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Full Length Research Article

Assessing Water Absorption and Root-Shoot Dynamics of Native Philippine Tree Species for Flood Mitigation and Environmental Management

Shiella Lynn Dali-on Goyo*, Victor Lobrigas Corbita, Glendel Cotejo Acog, Diana Rose Balaba, Jessa Joy Tomoc Estrada, Joel Andig Mercado

Department of Forestry, College of Forestry and Environmental Science, Caraga State University, Ampayon Butuan Philippines
* Corresponding Author. E-mail address: lalyndalion@gmail.com

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ABSTRACT

Over the years, excessive stormwater run-off has been a primary environmental concern in almost every part of the world. This study aimed to assess the water absorption capacity and root-shoot ratio of the three native species, namely *Vitex parviflora*, *Pterocarpus indicus*, and *Diospyrus discolor,* in the Philippines. The study used an experimental design with a total number of 63 experimental seedlings. After over a month of transplanting, the researchers collected the data by uprooting 1 sample per box and recording its weight. The uprooted samples were then submerged into a container with enough water, and the plant waited until it absorbed enough water before being weighed again. Root and shoot ratio were also computed using its dry weight. The results showed a significant difference in terms of absorption rate between the three native species. *V. parviflora* garnered the highest water absorption rate, followed by *P. indicus* and *D. discolor*. Root-shoot ratio was highest in *D. discolor* while lowest in *V. parviflora.* No significant correlation was found between root and shoot biomass regarding water absorption capacity. These findings highlight the importance of selecting specific tree species for environmental management and flood mitigation efforts in the Philippines.

1. Introduction

Excessive stormwater run-off has been a primary environmental concern in almost every part of the world. One of the misfortunes or natural calamities brought on by water overflowing in a dry area is a flood (Aldardasawi and Eren 2021) and is one of the calamities responsible for human life destruction that occurs in different places around the globe (Glago 2021). It has resulted in significant economic losses in various sectors because it transfers a range of contaminants into other channels, including fertilizers, pesticides, heavy metals from automobiles, and other pollutants that can impair human and wildlife health. Following widespread flooding, societal and policy concerns about flood risk and its consequences have grown significantly. Last November 2013, Super Typhoon Yolanda killed almost 6,300 individuals, and the total economic loss was estimated at USD 13 billion (Athawes 2018).

Trees are well known for their ability to manage run-off because they generously absorb rainfall and retain some of it on their leaves and bark. Additionally, their underground roots hold the soil in place and encourage infiltration, which is crucial in lowering the quantity of surface run-off that could potentially result in catastrophic flooding (Blezniuc et al. 2024). Depending on its size and species, a single tree may hold 100 liters of water in its bark, according to (Siegert and Ilek 2022), at least until it saturates after one to two inches of rain. Siegert and Ilek (2022) added that urban trees can help reduce an estimated 2–7% of annual run-off. Also, depending on precipitation and soil water availability, mature trees utilized 45–69 times more water than saplings during maximum water uptake (Mata-González et al. 2020). As a result, increasing tree cover is recommended as an effective way of enhancing the storage capacity of catchment areas to extend the lag time, lower watercourse discharge, and reduce the risk of flooding (Dixon 2016). The importance of trees in stormwater retention and the advantages to public health and municipal budgets should be recognized. It is another reason tree planting and conservation are important in our communities.

The Philippine government has implemented some policies to pursue sustainable development for the conservation of biodiversity and climate change mitigation and adaptation through Executive Order Number 26 series of 2011, known as the National Greening Program (NEDA 2022). Over six years, from 2011 to 2016, 1.5 billion trees, or around 1.5 million hectares, will be planted under this decree, but then extends to 2028 through Executive Order 193 series of 2015, inside the different public domain lands. Some groups support restoring forests and other land use management initiatives by using native species; however, policies and initiatives that do not adequately recognize or comprehend the ecological roles of native species have resulted in reforestation efforts that utilize exotic species (FOFO 2022). Unlike invasive species, native trees have improved timber production, agroecosystems, and the preservation and restoration of diverse forest ecosystems (Milan 2020). The ability of trees to intercept water when it is raining plays a vital role in nature and humans. Native trees are essential for capturing rainwater and lowering stormwater flow in urban and rural areas. According to research, the rate at which different tree species intercept precipitation varies; some can intercept as much as 60.9% of total precipitation (Asadian and Weiler 2009). Some native trees are more effective at harvesting cloud water droplets than invasive species (Takahashi et al. 2011). Other studies also showed that a mix of native species effectively decreases run-off in green roof systems (Fai et al. 2015), and enrichment planting drastically reduces surface water flow, soil erosion and nutrient loss (Chu et al. 2019). Native forests are vital in regulating hydrologic processes like infiltration, overland flow, and evapotranspiration (Meli et al. 2024). When invasive species replace native forests, hydrological processes may change, affecting nearby ecosystems and water supplies and decreasing the amount of water available for groundwater recharge (Catford 2017; Takahashi et al. 2011). These emphasize how crucial native species are to preserving eco-hydrological processes and how invasive species may have detrimental effects on run-off and water retention.

Narra *(Pterocarpus indicus*), molave (*Vitex parviflora*), and kamagong (*Diospyros discolor*) are three of the Philippines' most promising native species. *P. indicus* is a well-known native leguminous tree in the Philippines (Flores et al. 2021), used for reforestation and agroforestry (Sandoval 2019). Another is *V. parviflora*, which is best suited for afforestation and is regarded as the flagship species in Bohol because of its hardness and durability (Lomosbog and Gamil 2015). Furthermore, the *D. Discolor* is utilized for windbreaks and is regarded as one of the Philippines' toughest woods. This study aims to determine the water absorption rate and root and shoot ratio of the three native species in the Philippines.

2. Materials and Methods

2.1. Experimental Design

Three replications totaling seven sample seedlings each were used in a completely randomized design of this experiment. *V. parviflora*, *P. indicus*, and *D. discolor* were the three native species of the Philippines used in this study. The average annual humidity and precipitation at Barangay Baobaoan Butuan City, Agusan del Norte, Philippines, where this study was conducted, are 82.55% and 81.27 mm, respectively (Weather and Climate 2024). The three native species' shoot-to-root ratios and rates of water absorption were considered.

2.2. Seedlings Preparation

The Provincial Environment and Natural Resources Office (PENRO) in Agusan del Norte was contacted to obtain the seedlings used for the study. Each species had 21 seedlings, for a total of 63 seedlings that were 6 months old and had identical heights between 30 and 40 cm. The seedlings were then transferred to the experimental boxes filled with loam soil measuring 2 m × 1 m with 0.5 m depth. The seedlings were then randomly transplanted inside the box and were placed in an open area where they could get enough sunlight. The seedlings were acclimatized and watered regularly for more than two months.

2.3. Data Gathering Procedures

This study assessed the water absorption capacity and root and shoot ratio of the three native species. After an acclimatization period of over two months, we started collecting data for the water absorption capacity by randomly uprooting one seedling per replicate. The uprooted seedlings were washed to remove the soil from their roots and weighed using a digital scale (mass 1). After recording its weight, it was submerged into a container with enough water and waited for 20 minutes until the plants absorbed enough water and then weighed again (mass 2). After 15 to 20 minutes, the plants absorb the exact amount of water they need, never too little or too much (Nguyen 2022). The process was repeated every day for 21 consecutive days by uprooting one seedling per species per replicate every 6 am, where evaporation is still low. The potential water uptake was determined by computing the difference between mass before and after submergence. The water absorption rate was computed using the adapted and modified Equation 1:

$$Wa = \frac{Wf - Wi}{Wi} \tag{1}$$

where Wa is the water absorption, Wf is the weight of the plant after immersion (g), and Wi is the weight of the plant before immersion (g) (Harouna et al. 2019).

The root portion used in this study was taken from the root collar down to the root tip. The dry weights of the roots and shoots were measured using a digital weighing scale, and they were oven-dried at 80°C until they reached their constant weight. Its roots were cut off from its shoots. Equation 2 was used to determine the root-shoot ratio (RSR) (Corbita et al. 2024):

$$RSR = \frac{\text{Dry weight of roots}}{\text{Dry weight of shoots}} \tag{2}$$

2.4. Data Analysis

The water absorption and root-shoot ratio data were analyzed using a one-way analysis of variance (ANOVA) to determine if there were statistically significant differences between the means of different native tree species. The ANOVA test was appropriate for comparing the variability within and between groups, with a significance level of $p < 0.05$. Moreover, a Pearson correlation analysis assessed the strength and direction of the linear relationships between continuous variables. Pearson's correlation coefficient (r) was computed, with values ranging from -1 to 1, where positive values indicate a direct relationship and negative values indicate an inverse relationship. Statistical significance was considered at $p < 0.05$. ANOVA and correlation analysis were conducted using the freeware statistical tool for agricultural research (STAR) version 2.0.1. (IRRI 2014).

3. Results and Discussion

3.1. Water Absorption Capacity

Fig. 1 shows the mean water absorption rate of the three native species. The result revealed that *V. parviflora* garnered the highest water absorption rate among the two other species with 0.40 g, followed by *P. indicus* with 0.26 g, and the lowest was *D. discolor*, which garnered 0.23 g. This result suggests that *V. parviflora* absorbs water more efficiently than *P. indicus* and *D. discolor*, making it a promising species for flood mitigation. Not all trees, plants, and shrubs absorb the same amounts of water; some can use more water than others (Ringers 2021). In a study conducted by Burcer et al. (2021), they examined the root growth potential of *V. parviflora* among other species. They found that root-pruned seedlings developed new and longer roots, contributing to higher root biomass. The higher the root biomass, the higher the water absorption rate.

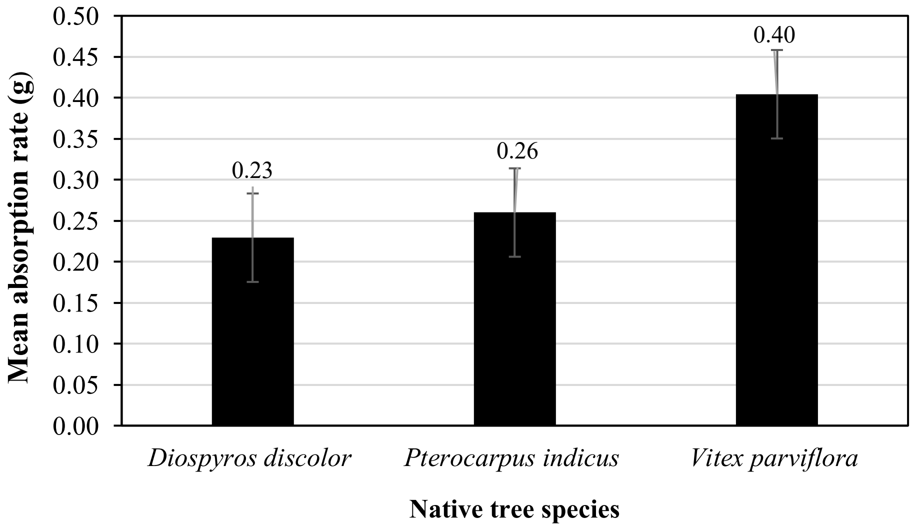

Fig. 1. Water absorption rate of the three native species.

High water-absorbing plants are more efficient in transpiration, whereas trees play a crucial role in the water cycle by transpiring water into the atmosphere (Ekhuemelo et al. 2016). Differences in water absorption among plants are attributed to the deposition of suberized barriers in root anatomical structures, which can vary in composition, microstructure and localization

(Kreszies et al. 2018). Although there is a lack of studies specifically focusing on the root anatomical structures of *V. parviflora* in relation to its water absorption capacity, the species is recommended for reforestation due to its high water-use efficiency (Rebugio et al. 2016). Its xylem tissues are well-developed, ensuring efficient water transport from the roots to the leaves, even in dry environments. Additionally, the roots of *V. parviflora* can form symbiotic relationships with mycorrhizal fungi, which enhance nutrient absorption efficiency (Tulod et al. 2012).

Table 1 shows a significant difference in the water absorption rate among three native species after submerging. These results may be due to differences in their morphological and physiological properties (Shafaei et al. 2016). Research has also shown that fast-growing tree species typically transpire faster than slow-growing tree species (Liu et al. 2021; Tardieu and Parent 2017). This phenomenon frequently results in lower soil water content (Evaristo and McDonnell 2019) and higher water uptake rates for the fast-growing species (Hong et al. 2020; Krishnaswamy et al. 2013). Fast-growing species may move more water and absorb more carbon because they have stronger hydraulic conductivity and photosynthetic capability (Lamour et al. 2023; Wang et al. 2024). These species have increased stomatal conductance and invest more nitrogen in photosynthetic machinery, which promotes rapid growth (Lamour et al. 2023). *V. parviflora* is considered a growing species, while *P. indicus* and *D. discolor* are slow-growing species (Aguilos et al. 2020).

Table 1. ANOVA in the water absorption rate among three native species

Native Species (I)	Mean Native Specie (J)	Mean Difference (I-J)	Test statistics	p-value	Remark
P. indicus	*V. parviflora*	−0.237	−8.287	< 0.001	Significant
	D. discolor	−0.099	−3.467	0.008	Significant
V. parviflora	*D. discolor*	0.138	5.311	< 0.001	Significant

3.2. Root-Shoot Ratio

The weight ratio of a plant's roots to its top is commonly expressed as the root-shoot ratio (Qi et al. 2019). **Fig. 2** shows that *D. discolor,* with a value of 0.370 g, has the greatest value, followed by *P. indicus* (0.237 g) and *V. parviflora* (0.236 g) at the lowest. One of the most important metrics for assessing the health of plants is the root-shoot ratio (Agathokleous et al. 2019), which is influenced by factors like fertilization and irrigation (Bláha 2019; Yang and Zhou 2010). Variations in this ratio can depend on species and their environmental adaptations. For instance, species adapted to nutrient-poor soils often exhibit a higher root-shoot ratio to enhance water and nutrient absorption (Lopez et al. 2023). Nutrient availability plays a key role in determining root-shoot ratios (Kudoyarova et al. 2015; Roycewicz and Malamy 2012; Sathiyavani 2017). Nutrient deficiencies, particularly in nitrogen and phosphorus, increase the ratio in arable crops (Lopez et al. 2023). Conversely, a higher phosphorus supply promotes shoot growth more than root growth, resulting in a lower root-shoot ratio (Kim and Li 2016).

Additionally, biomass partitioning is influenced by seed mass, with larger seeds generally leading to lower root-shoot ratios and greater nutrient-use flexibility (Mašková and Herben 2018). However, the results of this study contradict this trend. Among the three native species, *D. discolor* has the largest seed yet exhibits the highest root-shoot ratio (0.370g), opposite to the expected pattern. This implies that root-shoot allocation in these species may be more influenced by variables other than seed mass, such as species-specific growth tactics, environmental influences, or genetic adaptations. It is possible that *D. discolor* prioritizes root growth despite its larger seed size to enhance water and nutrient uptake, potentially as an adaptive response to its natural habitat.

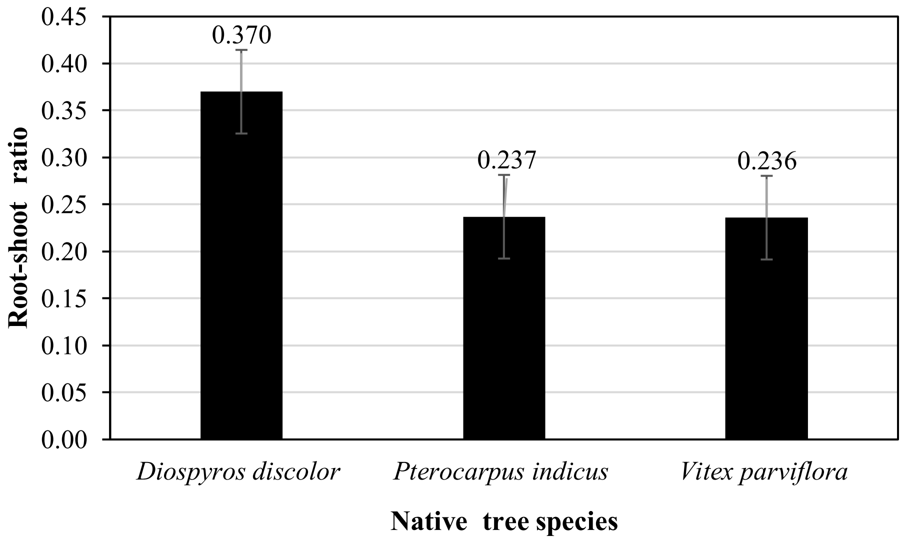

Fig. 2. Root-shoot ratio of the three native species.

This ratio significantly impacts a plant's ability to absorb water and nutrients. A high root-shoot ratio may limit the growth of the plant's leaf area (Poorter and Ryser 2015), potentially reducing its photosynthetic rate. However, in some cases, a high root-shoot ratio benefits plants by allowing them to access deeper soil layers, promoting higher above-ground biomass and greater stress resistance (Bláha 2019). The lower root-shoot ratio of *V. parviflora* suggests that it allocates more biomass to shoots, potentially requiring nutrient-rich soils for optimal growth (Mašková and Herben 2018).

3.3. Correlation between Water Absorption and Root-Shoot Ratio

Table 2 shows the correlation between water absorption and the root-shoot ratio. The results reveal a moderately negative correlation (r ≈ -0.643), suggesting that as the plant's water absorption capacity increases, there is a tendency for the root-shoot ratio to decrease.

Table 2. Pearson correlation between water absorption capacity and root shoot ratio of three native species

Variable		Correlation coefficient	Remarks	p-value	Remarks
Water absorption	Root-shoot ratio	-0.6429	Negatively correlated	0.5555	No significant relationship

This negative correlation implies that plants with greater water uptake allocate relatively more resources to shoot growth than root growth. This finding aligns with general plant physiology. Under conditions where water is readily available, plants prioritize shoot growth (e.g., leaf and stem development) to maximize photosynthetic activity, as more shoots and leaves increase the surface area for light absorption and carbon fixation. This is consistent with the theory that plants reduce their need for extensive root systems when water is abundant because the roots' primary function—water and nutrient uptake—can be achieved without a large root mass (Li et al.

2024; Poorter et al. 2012). Also, it is possible for some species to increase water absorption by reducing the root-shoot ratio (Yan et al. 2022). Despite the observed correlation, the test results show that the relationship is not statistically significant ($p > 0.05$).

4. Conclusions

Based on the results, it can be concluded that each native tree's water absorption capability varies greatly. *V. parviflora* had the highest water absorption rate, while *D. discolor* exhibited the highest root-shoot ratio. However, no significant correlation was found between root-shoot ratio and water absorption. Interestingly, *D. discolor* had a higher root-shoot ratio despite its larger seed size, contradicting existing literature. This suggests that species-specific adaptations may influence biomass allocation more than seed mass alone. *V. parviflora* may be ideal for rapid water uptake, while *D. discolor* could benefit deeper soil stability. Further studies should focus on understanding root-shoot dynamics and water-use efficiency under actual field conditions to assess better these species' potential for flood mitigation and environmental management.

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Author Contributions

These are the contributions of the following authors: S.L.D.G.: Conceptualization, methodology, supervision, data curation, writing – original draft preparation, review and editing; V.L.C: Conceptualization, data analysis, writing – review and editing; G.C.A.: Methodology, data curation, writing – original draft preparation; D.R.B.: Methodology, data curation, writing – original draft preparation; J.J.T.E.: Methodology, data curation, writing – original draft preparation; J.A.M: Methodology, Writing- original draft preparation.

Conflict of Interest

The authors declare no conflict of interest.

Declaration of Generative AI and AI-Assisted Technologies in the Manuscript Preparation

During the preparation of this work, the authors used Quillbot.com, a paraphrasing tool, to smartly enhance the clarity of the writing, making it easy for the readers to understand and avoid plagiarism. After using this tool/service, the authors reviewed and edited the content as needed and took full responsibility for the publication's content.

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