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COMPARATIVE STUDY ON THE STORMWATER RETENTION OF ORGANIC WASTE SUBSTRATES BIOCHAR, SAWDUST AND WOOD BARK RETRIEVED FROM PSIDIUM GUAJAVA L. SPECIES

SUMMARY

This research compares the stormwater retention performances of an organic waste growing medium extracted from the widely available *Psidium guajavala* L species in Sri Lanka. Rainfall gauges were manually constructed to outsource accurate precipitation data, and the study was conducted throughout the entire month of January 2023. A stormwater retention curve was constructed for the Biochar, Sawdust and Wood bark substrates and the hotspots were compared. Furthermore, the results were validated using a volumetric comparison of water retention. The experimental outcomes have shown that Biochar exhibits strong water retention ability and enables the overlaying vegetation to acquire nutrients without external obstacles. The main reason for this exceptional performance was biochar's low evaporation levels and high porosity. In contrast, Sawdust was found to be the worst performer in terms of water retention due to its high thermal conductivity. These experimental studies were rationalised by outsourcing the specimen from the same tree. Our recommendations suggest that the biochar manufacturing industry needs to be improved in the future since it provides a sustainable and effective alternative in terms of eco-friendly substrates.

Keywords: rainfall gauges; precipitation data; volumetric comparison; porosity; thermal conductivity

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INTRODUCTION

Modern agricultural systems heavily incorporate the use of chemical fertilisers in order to concentrate on high outputs within a short period. This aggravating factor has resulted in an increase in the production of genetically modified and chemically intensive fertilisers for agricultural lands (Popp, Pető, & Nagy, 2013; Zhang *et al.*, 2022). Even though these performance-enhanced fertilisers boost plant growth and comply with international standards, these genetically modified fertilisers result in impairments among the shoot and root systems, alter nutritional characteristics, and cause permanent variations in the genetic characteristics of offspring. These alterations not only challenge the longevity of plant species, but they also cause detrimental health ailments due to the toxic chemical accumulation in body during the vegan food intake (Chandini, Kumar, & Prakash) and results diabetes, cancer and nerve related diseases.

These ongoing issues result in the necessity to find alternative substrates from natural sources with optimal nutrient content, and these substrates provide ample storage to mitigate the likelihood of successive surface discharges. Ideal levels of water retention will enhance the water quality of soil substrates and facilitate effective ionic exchange in minerals (S. Kader, Jaufer, Shiromi, & Asmath, 2021; Liu *et al*., 2019). By considering these issues, several studies were compared and found that the natural organic waste substrates are the most feasible solutions in terms of availability in Sri Lanka. Furthermore, it was identified that the most commonly identified organic wastes in Sri Lanka are Biochar, Sawdust, and Wood bark (Dareeju, Meegahage, & Halwatura, 2010; S. A. Kader, Spalevic, & Dudic, 2022). This study has outsourced Biochar, Sawdust and Wood bark from the same *Psidium guajava* L. species since it is an abundant source of thick stems and roots (Burt & Weerasinghe, 2014).

Apart from the substrate type, the water retention capacity of the growing medium could be affected by environmental factors, particularly storm frequency (Schultz, Sailor, & Starry, 2018). Study based on green roof substrates in Portland (Stovin, 2010) have found that rainfall intensity has substantial influence on stormwater retention. As a result, the month of January was chosen to be implemented with field observations in this study, as January is one of the most rainy months in the Sri Lankan climate context (Burt & Weerasinghe, 2014).

Various strategies have previously been employed in earlier research to obtain run-off and precipitation data. Hydrologic Services RG703 8-inch tipping bucket rain gauge was used to collect rain gauge readings, and two Campbell Scientific SM616 soil water content sensors were placed on separate factions of growing medium to evaluate the soil water retention at 5-minute intervals. The roof drain was split to gather runoff data discretely, and a 'Tracom 60-degree extra-large trapezoidal flume' was employed (Bliss, Neufeld, & Ries, 2009). Furthermore, a 'Greyline LIT25 ultrasonic sensor' has been used to determine the depth of the water in laboratory scale (S. Kader, Chadalavada, Jaufer, Spalevic, & Dudic, 2022). Due to budget constraints and limited facilities, this approach was not used in the current study. Studies on water runoff under different vegetation species were conducted using the tray test for accumulating the runoff data (Nagase & Dunnett, 2012). This method is only viable in the laboratory with anthropogenic rainfalls. Since the main objective of this study is to find the most effective organic waste substrate for water retention in terms of practical applications, we preferred that our case studies be conducted on real-time rainfalls. Large covers would be required in trays during real rainfall scenarios to collect the rainwater. To avoid these practical concerns, a more manual-based technique was decided to be adopted using bucket rain gauges similar to (VanWoert *et al.,* 2005) for undertaking control over the measurements. These experimental setups would provide insights regarding the best-performing substrate species in terms of water retention and runoff performances, their corresponding rationales, and further significance in terms of industrial applications.

MATERIAL AND METHODS

Outsourcing of specimens

Substrates were prepared using the organic wastes from *Psidium guajava* species, namely biochar, sawdust, and wood bark from the agricultural farms in Akkaraipattu (7.225731, 81.823918), at Eastern Province of Sri Lanka. Biochar was extracted using feedstocks of *Psidium guajava* in the biochar kiln. Sawdust and wood bark were outsourced and chiselled into small aggregates to enhance their firm mix with soil particles. The substrate mix proportions (substrate:soil) were 60:40, derived from the study (S. A. Kader *et al*., 2022).

Experimental setup

Structure of vegetation platforms Wooden platforms were made with substrates planted *Trandescantia fluminensis* to acquire rapid observations (S. A. Kader *et al*., 2022). The dimension of platforms were decided upon comparing several studies such as (Nagase & Dunnett, 2012; Kader, 2022; Soulis, Ntoulas, Nektarios, & Kargas, 2016; VanWoert *et al*., 2005). Since the slope of the platforms was 2% in the considered research articles, this experimental study incorporated 1 x 2 m vegetation platforms with a 2% slope to determine the capability to retain water in substrate. All platforms included a 5 cm-thick *Trandescantia fluminensis* substrate layer, a 2 mm-thick adhesive waterproofing membrane, a drainage layer, and a non-woven geotextile layer.

Measurement of runoff and rainfall

The runoff water was stored in 15-litre containers, and the volume was measured with measuring cups. The rainfall gauge was installed 0.5 m above ground level, close to the platforms. Throughout January 2023, rainfall and runoff data were gathered every 24 hours. The collected data were translated into depths using the following equations:

$$\text{Precipitation depth} = \frac{\text{Volume of water in rain gauge}}{\text{Funnel area}}$$ (**Equation 1**)

$$\text{Runoff depth} = \frac{\text{Volume of water in containers}}{\text{Platform area}}$$ (**Equation 2**)

Stormwater retention depth = Precipitation depth – Runoff depth (**Equation 3**)

RESULTS AND DISCUSSION

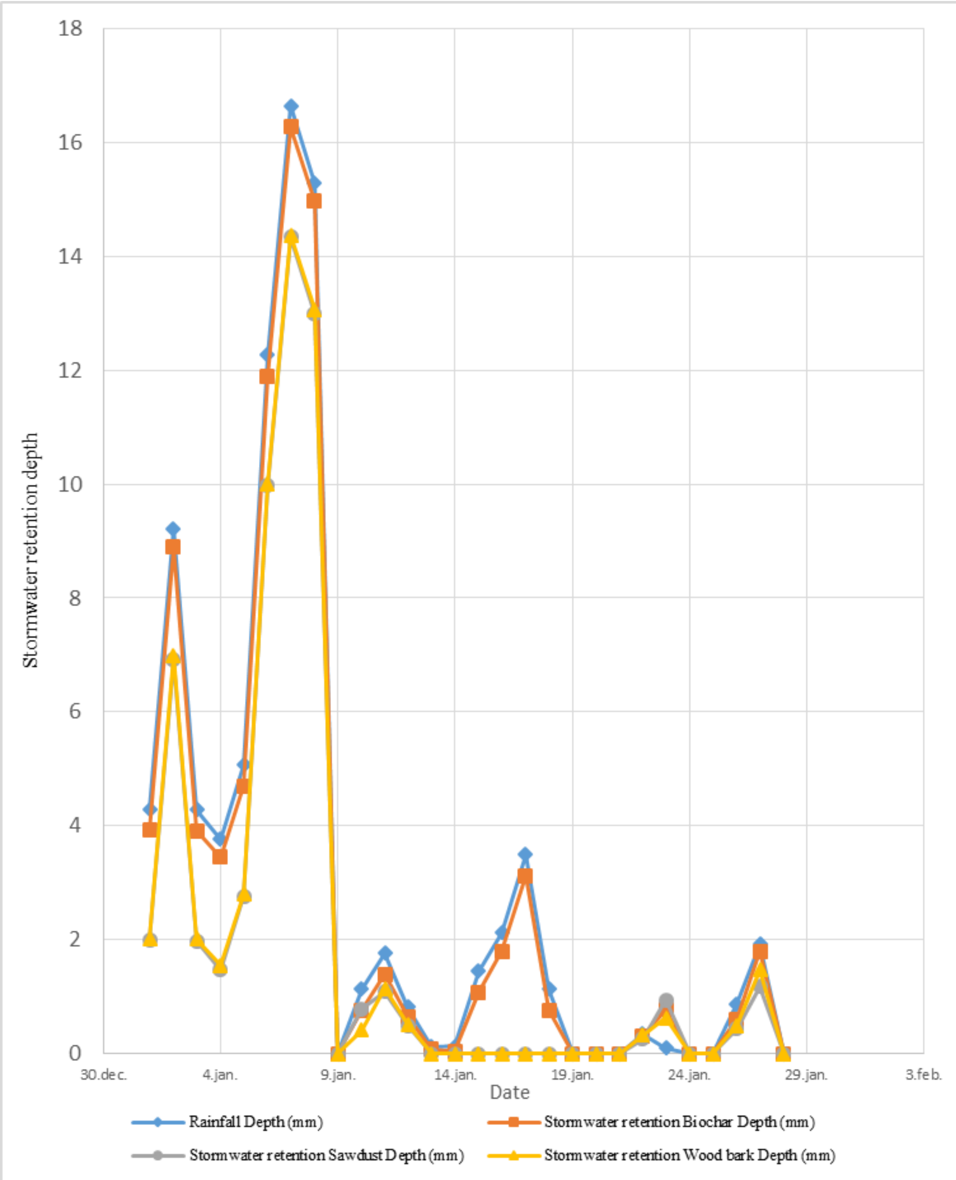

Figure 1: Stormwater runoff depth curve

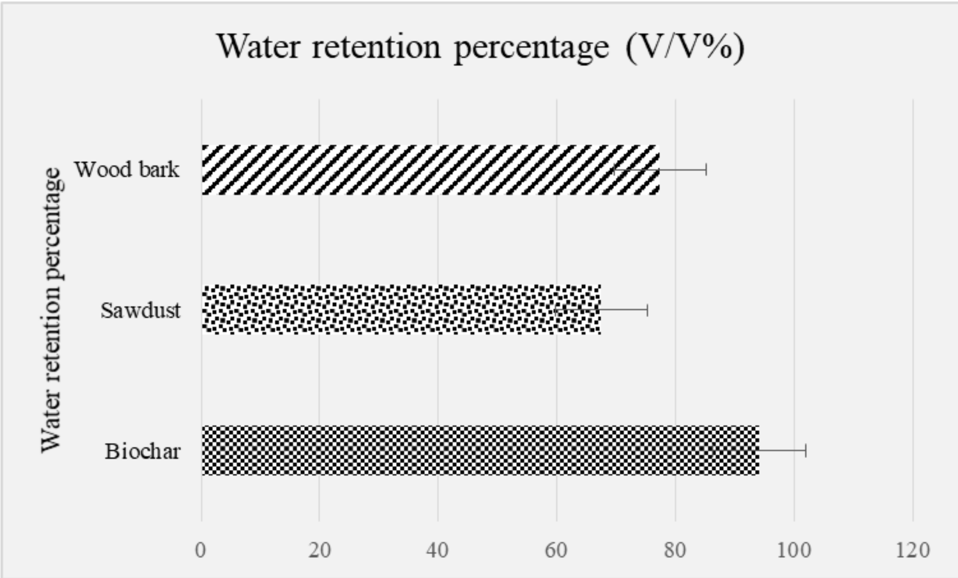

Figure 1: Water retention curve

According to Figure 1, the rainfall precipitation levels in January 2023 ranged from 0 to 16.639 mm. Maximum stormwater retention was observed among Biochar substrate at 16.268mm, corresponding to the maximum rainfall. Minimal stormwater runoff prevailed among Sawdust substrates since it exhibited the lowest retention levels for the majority of the study period. Based on the results of Figure 2, the maximum water retention percentage was occupied by Biochar at 94.13%, while sawdust remained the worst performer in terms of water retention. According to the review study, which correlates biochar research, climate change scenarios, and soil science (Sohi, Lopez-Capel, Krull, & Bol, 2009), the present status of Biochar research lacks experimental and field based studies upon its water retention capacity.

The main reason for the exceptional water storage ability of Biochar is its capability to maintain minimal evaporation levels (Kumar *et al*., 2020). According to the field based study of (Novak *et al*., 2009) revealed that 2% mixes of biochar made from different plants feedstocks increased the water retention capacity of a sandy loam type of soil. According to the study, biochar amendments increased the water-retention capacity of soil mixtures by 7%-16% at different temperatures, as measured by increasing the retort temperature from 250°C to 750°C. The ability of biochar to increase water retention capacity could have far-reaching consequences in drought-prone areas, particularly during urban vegetation (S. Kader, S. Chadalavada, *et al*., 2022; Karhu, Mattila, Bergström, & Regina, 2011). Further studies have also indicated that, high water retention of substrate facilitates vegetation with accelerated water and nutrient uptake in plants (S. Kader, Novicevic, & Jaufer, 2022; Zejak *et al*., 2022). Wood bark performs decently in terms of stormwater retention because it reduces the stress of rainwater, allowing it to infiltrate the soil more efficiently and greatly reducing evaporation from the soil surface.

The high thermal conductivity of Sawdust remains the primary cause of the increased rate of evaporation, thus causing high porosity (S. Kader, Jaufer, L., 2022). Sawdust substrate particles will lose their capacity to combine with the soil to form compact pores for retaining water against gravity owing to their high thermal conductivity. Therefore, the execution of Sawdust substrates would incur high maintenance and repair costs in terms of practical applications in gardens and green roofs.

CONCLUSIONS

A comparative study based on the stormwater retention capacities of the three commonly available organic substrates from Sri Lanka, such as Biochar, Sawdust and Wood bark, was conducted in this study using a field-scale experimental setup. Rational outcomes were facilitated by outsourcing all three types of substrate specimens from the same *Psidium guajava* L. species from a farmland in the Ampara district of Sri Lanka.

The biochar specimen demonstrated maximum stormwater retention capacity due to its low evaporation characteristics and ability to maintain high compactivity within aggregates. In contrast, Sawdust has shown the least water retention capacity due to its high thermal conductivity. The findings of this study have suggested the importance of considering the best feasible water-retaining growing medium for enhancing optimal nutrient and mineral uptakes in tree root systems. The key outcome of this study should be considered by global stakeholders in the agricultural industry, and necessary measures need to be taken to promote Biochar production industries using locally available sources. Future studies need to be made in the case of using machine learning tools and remote sensing-based analytical studies to quantify the water retention ability since the state-of-the-art field-scale test methods are highly time-consuming.

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