highest contents of N, P and K of 0.18%, 600Ppm and 7.18meq/100g while sand alone recorded the lowest content of these nutrients compared to other treatments. The highest values of organic matter and carbon were obtained in peat moss 100% with 89.70 and 52.03% respectively followed by T_4 and T_3. Sand alone medium also recorded the lowest OM and OC contents compared to the other formulated media (Figure 2).

DISCUSSION

The physical and chemical characterization of formulated growing media from different mixtures of substrates such as sand, carbonized rice husks and goat manure has never been investigated in Rwanda. The results obtained revealed that as goat manure increased in the medium as the medium had low bulky density and high porosity. These results agree with those of Mupondi et al. (2010) who reported that goat manure reduced bulky density and increased porosity of growing media. Supportively, Seguel et al. (2013) got reduced bulky density of soils when mixed with goat manure. In addition, Carbonized rice husks also reduced bulky density and improved porosity of the growing media which could be attributed to their low bulky density and high porosity as natural substrates (Varela et al., 2013). This is also supported by Jeon et al. (2010) who reported that CRH improved porosity of soils and Orge and Abon (2012) who indicated that incorporating them in the soils reduce bulky density of those soils. Peat moss (T1) has low bulky density and high porosity by nature (Aendekerk, 2000) while sand (T2) had high bulky density due to its heaviness (El-Hamed et al., 2011) and improves aeration of the media due to its porosity (Gungor and Yildirim, 2013). The significant differences in chemical properties of the formulated media could be attributed to differences in natural chemical composition of the substrates used. The results indicated that the ratios of 50 and 40% of GM in a

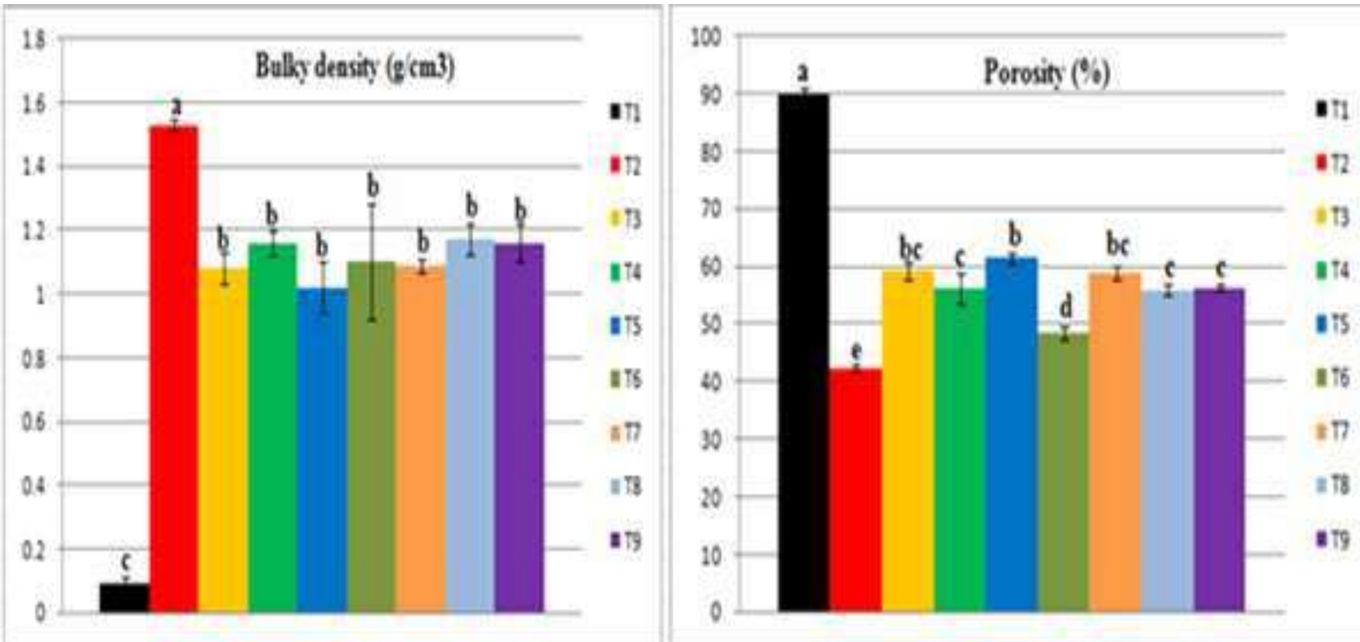

Figure 1. Physical properties of different formulated growing media. T_1: Peat moss 100%, T_2: Sand 100%, T_3: Top soil + Goat manure 70%: 30%, T_4: Sand + Goat manure 50%: 50%, T_5: Sand + Goat manure + Carbonized rice husk 50%: 40%: 10%, T_6: Sand+ Goat manure + Carbonized rice husk 50%: 30%: 20%, T_7: Sand+ Goat manure + Carbonized rice husk 50%: 20%: 30%, T_8: Sand+ Goat manure + Carbonized rice husk 50%: 10%: 40% and T_9: Sand + Goat manure + Carbonized rice husk 50%: 0%: 50%. Different letters above the bars indicate significant difference according to Tukey's test ($p \leq 0.05$) and the bars stand for standard deviations (SD).

growing medium revealed in high concentration of OM, OC and major elements (N, P and K) compared to other treatments. This could be explained by that GM has essential elements such as nitrogen, phosphorus, potassium, with general concentrations of 2.2-3.4, 0.3-0.7 and 1.5-2.5 respectively and increases the organic matter content in the medium (Azeez and Averbeke, 2010). However, the increase in GM ratios generally increased EC levels in the media. This resulted are in agreement with Mowa et al. (2017) who showed that GM increased the EC levels of a growing medium. CRH also improved concentration of essential elements and organic matter because as their ratios were increasing as the concentrations were increasing. These resulted are supported by the reason that CRH contain phosphorous, calcium, potassium, magnesium and they act as organic fertilizer ingredient (Orge and Abon, 2012). As CRH ratio increases as the EC levels of a growing medium were reducing. These results might be due to the fact that CRH alone had lower levels of EC and high levels of K which thereafter provided K+ and improved physical properties which resulted in reduced Na+ and hold a lower exchangeable sodium percentage level and higher K+/Na+ ratio in the medium (Phuong et al., 2020). On another, sand alone showed low concentration levels of chemical properties which may be due to its nature of having very low concentration of these major elements while PM resulted in the best chemical properties compared to formulated media due to that it normally contains more organic matter, nitrogen and phosphorus (Atif et al., 2016).

Conclusion

The mixture of sand, goat manure and carbonized rice husks as growing medium substrates at different ratios have significantly influenced the physical and chemical properties of formulated media. The significant differences observed in the study are affected by differences in physical and chemical properties concentrated in the substrates and their ratios in a given growing medium. An increase in the ratios of CRH and GM resulted in reduced bulky density, enhanced porosity and nutritional status of a medium. The mixture of GM and CRH with sand substrates improves levels of OM, OC, N, P and K of the medium. An increase in levels of CRH while reducing the levels of GM resulted in reduces EC levels in a medium and vice-versa. The treatments T_5, T_6, T_7, T_8 and T_9 can be used for crop production to search the best alternative growing medium because they revealed good physical and chemical properties to other treatments compared to peat moss. Further studies should identify other local and available substrates which may result in the best physical and chemical properties to search the best alternative growing medium to peat moss for production of

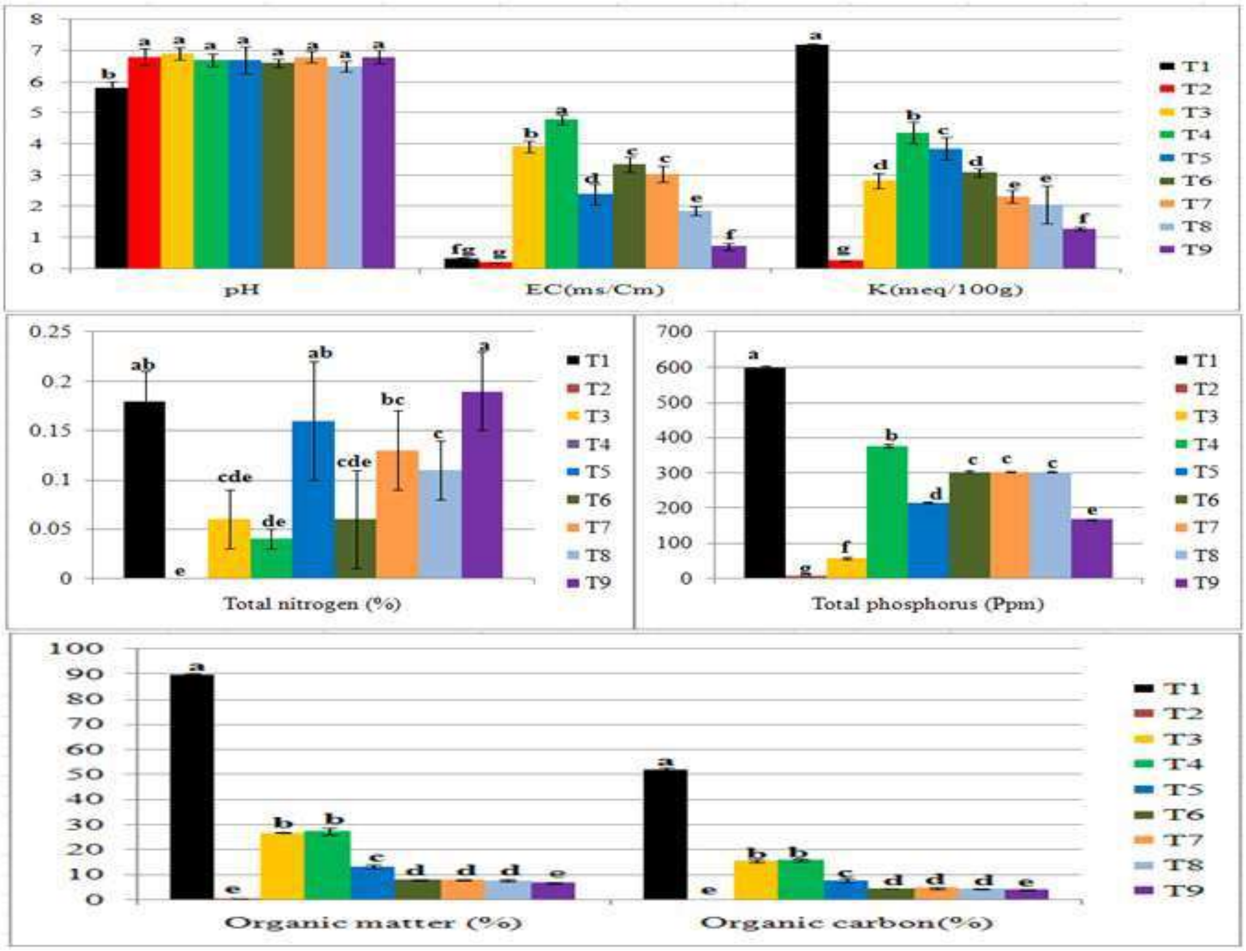

Figure 2. Chemical properties of different formulated growing media. T_1: Peat moss 100%, T_2: Sand 100%, T_3: Top soil + Goat manure 70%: 30%, T_4: Sand + Goat manure 50%: 50%, T_5: Sand + Goat manure + Carbonized rice husk 50%: 40%: 10%, T_6: Sand+ Goat manure + Carbonized rice husk 50%: 30%: 20%, T_7: Sand+ Goat manure + Carbonized rice husk 50%: 20%: 30%, T_8: Sand+ Goat manure + Carbonized rice husk 50%: 10%: 40% and T_9: Sand + Goat manure + Carbonized rice husk 50%: 0%: 50%. Different letters above the bars indicate significant difference according to Tukey's test ($p \leq 0.05$) and the bars stand for standard deviations (SD).

quality transplants.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Aendekerk TGL (2000). International substrate manual: analysis, characteristics, recommendations. Frank-Paul ter Berg: Elsevier international business information.

Anderson JM, Ingram JSI (1993). Tropical Soil Biology and Fertility: A Handbook of Methods. CAB International, Wallingford, UK, pp. 95-99. Asaduzzaman M, Saifullah M, Mollick ASR, Hossain MM, Halim GMA, Asao T (2015). Influence of soilless culture substrate on improvement of yield and produce quality of horticultural crops. Soilless culture- Use of substrates for the production of quality horticultural crops. Intech pp. 1-32. http://dx.doi.org/10.5772/59708.

Atif MJ, Jellani G, Malik MHA, Saleem N, Ullah H, Khan MZ, Ikram S (2016). Different growth media effect the germination and growth of tomato seedlings. Science, Technology and Development 35(3):123-127. https://doi.org/10.3923/std.2016.123.127.

Azeez JO, Averbeke VW (2010). Nitrogen mineralization potential of three animal manures applied on a sandy clay loam soil. Bioresource Technology 101(14):5645-5651. https://doi.org/10.1016/j.biortech.2010.01.119.

Baiyeri KP, Mbah BN (2006). Effects of soilless and soil-based nursery media on seedling emergence, growth and response to water stress of African breadfruit (*Treculia Africana* Decne). African Journal of Biotechnology 5(15):1405-1410. http://www.academicjournals.org/AJB.

Baruah TC,Barthakur HB (1998). A Textbook of Soil Analysis. PMT Ltd, New Dehli.

Blok C, Jackson BE, Guo X, De Visser PH, Marcelis LF (2017). Maximum plant uptakes for water, nutrients, and oxygen are not always met by irrigation rate and distribution in water-based cultivation systems. Frontiers in Plant Science 8(14):562-570. https://doi.org/10.3389/fpls.2017.00562.

Dunn C, Freeman C (2011). Peatlands: our greatest source of carbon credits. Carbon Management 2(3):289-301.

https://doi.org/10.4155/cmt.11.23.
El-Hamed K, Elwan M, Shaban W (2011). Enhanced sweet corn propagation: studies on transplanting feasibility and seed priming. Vegetable Crops Research Bulletin 75(6):31-50. https://doi.org/10.2478/v10032-011-0016-4.
Gungor F, Yildirim E (2013). Effect of different growing media on quality, growth and yield of pepper (*Capsicum annuum* L.) under greenhouse conditions. Pakistan Journal of Botany 45(5):1605-1608.
Jeon WT, Seong KY, Lee JK, Oh IS, Lee YH, Ok YS (2010). Effects of green manure and carbonized rice husk on soil properties and rice growth. Korean Journal of Soil Science and Fertilizer 43(4):484-489.https://www.koreascience.or.kr/article/JAKO201020842653766.pdf.
Kuisma E, Palonen P, Yli-Halla M (2014). Reed canary grass straw as a substrate in soilless cultivation of strawberry. Scientia Horticulturae 178(5):217-223. https://doi.org/10.1016/j.scienta.2014.09.002.
Landis TD, Jacobs DF, Wilkinson KM, Luna T (1990). Growing media. In: Landis TD, Tinus RW, McDonald SF, Barnrtt JF (Eds.). The container tree nursery manual. Washington, DC: US Department of Agriculture, Forest service P 80.
Maher M, Prasad M, Raviv M (2008). Organic soilless media components. In Raviv M., Lieth H, Bar-Tal A (Eds.). Soilless culture: Theory and practice pp. 459-504. https://doi.org/10.1016/B978-044452975-6.50013-7.
Mowa E, Akundabweni L, Chimwamurombe P, Oku E, Mupambwa HA (2017). The influence of organic manure formulated from goat manure on growth and yield of tomato (*Lycopersicum esculentum* L.). African Journal of Agricultural Research 12(41):3061-3067. https://doi.org/10.5897/AJAR2017.12657.
Mupondi LT, Mnkeni PNS, Muchaonyerwa P (2010). Effect of pine bark goat manure medium on seedling growth and N, P, K concentration of various vegetables. South African Journal of Plant and Soil 27(4):305-311. https://doi.org/10.1080/02571862.2010.10639999.
Ndayambaje JD, Heijman, WJ, Mohren GM (2013). Farm woodlots in rural Rwanda: purposes and determinants. Agroforestry Systems 87(4):797-814. https://doi.org/ 10.1007/s10457-013-9597-x.
Okalebo JR, Gathua KW, Woomer PL (2002). Laboratory methods of soil and plant analysis: a working manual. Nairobi: TSBF-CIAT and SACRED Africa Nairobi 21:25-26.
Oladele SO, Adeyemo AJ, Awodun MA (2019). Influence of rice husk biochar and inorganic fertilizer on soil nutrients availability and rain-fed rice yield in two contrasting soils. Geoderma 336:1-11. https://doi.org/10.1016/j.geoderma.2018.08.025.
Olle M, Ngouajio M, Siomos A (2012). Vegetable quality and productivity as influenced by growing medium: a review. Agriculture 99(4):399-408.
Orge R, Abon J (2012). Design improvement of the PhilRice continuous-type rice hull carbonizer for biochar production towards sustainable agriculture. International Journal of sustainable Development 5(8): 83-96.
Phuong NTK, Khoi CM, Ritz K, Linh TB, Minh DD, Duc TA, Toyota K (2020). Influence of Rice Husk Biochar and Compost Amendments on Salt Contents and Hydraulic Properties of Soil and Rice Yield in Salt-Affected Fields. Journal of Agronomy 10(8):1101. https://doi.org/10.3390/agronomy10081101.
Raviv M, Wallach R, Silber A, Bar-Tal A (2002). Substrates and their analysis. Hydroponic production of vegetables and ornamentals 25-105.
Robbins JA, Evans MR (2011). Growing media for container production in a greenhouse nursery. Availabe at http://www.uaex.edu/Other_Areas/publications/PDF/FSA-6098pdf.
Sarian ZB (2008). Carbonized rice hull has important uses. Agriculture (Philippines) 12(1):56-57.
Seguel O, Baginsky C, Contreras A, Covarrubias JI, González C, Poblete L (2013). Physical properties of a fine textured haplocambid after three years of organic matter amendments management. Journal of Soil Science and Plant Nutrition 13(3):690-705. http://dx.doi.org/10.4067/S0718-95162013005000055.
Varela MO, Rivera EB, Huang WJ, Chien C, Wang YM (2013). Agronomic properties and characterization of rice husk and wood biochars and their effect on the growth of water spinach in a field test. Journal of Soil Science and Plant Nutrition 13(2):251-266. http://dx.doi.org/10.4067/S0718-95162013005000022.