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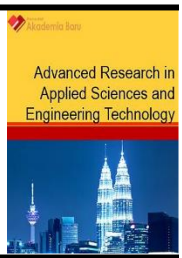

Rainfall Interception Characteristics of *Dracaena Sanderiana* and *Breynia Distincha*

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ABSTRACT

Interception of plants commonly used in urban landscape has not been widely studied compared to forested and cultivated area. Understanding the interception characteristics of these plants can facilitate the selection of the right plant type or combination in order to promote interception as a mean to improve the urban water cycle and urban built environment. Two (2) tropical plants are considered in this study, namely, Dracaena Sanderiana and Breynia Distincha, both with distinct plant structure, plant height, canopy size, number of leaves per plant, leaf size and leaf shape. Rainfall interception characteristics are investigated in laboratory environment using standard hydrology apparatus for different plant density. Artificial rainfall intensity of fixed duration is varied to measure the volume and duration of outflow, and volume intercepted. Results show that runoff begins earlier for higher rainfall intensity and lower plant density. The volume and duration of outflow increases with rainfall intensity and interception increases with canopy cover ratio and leaf area ratio for both plants. At lower plant density, Breynia Distincha has lower interception compared to Dracaena Sanderiana. However, at high plant density, Breynia Distincha demonstrates much better interception capacity even though the canopy cover and leaf area ratios are smaller than Dracaena Sanderiana. The phenomenon may be attributed to coalescence of water droplets that either flow down as stemflow or drip off the leaves under gravitational action. The firm small leaves of Breynia Distincha oriented at near horizontal are more likely to retain the intercepted rainwater compared to the slender soft leaves of Dracaena Sanderiana. This shows that closely spaced Breynia Distincha can be effective in increasing urban interception.

Keywords:
Breynia Distincha; canopy cover; Dracaena Sanderiana; interception; leaf area ratio

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1. Introduction

The amount of rainfall captured by plants is known as rainfall interception. It is part of the hydrological cycle where raindrops do not reach the ground but are stored temporarily on the surface of leaves, branches and bark. Interception rate depends on meteorological and rainfall factors, as well as the plant characteristics [1]. Although plant surfaces are able to store just a few millimetres of water film, which translate to a small, or often negligible component of the overall water balance especially in heavy or long duration rainfall events, interception effect can be pronounced for minor

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rainfall events, where the cumulative quantity of water loss in a series of continuous mild storm becomes noticeable [2].

Interception can be significant in a densely grown area such as forests where the thick and layered canopy structure provide relatively large interception storage capacity. Different plant species have different canopy attributes, size and structure, as well as size and shape of leaves (foliage), which dictates the total volume of water that can be stored [3]. Intercepted rainwater is usually loss to the atmosphere by evaporation or evapotranspiration. The process repeats itself by the next rainfall event if the surfaces are dried in-between rainfall events, which is subjected to factors such as wind, humidity and temperature [4].

Interception reduces throughfall as a direct consequence, i.e. the amount of rainwater that reaches the ground surface beneath the canopy, thus effectively reducing rainfall erosivity on surface soil and surface soil moisture content [5]. Change of landscape from forested area to urban or sub-urban landscape can reduce surface mean infiltration rate significantly, hence altering the urban hydrology. In addition, increased evapotranspiration attributed to interception by plant canopy has a cooling effect which improves the urban built environment to its occupants [6]. Interception has also been used as phytocap to prevent leachate of landfill area [7].

Interception of forested and cultivated area have been extensively researched. The former serves to understand the natural ecosystem [4,5,8], whereas the latter is of significance to irrigation planning and plant yield analysis [3,9,10]. On the contrary, interception in the urban landscape has not been widely undertaken. In fact, [11] argues that the differences between the forest and agriculture ecosystem do not permit the extrapolation of interception model from one to another.

As a tropical country, the urban landscape in Malaysia is characterized by a variety of plants which are chosen typically on aesthetic reason, price, availability and the ease to grow and maintain etc. [12]. Understanding the interception characteristics of these plants can facilitate the selection of the right plant type or combination in order to promote interception as a mean to improve the urban water cycle [13].

Although field study of interception is prevalent, it remains a challenging task due to practical reasons, including logistics and methodology [11]. Laboratory observations offer the advantage of measuring water inflow and outflow in a controlled environment but interception behaviour of a single plant may not be directly extended to a collective plant community, less so to a landscaped plot with multiple plant type.

In this study, we carry out laboratory investigation of the interception by two tropical plant type, namely, Dracaena Sanderiana and Breynia Distincha, which are commonly used in urban landscape. By varying the rainfall intensity and plant density, we determine the effect of canopy cover ratio and leaf area ratio on the runoff volume, runoff duration and interception volume

2. Methodology

2.1 Hydrological Apparatus

A hydrology apparatus measuring 2.05 m long 1.02 m wide 1.98 m tall, with an effective test catchment area of 1.60 m by 1.0 m, i.e. 1.6 m^2, is used in the present study. The artificial rainfall simulator comprises eight (8) sprinklers where the rain intensity can be controlled using a valve located at the inflow pipe. The rain chamber is covered with plastic screens on all sides and at the top to prevent loss of water droplets and to protect the test chamber from any wind effect. The apparatus is located indoor and thus is not subjected to direct sunlight.

The catchment area of the hydrology apparatus is filled with standard sand to a thickness of 0.18 m to represent the soil stratum. The standard sand is light grey or whitish, polished with irregular particle shapes, with at least 98% of the finest containing silica.

Input rainwater falls on the catchment surface and flows as surface runoff or infiltrates to form subsurface soil moisture and groundwater table. The water table can be visualized and measured using twenty (20) piezometers attached to the base of the apparatus. There is a weir on the downstream end of the apparatus where runoff water is discharged into a collection pond for volume measurement.

2.2 Plant Type

Two (2) types of tropical plants, namely, Dracaena Sanderiana and Breynia Distincha, are tested in the present study (Figure 1 and 2). Due to limitation of the hydrology apparatus dimension, the plants is obtained from nursery with size that fits into the test chamber.

Dracaena Sanderiana (Figure 1), better known as lucky bamboo, is a species of flowering plant in the family Asparagaceae. It is categorized as a perennial herb which can reach a height of 100 cm. It has flexible strap-shaped leaves and slender fleshy stems. The leaves can go up to 15 to 20 cm long and 1.5 to 4 cm wide at the base. It requires bright, ventilated areas, can tolerate dry air and does not require constant watering, very tenacious and rather difficult to destroy.

Breynia Distincha (Figure 2), otherwise known as snow shrub, is a plant in the family Phyllanthaceae. It is a tropical shrub which can grow up to 120 cm tall. It has wide leaves which are flat and almost round. The leaves mottled with pink, red, purple and green. Sometimes it is grown as a bedding plant.

Although both plants are of broadleaf type, they differ significantly in terms of the leaf shape and size, as well as the plant structure – Dracaena Sanderiana being upright and much taller, whereas Breynia Distincha being stout and outspread from the main stem. In addition, Breynia Distincha has slightly smaller canopy size but significantly more leaves per plant (Table 1).

Fig. 1. Dracaena Sanderiana

Fig. 2. Breynia Distincha

Table 1
Canopy cover ratio and leaf area ratio

	Dracaena Sanderiana	Breynia Distincha
Canopy diameter (cm)	20	18
Canopy cover (m^2)	0.0314	0.0227
Average plant height (cm)	40	15
Number of leaf (average per plant)	107	210
Average leaf area (m^2)	0.0026	0.0003
Number of plants		
Low Density	14	15
High Density	28	30
Canopy cover area ratio		
Low density	0.27	0.21
High Density	0.55	0.43
Leaf area ratio		
Low density	2.43	0.59
High density	4.87	1.18

2.3 Plant Density and Canopy Cover Ratio

Plant density, or plant spacing, is the amount of space between plants. The more closely spaced the plants, the higher the density. For the purpose of this study, the test cases are configured for high and low plant densities for both plants (table 1), where the high-density cases have double the number of plants of their respective low-density cases. Measurements show that the average diameter of the canopy of both plants differ by about 10%, giving canopy cover of 0.0314 m^2 for Dracaena Sanderiana, which is 38% larger than the 0.0227 m^2 for Breynia Distincha. Considering the number of plants for the low-and high-density cases where there is no overlap of the canopies, the canopy cover ratio is calculated as the total canopy cover area over the test catchment area of 1.6 m^2, giving 0.27 and 0.55 for Dracaena Sanderiana, and 0.21 and 0.43 for Breynia Distincha, respectively.

2.4 Leaf Area Ratio

Leaf area ratio (otherwise known as the leaf area index, LAI) is defined as the ratio of the one-sided total leaf area to the total horizontal surface ground area. The typical value of LAI may range from 0 (bare ground) to 10 (dense conifer forest). As summarized in Table 1, the average leaf size of

Breynia Distincha is much smaller (0.0003 m^2) compared to Dracaena Sanderiana (0.0026 m^2), but each plant has almost double the number of leaves. Nevertheless, the leaf area ratio of Breynia Distincha are still considerably lower, at 0.59 and 1.18 for the low- and high-density cases respectively, whereas the leaf area ratio of Dracaena Sanderiana are 2.43 and 4.87 for the same cases.

2.5 Rainfall Intensities and Soil Moisture

The range of rainfall intensities considered in the experiments are 74 mm/h, 93 mm/h and 112 mm/h, representing the low, medium and high rainfall intensities, respectively, selected based on the lower and upper limits of the pump capacity, with a total rainfall duration of 10 minutes. Based on the rain duration, the intensities correspond to events well below 2-year annual recurrence interval (ARI) in Ampang station, hence typifies regular rainfall in an urban location at central Peninsular Malaysia [14]. Total rainfall input is thus calculated based on the rainfall intensity over the test catchment area for a period of 10 minutes.

The test plant specimens come embedded in its own soil in individual plastic pot or polyethylene bag. They are place into the sand so that the plant soil surface is levelled with the test area sand surface. In order to control the soil moisture condition, the sand layer is pre-saturated in all tests so that a steady state water table is formed as verified from the piezometers. After the 10-min artificial rain, the final reading of volume and duration of runoff discharge is taken when the groundwater table recover to its pre-test condition, and the intercepted volume calculated as the difference between the total rainfall input and runoff output volume.

Gash [1] model interception as a three-step process comprising the wetting phase, the saturation phase and the drying phase. In order to ensure that the drying process is thorough, the plants are left overnight for proper drying before the next test case is carried out.

3. Results and Discussions

Figure 4 and 5 show increase of runoff and interception volume with higher rainfall intensity in all cases, where high plant density reduces runoff volume and increases interception. From the plot, it can be observed that rate of increase of interception reduces and is expected to plateau for higher intensity. The medium rainfall intensity is 25.7% higher than the low intensity. It produces 28.6% more interception for Dracaena Sanderiana high density case, and up to 33.3% more interception for the low density case. The same intensity produces 40% more interception for Breynia Distincha low density case, but only 12.5% more interception for the high density case. The high rainfall intensity is 20.4% higher than the medium intensity. However, the increase in interception volume does not exceed 22.2% (Breynia Distincha high density case).

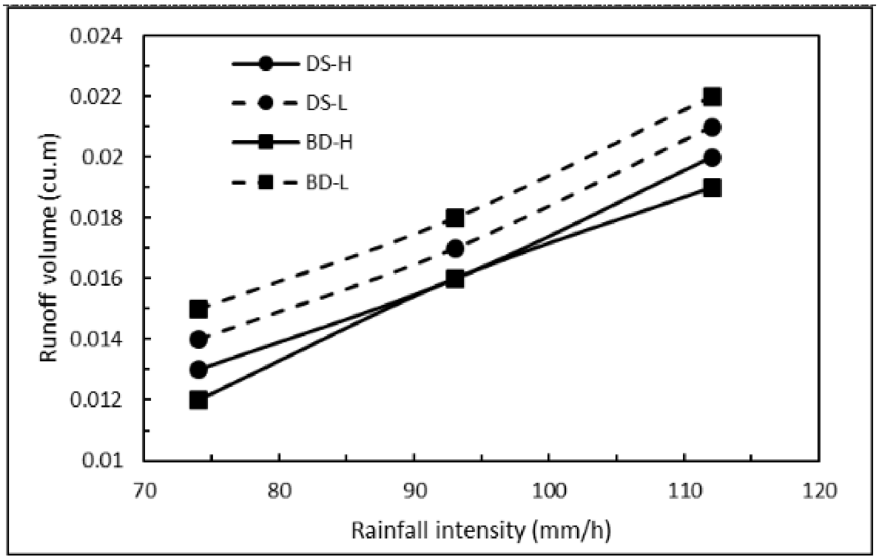

Fig. 4. Runoff volume as a function of rainfall intensity

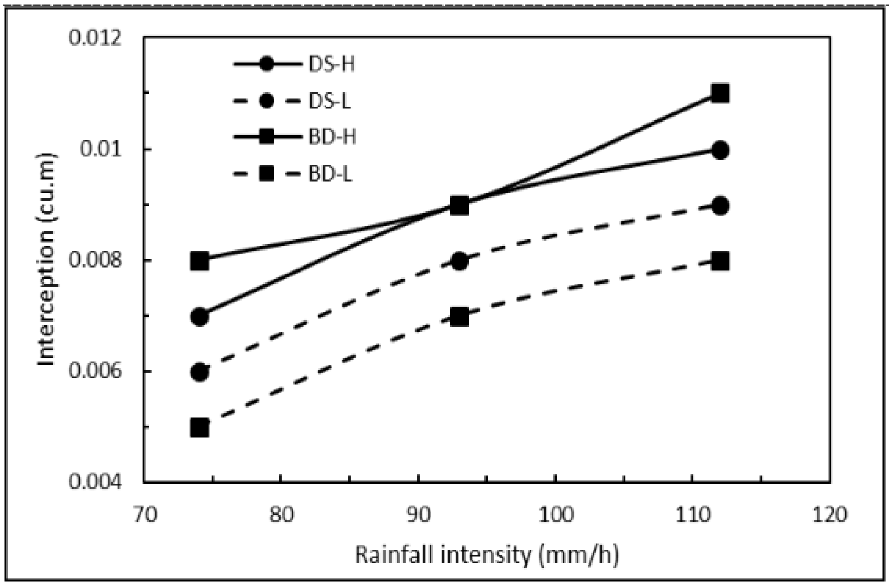

Fig. 5. Interception as a function of rainfall intensity

Figure 6 and 7 show the runoff and interception volume as a function of canopy cover ratio. At low plant density, Breynia Distincha has lower canopy cover ratio and thus lower interception compared to Dracaena Sanderiana. However, when the canopy cover ratio doubles for both plants, the runoff volume reduces more significantly for Breynia Distincha, and hence a corresponding higher increase in interception compared to Dracaena Sanderiana. For the same rainfall intensity, high density Dracaena Sanderiana shows increase of interception by 16.7%, 12.5% and 11.1%, respectively, whereas Breynia Distincha shows increase of 60.0%, 28.6% and 37.5%, respectively, for the low, medium and high intensity. In fact, for high plant density, although the canopy cover ratio of Breynia Distincha is only 0.43, which is less than 0.55 of Dracaena Sanderiana, it recorded higher interception for all three different rainfall intensities. This shows that Breynia Distincha has higher interception capacity which may be attributed to other factor.

Figure 8 and 9 show the runoff and interception volume as a function of leaf area ratio. The leaf area ratio of Breynia Distincha is much lower, giving higher runoff and lower interception at low plant density. However, at higher plant density, even though the leaf area ratio of Breynia Distincha is still much lower than Dracaena Sanderiana, it recorded lower runoff and higher interception for all three rainfall intensities. The observation is consistent with the effect of canopy cover ratio, which thus requires an explanation of what contributed to the higher storage capacity in Breynia Distincha.

Empirical equation shows that canopy storage capacity is proportional to the leaf area index [15]. However, the relatively large leaf size of Dracaena Sanderiana may counter the storage function where water droplets coalescence promptly to form larger droplets that either flows down as stemflow or drip off the leaves under gravitational action. Its leaf structure which is much softer and flexible may accelerate the above losses whereas the firm small leaves of Breynia Distincha oriented at near horizontal are more likely to retain the intercepted rainwater

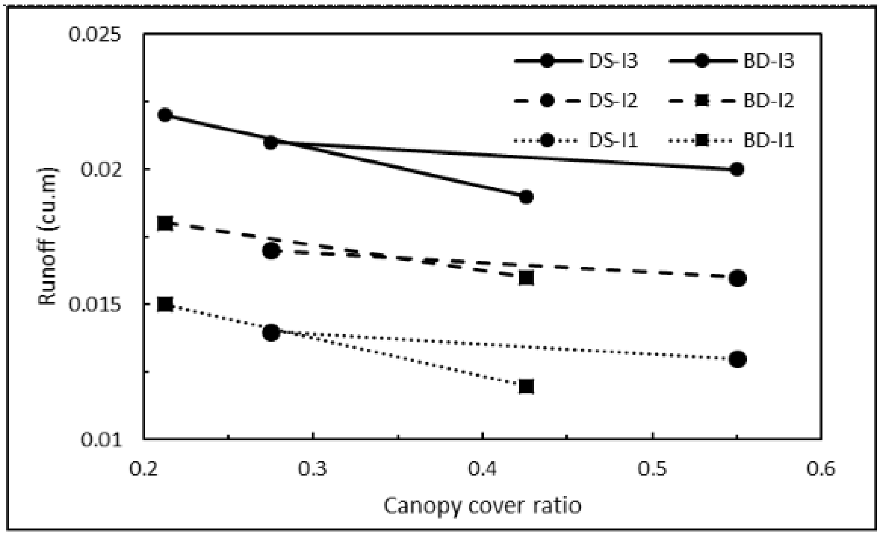

Fig. 6. Runoff volume as a function of canopy cover ratio

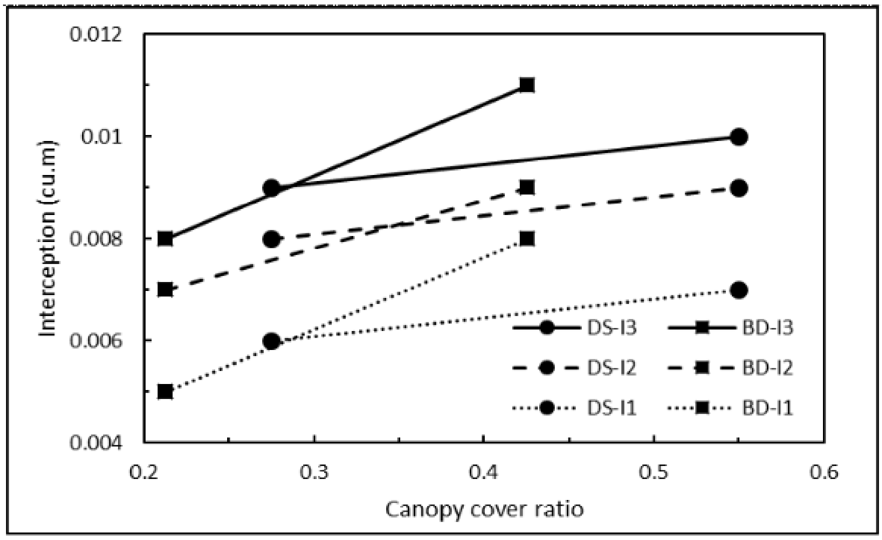

Fig. 7. Interception as a function of canopy cover ratio

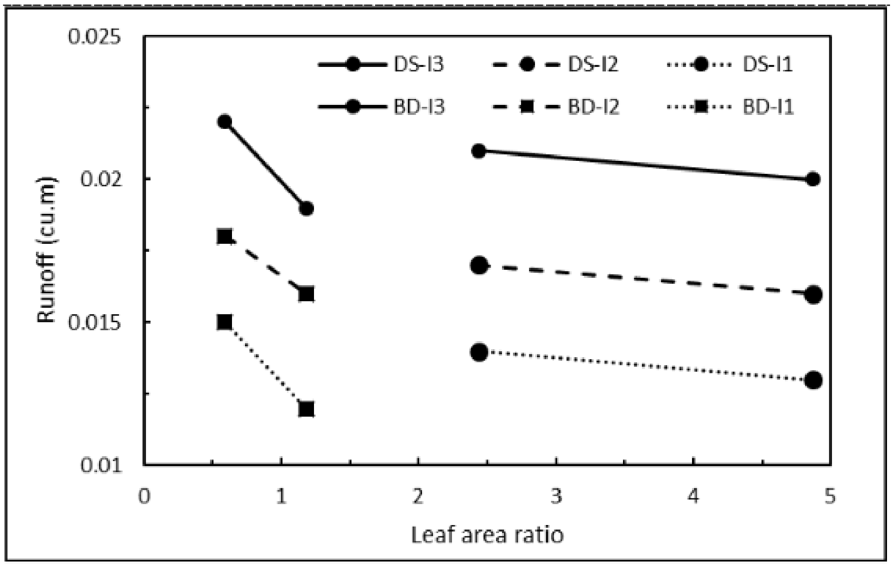

Fig. 8. Runoff volume as a function of leaf area ratio

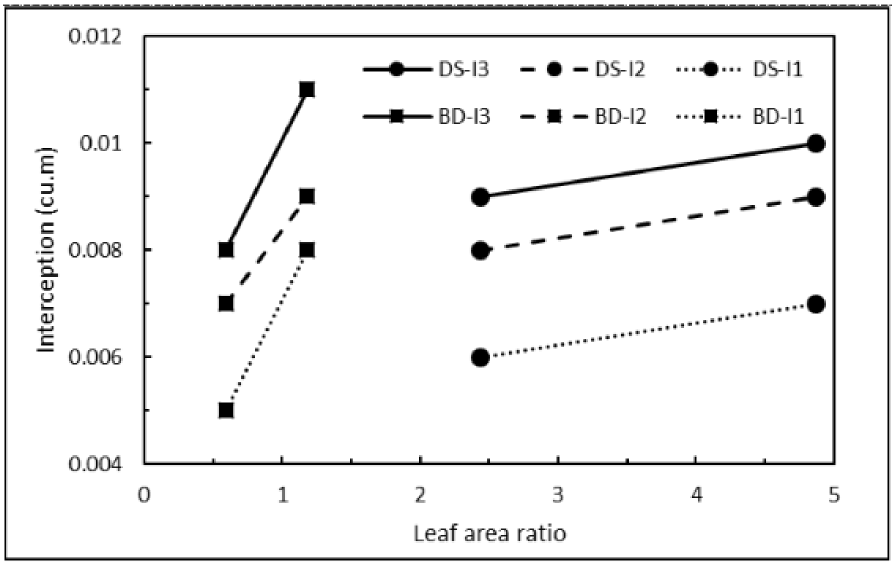

Fig. 9. Interception as a function of leaf area ratio

4. Conclusions

Study of interception characteristics of two (2) tropical plants, Dracaena Sanderiana and Breynia Distincha, were conducted using standard hydrology apparatus. Results show increased interception with rainfall intensity but at reducing rate. Runoff begins earlier and takes longer time to discharge completely for higher rainfall intensity. High plant density increases interception but the effect measured in terms of canopy cover ratio and leaf area ratio reveals slightly different characteristics. The doubling effect of canopy cover ratio causes significantly higher increase of interception volume for Breynia Distincha, of which the actual interception is higher than Dracaena Sanderiana despite the lower value of canopy cover ratio. Examination of leaf area ratio corroborates higher interception by Breynia Distincha although the leaf area ratio for density density case is much lower than Dracaena Sanderiana. The finding contradicts the empirical correlation where canopy storage capacity is known to be proportional to the leaf area ratio (index). We conclude that the broad, soft and flexible leaf structure of Dracaena Sanderiana lends itself to promote water droplets coalescence and loss via stemflow whereas the relatively firm and horizontal leaves of Breynia Distincha can retain water better although they are smaller.

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