



Original article

Physio-chemical characterization of indigenous agricultural waste materials for the development of potting media

Sidra Kiran^{a,1}, Javed Iqbal^{b,1}, Subhan Danish^{c,d,*}, Allah Bakhsh^e, Syed Inam Ullah Shah Bukhari^a, Fatma Bibi^a, Khaled D. Alotaibi^f, Shah Fahad^{g,h,*}, Omaira Nasifⁱ, Ali Tan Kee Zuan^{j,*}, Rahul Datta^{d,*}^a Mango Research Institute, Old Shujabad Road, Multan, Punjab, Pakistan^b Mango Research Station, Shujabad, 59220 Punjab, Pakistan^c Department of Soil Science, Bahauddin Zakariya University, Multan, Punjab, Pakistan^d Department of Geology and Pedology, Faculty of Forestry and Wood Technology, Mendel University in Brno, Zemedelska1, 61300 Brno, Czech Republic^e Horticultural Research Station Soon Valley, Noswhera, Khushab, Punjab, Pakistan^f Department of Soil Science, King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia^g Hainan Key Laboratory for Sustainable Utilization of Tropical Bioresource, College of Tropical Crops, Hainan University, Haikou 570228, China^h Department of Agronomy, The University of Haripur, Khyber Pakhtunkhwa 21120 Pakistanⁱ Department of Physiology, College of Medicine and King Khalid University Hospital, King Saud University, Medical City, PO Box-2925, Riyadh 11461, Saudi Arabia^j Department of Land Management, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia

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ABSTRACT

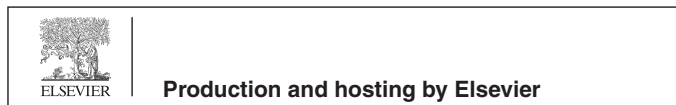
Organic residues are an important factor that directly affects fruiting tree seedlings' health at earlier stages. It provides a suitable environment for seedling growth by providing better nutrient ions, water, and aeration. However, low organic contents and high shrinkage of most organic materials mostly deteriorate ideal potting media characteristics. Low aeration, high water, and nutrients leaching decrease seedling growth and cause a significant loss of valuable resources. That is why the current study was conducted to screen out the best indigenous materials based on particle size to produce good characteristics bearing potting media. For that, eight different ingredients, i.e., "sugarcane", "coconut coir", "wheat straw", "rice straw", "corn cob", "leaf litter", "farmyard manure", and "sunflower heads" were collected. Initially, all the materials were air-dried and processed as per requirement. After grinding, three particle sizes (fine = < 2 mm, medium = 3 mm and coarse = 5 mm) were separated by sieving. Results showed that decreasing particle size in "rice straw", "corn cob", "farmyard manure", and "sunflower head" decreased leachate pH. Higher EC in leachates was negatively correlated with particle size in all potting media ingredients. Except for farmyard manure, fine particle size increases the water-holding ability of potting media ingredients. However, air-filled porosity was associated with a decrease in particle size of potting media in gradients. In conclusion, farmyard manure, "sunflower heads", "leaf litter" and "sugarcane" should be incorporated while making a combination for potting media. More investigations are suggested by mixing different particle size ingredients to prepare potting media.

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* Corresponding authors.

E-mail addresses: sd96850@gmail.com (S. Danish), shah_fahad80@yahoo.com (S. Fahad), tkz@upm.edu.my (A.T.K. Zuan), rahulmedcure@gmail.com (R. Datta).¹ Authors have equal contribution.

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1. Introduction

Mango (*Mangifera indica* L.) is a prominent exportable fruit of Pakistan that thrives best in the summer season and manifests its golden glimpse encrypts the front shelf of mega malls, vendors, and even in the Fruit & Vegetable Markets around the globe. Pakistan ranks 6th in mango production globally, with 1,758 thousand tons of production. Punjab province (31.1704° N, 72.7097° E) has 98.49 thousand hectares with an annual production of 1330.16 thousand tons (FAO, 2018). During the recent past, rapid technological and varietal advancement has a paradigm shift from conventional 35 plants per acre to ultra-density plantation system

that accommodates > 1300 plants per acre, accordingly (Ullah et al., 2017). Keeping in view this revolution, certified and clean mango nursery plants' production has great demand among orchardists. The mango nursery production system has also shifted plants into the soil to a substrate or growing media, which entails a single ingredient to blend various ingredients that facilitate moisture, air, porosity, nourishment, and anchorage. Soil is not considered a good source for growing nurseries due to weeds, salts (Abad et al., 2002), chemical residue (Bachman and Metzger, 2007).

Soil properties changes with the land use (Marfo et al., 2019a, 2019b). Soil alternative source for the growth of plants in nurseries encompasses growing media, substrate, supporting media, aggregate system, potting media of those soil materials (sole or in combination), other than soil like crops based (straw, stubble, dry seed shell, peels, bark, wood saw/dust, waste of agro-industry, fire ash, and volcano ash, raw ore mineral, thermopore, gravel, sand etc.) used as whole or after grinding or shredding into small particles (Savvas et al., 2013). Bigger particle size creates easy water drainage, quick drying of the substrate, and poses less decomposition. However, smaller particle size retains water for a longer duration, occupies more air space, and is subjected to high decomposition. A homogenous substrate has all the ingredients similar in nature, but a non-homogenous substrate has a bigger particle size and is easily differentiated into its original form after mixing as a raw or grinding process (Gruda et al., 2009).

The potting ingredients have the characteristic feature of the reservoir for water and plant nutrients, adequate oxygen exchange, anchorage or support for the plant, lower rhizosphere temperature excursion, standardization, lightweight, virtual absence of pests. Root in media and microbial community interact each other (Pathan et al., 2018). The potting ingredients were responsive to volume limitation, balanced fertilizer ratios requirement, potential expense, and rapid deficiency of certain nutrients. The use of Biostimulants reduces the need for fertilizers (Abbas et al., 2020; Izhar Shafi et al., 2020; Rafiullah et al., 2020; Ullah et al., 2020). The substrate of growing media encompasses the ease of growing young plants in various pot materials as earthen, plastic, cardboard, fiber, polyethylene and thermopore, etc. This research endeavor interconnects with the gradual production of soilless media based on local crop wastes. The wheat and rice produce dry stubble left after harvesting in the field and are a good source of nutrients and organic matters (Ahmad et al., 2012).

“Coconut coir” is imported from Sri Lanka and other countries and bears an expensive cost so that it can be replaced with indigenous crops-based sources as alternatives (Robertson, 1993), but also due to inconsistent supply (Bullock et al., 2012). The various organic products of crops and dairy animals due to fiber and minute nutrient quantity (Lamont and Elliott, 2016), wood biochar (Steiner and Hartung, 2014), pine tree substrate (Jackson et al., 2008), date palm wastes (Ghehsareh et al., 2012; Mohammadi Ghehsareh and Ghehsareh, 2013), vermicomposts (Gupta et al., 2014) “corn cob” (Haghighi et al., 2016), peanut shells (Mohammadi Torkashvand et al., 2015), and sunflower empty head and cotton spent mushroom compost (Lopes et al., 2015), have been identified as potting ingredients. The coconut peat exhibit hydrophobic properties due to fine particle size, while coir is hydrophilic due to its coarse particle size in the potting ingredients produce unsatisfactory results (Chong, 2015). Also, maize and sunflower crops, after grain and seed harvesting produce, the cob and head can be utilized as potential growing ingredients. Dry fallen mango leaves are also collected and used as “leaf litter,” while cow and buffalo dung is a good source of organic matter and be utilized as an ingredient for growing media. Rhizobacteria in media improve nutrient uptake and plant yield (Danish et al., 2020; Zafar-ul-Hye et al., 2020c, 2020a, 2020b).

Keeping in mind the importance of potting media, this research study was conducted with an aim to explore and select the best indigenous waste as potting material. Using indigenous waste material as potting media can play an influential role in the sustainable management of waste and benefit agriculture. The focus was also to select a better particle size to improve potting media's physical and chemical attributes. It is hypothesized that small particle size could improve pH, electrical conductivity (EC), water holding capacity, air-filled porosity, and bulk density of potting media prepared by using indigenous waste materials.

2. Materials and methods

2.1. Study site description

The experiment was conducted at Certified Mango Nursery of Mango Research Institute, Multan, during 2018–19. The site's GPS location was 30°09'12.0"N and 71°26'43.1"E with 126 m elevation from sea level and 186.6 mm annual precipitation. During the experiment, there was no rainfall. The temperature and humidity were maintained 28 ± 2 °C and $65 \pm 5\%$, respectively.

2.2. Source of potting materials ingredients

The substrate was made by variable quantity of various plant-based materials, i.e., stubbles leftover parts, mango dry and falling leaves as “leaf litter”, cow and buffalo dung as FYM according to the experiment plan. The “sugarcane” bagasse was procured from Sugar Mill, wheat and “rice straw” from the surrounding field. The maize cobs were procured after shelling of cobs and “sunflower heads” were used after separating seeds. “leaf litter” was made by collecting dry and fallen mango leaves under the tree canopy in the orchard. The cow and buffalo dung was collected from the local dairy farm.

2.3. Processing of potting ingredient

The stubbles of wheat, rice cobs from maize, empty head from sunflower, dry mango leaves and cow buffalo dung were sun-dried, followed by oven drying for 24 h at 60 °C to evaporate the available moisture. All the mixes were dried to ease the grinding process so that the final product was achieved.

2.4. Grinding dynamics and bags filling

The sun-dried potting mixes were ground in the rotary grinding mill electricity as a power source of 5 kW, 4200 rpm, stainless steel two blade 6 mm thickness and 20 cm long, having capacity of 50 kg/h grinding. The mesh of variable size is attached to separate the appropriate particle size of the potting mixes were classified as fine (<2 mm), medium (3 mm), and coarse (>5 mm). The three classified mesh sizes of grind potting mixes were filled into polybags (15 cm wide and 40 cm). Each bag has an equal quantity of material, i.e., 1.5 kg

2.5. Treatment plan and experimental design

There were eight different potting media and three-particle sizes, i.e., fine (<2 mm), medium (3 mm) and coarse (>5 mm), following a completely randomized design (CRD) with three replicates.

2.6. pH and EC of leachates

To determine the pH and EC of leachates of various media ingredients 1:10 ratio of material and distilled water are used to determine properties. Initially, 25 g of media of different particle sizes of fine, medium, and coarse were weighted on analytical grade weigh balance and taken in a plastic cup. After that, 250 mL of water was added. The cups were left for 24 h to get leachates. Finally, the leachates were run on pre-calibrated pH and EC meters to get pH and EC of leachates (Shaaban et al., 2013).

2.7. Water holding capacity

Water holding capacity was calculated by using the formula of

$$\text{Water Holding Capacity (\%)} = \frac{\text{Total water added} - \text{Water leachates}}{\text{Total Water Added}} \times 100$$

$$\text{Air Filled Porosity (\%)} = \frac{\text{Volume of air in mix}}{\text{Total volume of mix}} \times 100$$

2.8. Bulk density

Bulk density was calculated by weighing the weight of the material and using the formula of (Grossman and Reinsch, 2002) as

$$\text{Bulk Density (g cm}^{-3}\text{)} = \frac{\text{Dry weight of mix}}{\text{Volume of core}}$$

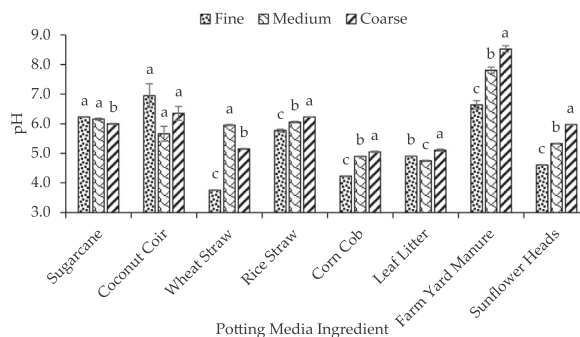
2.9. Statistical analysis

The standard statistical methodology was followed for the comparison of treatment. Two factorial ANOVA was applied to assess the significant effects of particle size and potting media. Tukey's test was applied for the comparison of each potting media at $p \leq 0.05$. Pearson correlation was also applied to check positive and negative correlation with significance. Interaction graphs were made using SPSS 20. Bars graphs were made by using excel 2019 (Steel et al., 1997).

3. Results

3.1. Media ingredients leachates pH

Results showed that particle size significantly affects the pH of all potting media ingredients except "coconut coir". However, particle size change did not differ significantly for the pH of "coconut coir" potting media ingredient. It was observed that the main and interactive effects of different potting media (PM) ingredients and particle size (PZ) were significant for pH. Interaction of PM and PZ was significant ($p \leq 0.05$) ordinal for pH attribute (Fig. 2A). Ingredients "sugarcane" (S) and "coconut coir" (CoC) showed a negative correlation with particle size for pH. However, the Pearson correlation for S (-0.9191) was significant, while CoC (-0.3574) was non-significant for pH. Potting media ingredients "rice straw" (0.9553), "corn cob" (0.938), "farmyard manure" (0.9676), and sunflower head (0.9987) showed significant positive but "leaf litter" (0.5473) and "wheat straw" (0.6271) non-significant positive correlation with the change in particle size (Fig. 2B). Individual one-way ANOVA showed no significant change in "sugarcane" pH, but coarse particle size significantly decreases the pH of "sugarcane" at fine and medium particle size. "Coconut coir" pH remained statistically alike with each other at fine, medium, and coarse particle size. For "wheat straw" pH was significantly high at medium particle size over fine. Similarly, the coarse particle size pH of "wheat straw" was also significantly high over fine particle



showed a significant difference at $p \leq 0.05$ compared by Tukey's Test.

Fig. 1. Effect of different particle size on pH of different potting media ingredients. Different letters showed a significant difference at $p \leq 0.05$ compared by Tukey's Test.

size (Fig. 1). In "rice straw", "corn cob", "farmyard manure," and "sunflower heads" decreasing particle size also decreases pH. However, fine and coarse "leaf litter" pH was significantly high compared to medium particle size.

3.2. Media ingredients leachates EC

Different particle size significantly affects the EC of all potting media ingredients. The main and interactive effects of PM and PZ were significant for EC. PM and PZ showed significant ($p \leq 0.05$) ordinal interaction for EC (Fig. 4A). All the PM i.e., S (-0.7238), WS (-0.8410), CC (-0.8967), LL (-0.9762), FYM (-0.9841) and SH (-0.8072) showed negative correlation with particle size for EC except CoC (-0.0837) and RS (-0.1737). (Fig. 4B). Individual one-way ANOVA showed no significant change was noted in "sugarcane" EC but fine particle size significantly increased EC in "sugarcane" at coarse and medium particle size. In "coconut coir" EC remained statistically alike with each other at fine and coarse particle size but at medium particle size, EC was significantly low from fine and coarse particle size. In the case of "wheat straw", EC was significantly higher at fine over medium and coarse particle size. Similarly, coarse and fine particle size EC of "rice straw" was also significantly high over medium particle size (Fig. 3). In "corn cob", "farmyard manure" and "leaf litter" decreasing particle size increased the EC. However, EC of fine and coarse "sunflower heads" was significantly high as compared to the medium PZ.

3.3. Media ingredients water holding capacity

Use of variable particle size significantly affects the water holding capacity (WHC) of all potting media ingredients. Main and interactive effects of PM and PZ were significant for WHC. Interaction between PM and PZ was significant ($p \leq 0.05$) ordinal for WHC (Fig. 6A). Except WS (0.4018), RS (0.1476) and FYM (0.9406) all the PM i.e., S (-0.5659), CoC (-0.8697), CC (-0.9326), LL (-0.6930), and SH (-0.9785) showed negative correlation with particle size for WHC (Fig. 6B). Medium particle size significantly improved "sugarcane" WHC over coarse PZ in "sugarcane". Similarly, fine particle size also significantly increased WHC in "sugarcane" from coarse PZ. For "coconut coir", WHC remained the same with each other at fine and medium particle size but significantly increased WHC compared to coarse particle size. In "wheat straw" WHC remained significantly high at medium PZ followed by coarse PZ size over fine PZ. Coarse and fine particle size of "rice straw" were also showed significantly high WHC over medium particle size (Fig. 5). In "corn cob", "sunflower heads" and "leaf litter" fine and medium PZ increased the WHC over coarse PZ. However, WHC of

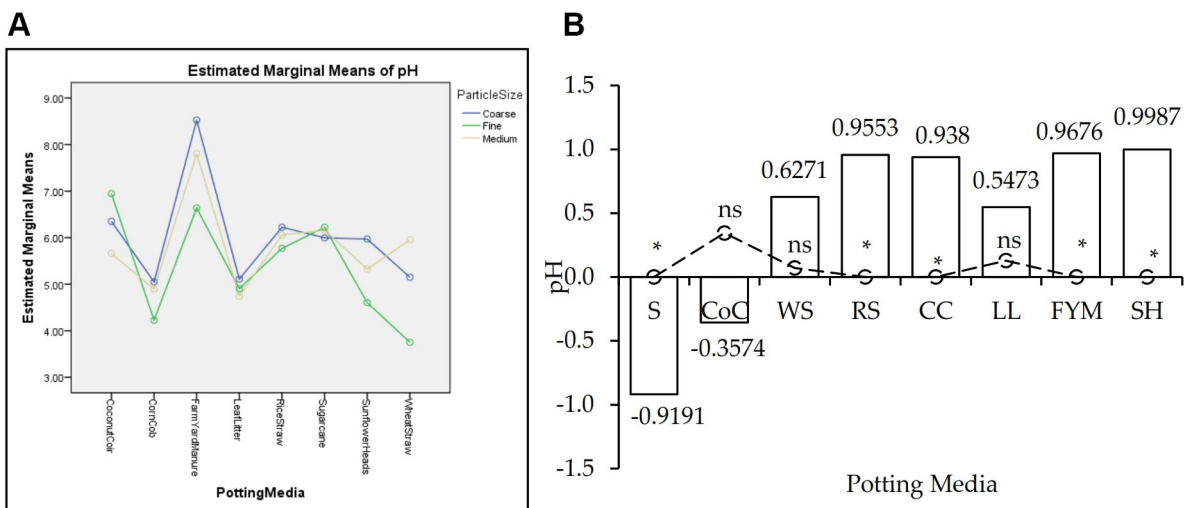


Fig. 2. Particle size and potting media ingredients interaction for pH (A) and Pearson correlation (B) graphs for pH. S = “sugarcane”; CoC = “coconut coir”; WS = “wheat straw”; RS = “rice straw”; CC = “corn cob”; LL = “leaf litter”; FYM = farmyard manure; SH = “sunflower heads”.

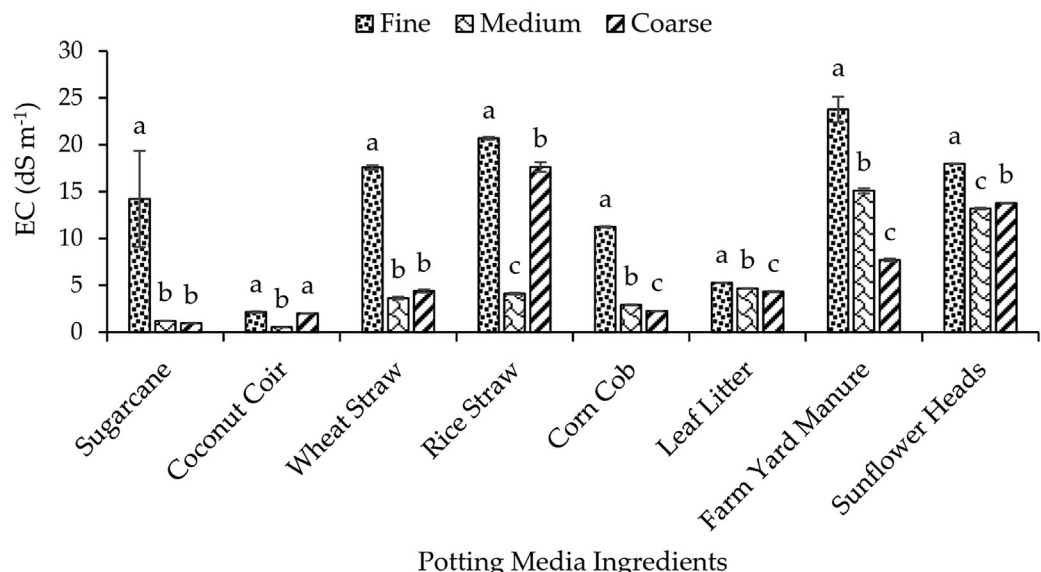


Fig. 3. Effect of different particle sizes on EC of different potting media ingredients. Different letters showed a significant difference at $p \leq 0.05$ compared by Tukey's Test.

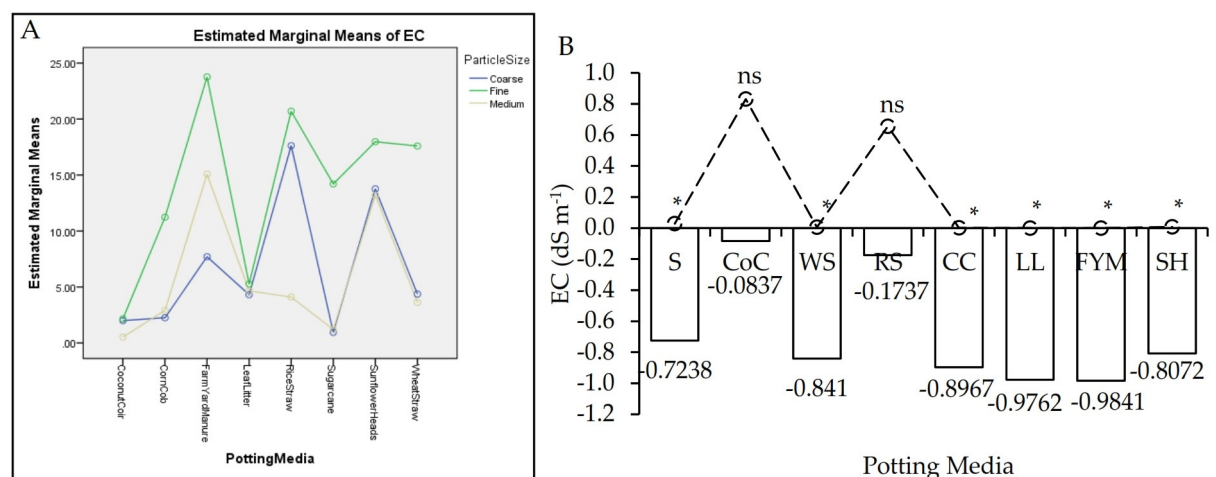


Fig. 4. Particle size and potting media ingredients interaction for EC (A) and Pearson correlation (B) graphs for EC. S = “sugarcane”; CoC = “coconut coir”; WS = “wheat straw”; RS = “rice straw”; CC = “corn cob”; LL = “leaf litter”; FYM = farmyard manure; SH = “sunflower heads”

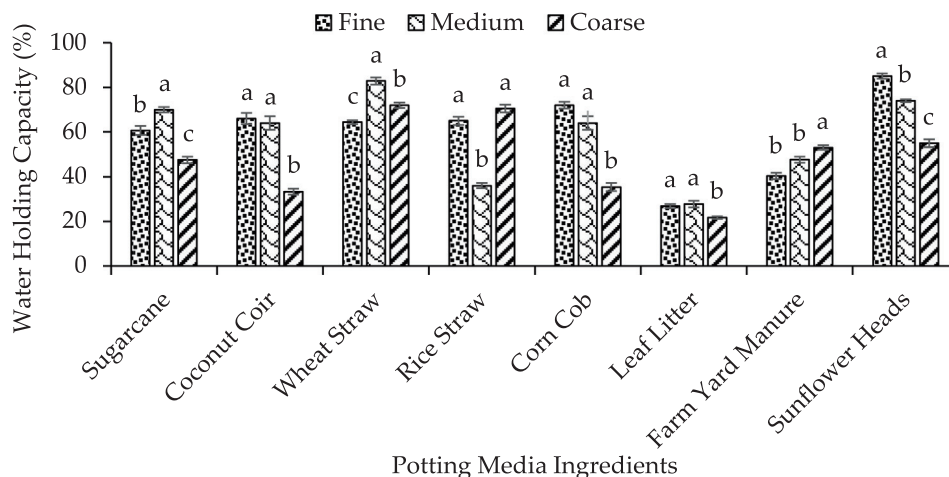


Fig. 5. Effect of different particle sizes on WHC of different potting media ingredients. Different letters showed a significant difference at $p \leq 0.05$ compared by Tukey's Test.

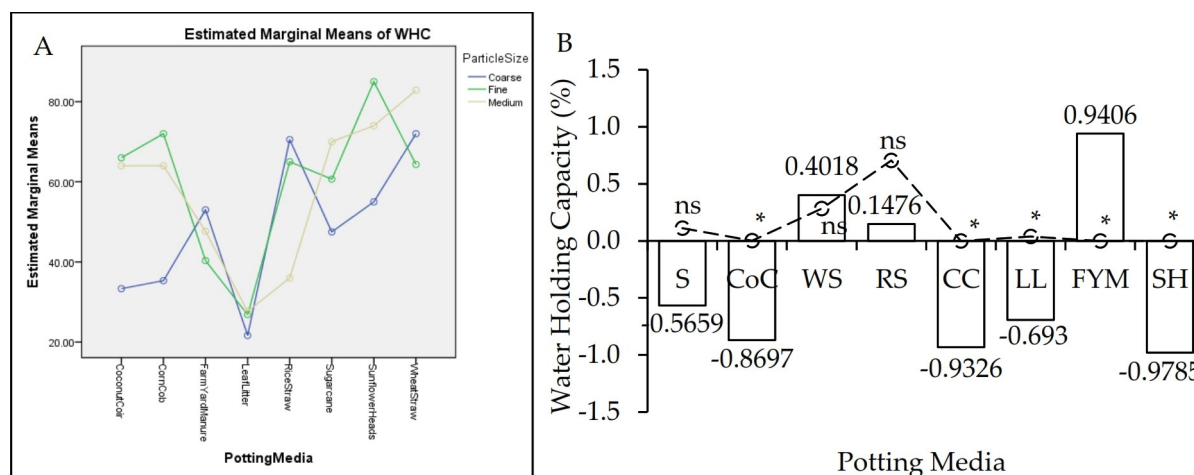


Fig. 6. Particle size and potting media ingredients interaction for WHC (A) and Pearson correlation (B) graphs for WHC. S = “sugarcane”; CoC = “coconut coir”; WS = “wheat straw”; RS = “rice straw”; CC = “corn cob”; LL = “leaf litter”; FYM = farmyard manure; SH = “sunflower heads”

coarse PZ in “farmyard manure” was significantly high as compared to medium and fine.

3.4. Media ingredients air filled porosity

Air-filled porosity (AFP) was significantly affected by the particle size of all potting media ingredients except for “coconut coir” and “corn cob”. Both PZ and PM main and interactive effects were significant for AFP. Two factorial ANOVA showed that interaction between PM and PZ was significant ($p \leq 0.05$) ordinal for AFP (Fig. 8A). Except CoC (0.5032) all the PM i.e., S (-0.9626), WS (-0.9679), RS (-0.9164), CC (-0.4083), LL (-0.8433), FYM (-0.9405) and SH (-0.9424) showed negative correlation with particle size for AFP (Fig. 8B). Fine particle size significantly improved “sugarcane”, “wheat straw”, “leaf litter”, “farmyard manure” and “sunflower heads” APC over coarse PZ. In “rice straw” and “leaf litter” no significant change was noted in AFP among fine and medium PZ. However, the PZ effect remained non-significant for AFP in “corn cob” and “coconut coir” (Fig. 7).

3.5. Media ingredients bulk density

Bulk density (BD) was significantly affected by the particle size of all potting media ingredients except for “coconut coir” and “corn cob”. Both PZ and PM main and interactive effects were significant

for BD. Two factorial ANOVA showed that interaction between PM and PZ was significant ($p \leq 0.05$) ordinal for BD (Fig. 10A). Except CC (0.4232) all the PM i.e., S (-0.9640), CoC (-0.5914), WS (-0.9479), RS (-0.9526), LL (-0.8413), FYM (-0.9206) and SH (-0.045) showed negative correlation with particle size for BD (Fig. 10B). Fine particle size significantly improved “sugarcane”, “wheat straw”, “leaf litter” and “farmyard manure” BD over coarse PZ. Fine and medium PZ were statistically alike with each other in “leaf litter”, but Fine PZ significantly increased BD in all other PM. In “coconut coir” straw and “corn cob” no significant change was noted in BD at all PZ. Also, no significant change was noted among coarse and fine PZ “sunflower heads” for BD. However, the PZ effect remained non-significant for BD in “sunflower heads” at fine and coarse PZ. (Fig. 9).

4. Discussion

Results showed a significant change in pH and EC of potting media ingredients leachates by changing the particle size, i.e., fine (<2 mm), medium (3 mm) and coarse (>5 mm). Decreasing farmyard manure, “rice straw”, “wheat straw”, “corn cob” and “sunflower heads” and significant leachate pH was due to exposure of high surface area for solubilization of ions by water. In contrast to above, a significant increase in EC by decreasing the particle size

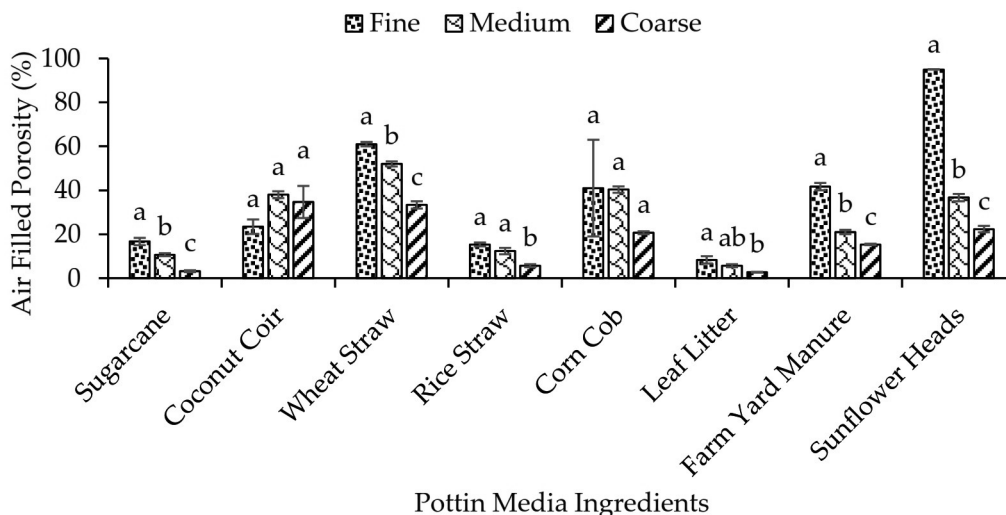


Fig. 7. Effect of different particle sizes on AFP of different potting media ingredients. Different letters showed a significant difference at $p \leq 0.05$ compared by Tukey's Test.

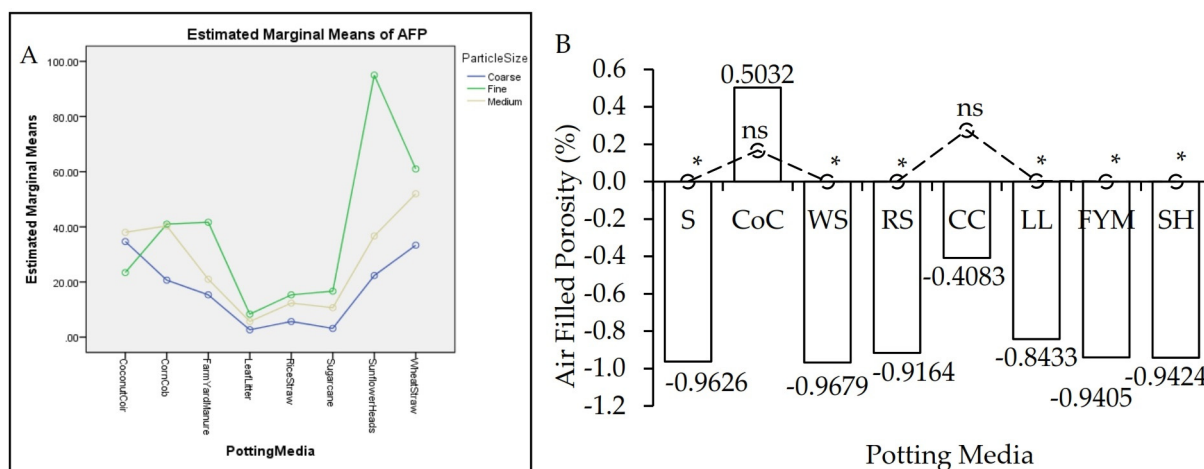


Fig. 8. Particle size and potting media ingredients interaction for AFP (A) and Pearson correlation (B) graphs for AFP. S = "sugarcane"; CoC = "coconut coir"; WS = "wheat straw"; RS = "rice straw"; CC = "corn cob"; LL = "leaf litter"; FYM = farmyard manure; SH = sunflower head.

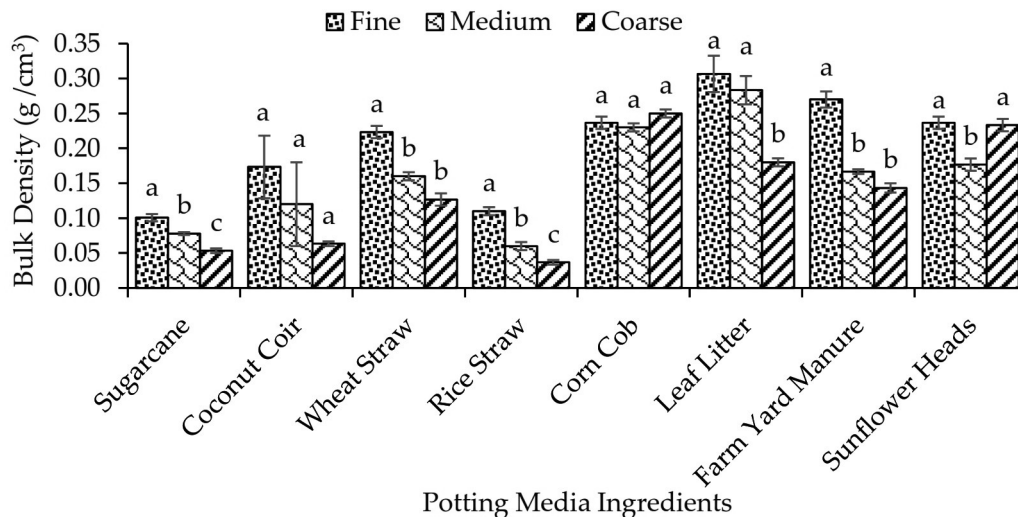


Fig. 9. Effect of different particle sizes on BD of different potting media ingredients. Different letters showed a significant difference at $p \leq 0.05$ compared by Tukey's Test.

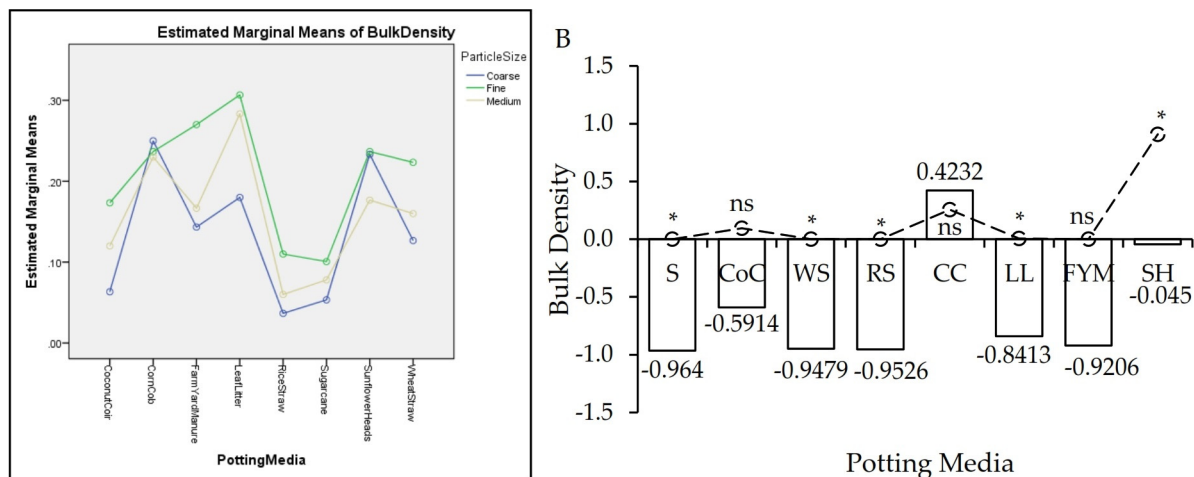


Fig. 10. Particle size and potting media ingredients interaction for BD (A) and Pearson correlation (B) graphs for AFP. S = “sugarcane”; CoC = “coconut coir”; WS = “wheat straw”; RS = “rice straw”; CC = “corn cob”; LL = “leaf litter”; FYM = farmyard manure; SH = sunflower head.

agrees with more ions solubilization by exposure of the ingredient's high surface area. According to Zhang et al. (2014), decreasing particle size increases the open surfaces of any material towards the external environment compared to large particle size. Mustafa et al. (2016) argued that the change in pH and EC of different organic potting materials are dependent on the type of salts present in the material. A higher amount of alkaline ions in feedstock increased pH and EC, while acidic ions in materials played an imperative role in decreasing the pH of extract. Furthermore, a higher amount of hydrogen ions also shows a higher rate of electrical conductivity. Hence, low soil pH due to a large number of hydrogen ions may encourage soil electrical conductivity. The current study's findings are also in line with the above argument, where a rapid change in pH also changes EC (Mohd-Aizat and Mohamad Roslan, 2014). This was possibly due to more solubilization of organic acids in the water while taking leachates. Sun et al. (2012) suggested that the dissolution rate becomes extremely fast when the particle size becomes low. This increases the concentration of ions in bulk solution as compared to large particle size dissolution. That's why the small particle size of potting media ingredients in the current study showed significantly high EC, especially in farmyard manure, “sunflower heads”, “corn cob”, “sugarcane”, rice and “wheat straw”. Poor soil aeration has a greater effect on the reduction of plant growth than root growth. At any given temperature, the plant growth rate can be linked to the soil oxygen level. Poor root respiration also reduces water and nutrients' absorption because chemical changes in the growth media limit total plant growth (Brady and Weill, 1999). It was noted that water-holding ability in some media ingredients (“sunflower heads”, “corn cob”, “coconut coir”) become significantly higher where particle size was small. This increase in water holding capacity was due to improved material porosity and less settling of small particle size ingredients. However, smaller particle size also decreases the water-holding ability, especially in farmyard manure, “sugarcane” and “wheat straw” might be due to the particle's settling at the bottom. Puustjarvi and Robertson (1975) argued that capillary pore production in materials while reducing particle size increases the water holding capacity of materials. These capillary pores production is dependent on screen size, way of grinding, and degree of screening for particles. However, in coarse particle size, many non-capillary pores increase the drainage of liquid media, thus reducing water holding capacity. Pearson correlation in current also showed similar results where size of particle was negatively correlated with the water holding

capacity in majority of media ingredients i.e., “sugarcane”, “coconut coir”, “corn cob”, “leaf litter” and “sunflower heads”. The positive correlation in some ingredients was might be due to presence of high number of non-capillary pores. The same results were also observed in air-filled porosity. Small particle size showed large air-filled pores in a majority of media ingredients except “corn cob”. Bures et al. (1993) described that shrinkage of any media is dependent on the coarse particles. Higher coarse particles in any media cause its settling at the bottom and decrease air-filled porosity. Furthermore, the distribution of particles also decides the shrinkage levels of media. However, higher bulk density in small-size particles of current media ingredients was possibly due to more particle settling at the bottom.

5. Conclusions

In conclusion, fine particle size in most potting ingredients is effective in decreasing the pH. For improvement in air-filled porosity and water-holding ability of any potting media, fine particle size is suggested. However, keeping in view the EC, medium particle size should be considered for potting media preparation. Farmyard manure, “sunflower heads”, “leaf litter” and “sugarcane” should be incorporated while making a combination for potting media. More investigations are suggested using currently selected particle size ingredients by growing mango seedlings at a commercial nursery scale.

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Data availability statement

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CRediT authorship contribution statement

Sidra Kiran: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation. **Javed Iqbal:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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