

## PHYSICOCHEMICAL CHARACTERISTICS OF SELECTED PALMYRA PALM GERMPLASM

MD NASAR UDDIN CHOWDHURY, MAHBUB ROBBANI, LITUN AHMED LABIB<sup>1\*</sup>  
AND SWAGATA AHMED

*Department of Horticulture, Patuakhali Science and Technology University,  
Patuakhali-8602, Bangladesh*

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### Abstract

The palmyra palm (*Borassus flabellifer* L.) is a climate-resilient, low-maintenance crop with significant nutritional and commercial importance. This study evaluated the physicochemical properties of four locally available palmyra palm germplasm types -PP<sub>1</sub> (blackish-yellow), PP<sub>2</sub> (blackish-red), PP<sub>3</sub> (light-black), and PP<sub>4</sub> (deep-black) collected from Dumki Upazila, Patuakhali to identify the most promising variety. Significant ( $p \leq 0.05$ ) variation was observed among the germplasms in both physical and chemical attributes. PP<sub>1</sub> recorded the highest fruit weight (1513.50 g), while PP<sub>2</sub> exhibited superior juice yield (503.20 ml), pulp-to-peel ratio (7.28:1), total soluble solids (20.14%), total sugar (5.68%), titratable acidity (0.331%), carotene content (35.06 mg/100 g FW), and total phenolic content (9.28 mg GAE/g). In contrast, PP<sub>3</sub> showed the lowest values in most parameters. The combination of high nutritional content and favorable processing attributes identifies PP<sub>2</sub> as the most promising germplasm for both nutritional enhancement and commercial exploitation. These findings provide a scientific basis for selecting superior palmyra palm varieties to promote cultivation and value-added product development in Bangladesh.

### Introduction

Palmyra palm (*Borassus flabellifer* L.), is an economically and ecologically important plant widely distributed across tropical and subtropical regions of the world (Eiserhardt *et al.* 2011). In Bangladesh, it is commonly known as 'Taal' and grows sporadically throughout the country, particularly in Pirojpur, Jessore, and Feni (Rana and Islam 2010). It is often found along roadsides, canals and river embankments, farm boundaries, and around homesteads. The fruit is rich in nutrients and possesses a broad spectrum of pharmacological properties including antidiabetic, hypocholesterolemic, antioxidant, antimicrobial, wound healing, anticancer, and mosquito larvicidal activities (Prasad *et al.* 2023, Mahilrajana *et al.* 2025). Notably, the palmyra palm is highly resilient to climatic variability and natural hazards (Rahman *et al.* 2025). It is a long-lived tree, capable of reaching heights up to 30 meters and living for over 100 years (Subramanian *et al.* 2024).

Bangladesh is a densely populated country with a population of 171.59 million, where more than 30% of people live in extreme poverty (Subramanian *et al.* 2024). As a result, malnutrition, particularly among children, is a significant concern (Haque *et al.* 2017). In such conditions, locally available fruits can serve as an ideal solution (Labib *et al.* 2025). The fruit of the palmyra palm is consumed at both immature and ripe stages. Immature fruits provide carbohydrates, dietary fiber, and a significant amount of energy (Mary and Jasmin 2022). Furthermore, immature fruits contain several phytochemicals with antioxidant and antidiabetic properties (Renuka *et al.* 2018). Ripe fruits are rich in vitamins A and C and contain high levels of calcium, magnesium, potassium, iron, and phosphorus, along with carbohydrates, protein, fat, and crude fiber

\*Author for Correspondence: <labibpstu@gmail.com>. <sup>1</sup>Crop Care Division, Square Pharmaceuticals PLC, Dhaka, Bangladesh.

(Mahilrajan *et al.* 2025). The fiber obtained from ripe palmyra fruit is used in the textile and paper industries as an alternative to synthetic materials (Rahman *et al.* 2024).

Several ripe palmyra palm germplasm become available during the season. However, consumers often face difficulty in identifying the best germplasm. The identification of promising palmyra palm germplasm would benefit both consumers and small-scale industries by enabling the selection of varieties tailored to specific needs. Therefore, the primary objective of this study was to characterize the commonly available palmyra palm germplasm based on their physical and nutritional properties in order to identify, select and conserve superior germplasm.

### Materials and Methods

Commonly available germplasms of ripe palmyra palm were collected from Patuakhali, Bangladesh. The geographical coordinates of the site are 22°26' N latitude and 90°22' E longitude, at an altitude of 3 meters above sea level. Physicochemical characterization was conducted at the Postharvest Laboratory of Patuakhali Science and Technology University, Patuakhali-8602, Bangladesh. The study was carried out from July 2024 to June 2025. Four commonly available types of ripe germplasms were collected (Fig. 1). The collected germplasms were coded as PP<sub>1</sub> - blackish yellow, PP<sub>2</sub> - blackish red, PP<sub>3</sub> - light black, and PP<sub>4</sub> - deep black. All analyses were conducted at room temperature under ambient air conditions.

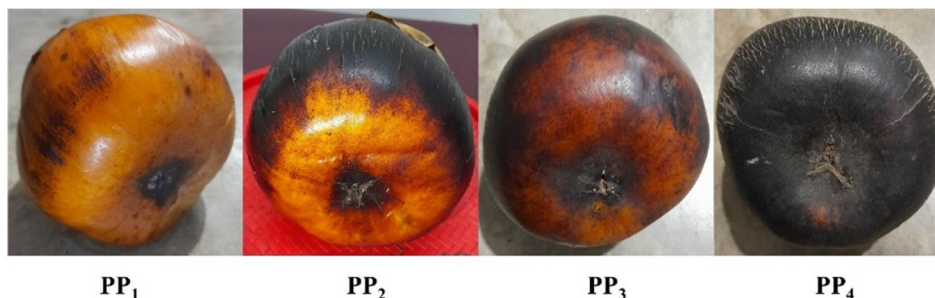


Fig. 1. Pictorial view of collected palmyra palm germplasm.

The physical qualities of each germplasm sample were evaluated by separating the fruit into four components: peel, pulp, fiber and seed. The total fruit weight and the weight of each component were measured individually using a digital balance (Model DJ-220 A, Japan) and recorded in grams (g). Juice was extracted from the pulp and its volume was measured in milliliters (ml). The residual fiber after juice extraction was also weighed. The pulp-to-peel ratio was calculated using the formula of Musa *et al.* (2024).

The nutritional qualities of pulp from the selected germplasms were analyzed to determine pH, total soluble solids (TSS), total sugar, titratable acidity (TA), carotene content and total phenolic content. The pH was measured using a glass electrode pH meter (Model GLP 21, Crison, Barcelona, EEC). TSS was determined with a digital refractometer (BOECO, Germany) and expressed as a percentage. Total sugar content (%), TA (%), carotene content (mg/100 g fresh weight), and total phenolic content (mg GAE/g) were estimated following the methods described by Paul *et al.* (2023) and Ahmed *et al.* (2024).

The experiment was arranged in a Completely Randomized Design (CRD) with five replications. Analysis of variance (ANOVA) was performed using JMP 14 statistical software (JMP® 14, SAS Institute Inc., Cary, NC, 1989-2021). Mean differences were determined using Tukey's Honest Significant Difference (HSD) post hoc test.

## Results and Discussion

Significant variation was observed in fruit weight, peel weight, fiber weight, seed weight, juice content, and pulp-to-peel ratio (Fig. 2). The average fruit weight of PP<sub>1</sub> was the highest (1513.04 g), while PP<sub>4</sub> had the lowest weight (901.36 g). PP<sub>2</sub> and PP<sub>3</sub> weighed 1193.74 g and 1124.00 g, respectively. Vengaiah *et al.* (2021) reported that individual palmyra palm fruit mass is approximately 927.78 g. Ali *et al.* (2010), in their study of morphological characteristics of palmyra palm fruits, found that the whole fruit weighed  $1324.55 \pm 85.99$  g in Kousseri and  $1270.04 \pm 116.69$  g in the Ngaoundere regions of Cameroon. The variation in fruit weight was attributed to the differences in germplasm size. The maximum peel weight (143.33 g) was recorded in PP<sub>1</sub>, followed by PP<sub>3</sub> (129.40 g) and PP<sub>2</sub> (112.20 g), with no significant statistical difference among them. The lowest peel weight (103.80 g) was found in PP<sub>4</sub>. The germplasm also showed distinct variations in fiber and juice content. Germplasm with higher juice content typically had lower peel weight which accounted for the differences observed among the germplasm (Shahkoomahally *et al.* 2021, Li *et al.* 2024). The highest fiber weight (29.78 g) was observed in PP<sub>3</sub>, while the lowest (11.65 g) in PP<sub>1</sub>. The fiber weights of PP<sub>4</sub> and PP<sub>2</sub> were 23.89 and 20.13 g, respectively. This significant variation in fiber weight among germplasm was primarily due to differences in juice content (Campbell *et al.* 2021) as higher juice content is associated with lower fiber content (Singh *et al.* 2023). Germplasm PP<sub>1</sub> had the highest seed weight (730.60 g), followed by PP<sub>3</sub> (694.87 g), PP<sub>2</sub> (559.41 g), and PP<sub>4</sub> (475.74 g), with PP<sub>4</sub> having the lowest. According to Vengaiah *et al.* (2021) seeds account for approximately 46% of the total fruit weight. Differences in seed weight were likely due to variations in size and shape among the germplasm (Han *et al.* 2025). PP<sub>2</sub> had the highest juice content (503.49 ml), while PP<sub>3</sub> had the lowest (269.68 ml). Juice content in PP<sub>1</sub> and PP<sub>4</sub> was 455.64 ml and 297.58 ml, respectively. The highest pulp-to-peel ratio (4.49:1) was observed in PP<sub>2</sub>, and the lowest (2.08:1) in PP<sub>3</sub>. The ratios for PP<sub>1</sub> and PP<sub>4</sub> were 3.18:1 and 2.87:1, respectively. The high pulp-to-peel ratio in PP<sub>2</sub> was due to its low peel weight and high juice content.

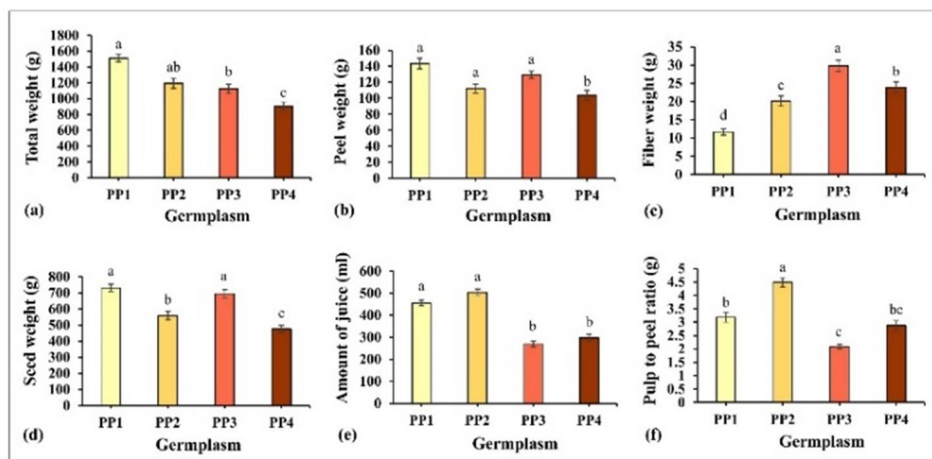


Fig. 2. Physical properties of palmyra palm germplasm. Different lowercase letters indicate significant differences ( $p \leq 0.05$ ). The vertical bars represent standard error.

The germplasm also exhibited significant differences in pH, TSS, total sugar, TA, carotene content, and total phenolics (Fig. 3). The highest pH (6.32) was recorded in PP<sub>4</sub>, followed by PP<sub>3</sub> (6.10) and PP<sub>2</sub> (5.29). The lowest pH (5.06) was observed in PP<sub>1</sub>. Wiboonsirikul (2024) reported a

pH range of 5.5 to 6.0. PP<sub>2</sub> exhibited the highest TSS (15.83%), while PP<sub>4</sub> had the lowest (10.27%). The TSS values for PP<sub>3</sub> and PP<sub>1</sub> were 12.82 and 11.98%, respectively. TSS in palmyra palm pulp ranged from 14.58-19.66% (Saranya *et al.* 2015). Total sugar content also showed significant variation among the germplasm. PP<sub>2</sub> had the highest value (5.68%), and PP<sub>1</sub> had the lowest (4.51%). The values for PP<sub>3</sub> and PP<sub>4</sub> were 4.63 and 5.15%, respectively. Allwin *et al.* (2023) reported total sugar content ranging from 4.47 to 5.62% in palmyra palm fruit. The high TSS content in PP<sub>2</sub> was consistent with its high sugar content, in agreement with the findings of Fukudome *et al.* (2022). Titratable acidity (TA) was highest in PP<sub>2</sub> (0.331%) and lowest in PP<sub>3</sub> (0.276%). The TA values for PP<sub>1</sub> and PP<sub>4</sub> were 0.302 and 0.289%, respectively. The TA values for PP<sub>3</sub> and PP<sub>4</sub> were statistically non-significant. Carotene content was also significantly different among the germplasm. PP<sub>2</sub> had the highest carotene content (32.93 mg/100g Fw), and PP<sub>4</sub> had the lowest (19.31 mg/100g Fw). PP<sub>1</sub> and PP<sub>3</sub> had carotene levels of 28.28 mg/100g Fw and 22.58 mg/100g Fw, respectively. Sangeetha *et al.* (2023) reported a carotene range of 15.5-35.4 mg/100g Fw in palmyra palm fruit. PP<sub>2</sub> also had the highest total phenolic content (7.82 mg GAE/g), while PP<sub>3</sub> had the lowest (5.36 mg GAE/g). PP<sub>1</sub> and PP<sub>4</sub> had phenolic contents of 6.39 mg GAE/g and 5.98 mg GAE/g, respectively. Selvakumar *et al.* (2020) reported phenolic content values of 9.297 mg GAE/g in the Anamaduwa region and 5.134 mg GAE/g in the Batticaloa region of Sri Lanka.

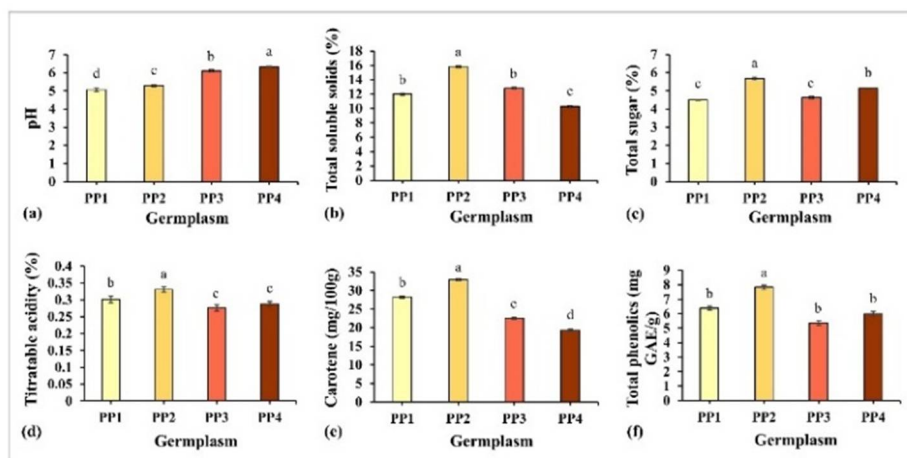


Fig. 3. Nutritional properties of palmyra palm germplasm.

Pearson correlation analysis revealed significant associations among various physicochemical attributes of the palmyra palm germplasm (Fig. 4). A strong positive correlation ( $p < 0.01$ ) was observed between pulp-to-peel ratio, titratable acidity, total phenolic content, juice yield, carotene content, and total soluble solids. Additionally, a significant positive correlation ( $p < 0.05$ ) was found among pH, fiber weight, peel weight, seed weight, total fruit weight, titratable acidity, total phenolics, and total sugar content. Conversely, seed weight and peel weight exhibited a significant negative correlation ( $p < 0.05$ ) with total sugar. A strong negative correlation ( $p < 0.05$ ) was also found between pH, fiber weight, carotene content, amount of juice, titratable acidity, and total fruit weight. The remaining parameters did not exhibit statistically significant associations. Principal Component Analysis (PCA) further elucidated the relationships among traits (Fig. 5). The first principal component (PC1) accounted for 57.5% of the total variance and was strongly associated with juice yield, carotene content, total fruit weight, peel weight, and seed weight. The second principal component (PC2), explaining 34.2% of the variance, was positively correlated with fiber

weight and pH. The spatial distribution of germplasm based on PCA revealed distinct groupings, suggesting considerable phenotypic diversity among the evaluated accessions. These correlations and multivariate patterns highlight key parameters influencing the nutritional and economic potential of the palmyra palm, with PP<sub>2</sub> emerging as the most promising germplasm.

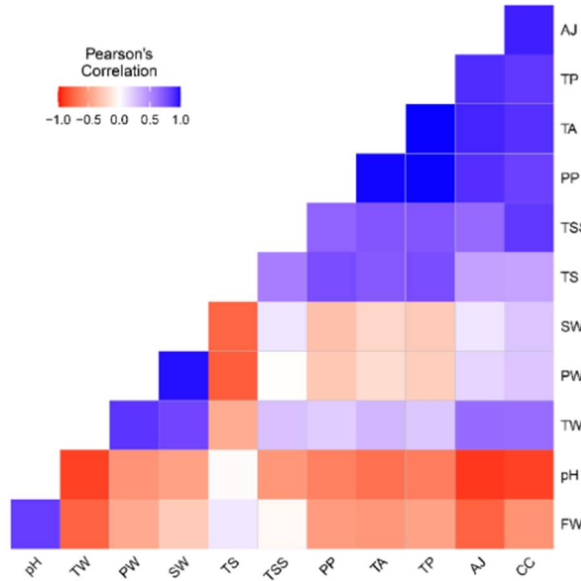


Fig. 4. Pearson (n) correlation between various parameters of in palmyra palm germplasm. TW : Total weight, PW : Peel weight, FW : Fiber weight, SW : Seed weight, AJ : Amount of juice, PP : Pulp to peel ratio, TSS: Total soluble solids, TS : Total sugar, TA : Titratable acidity, CC : Carotene content, TP : Total phenolics.

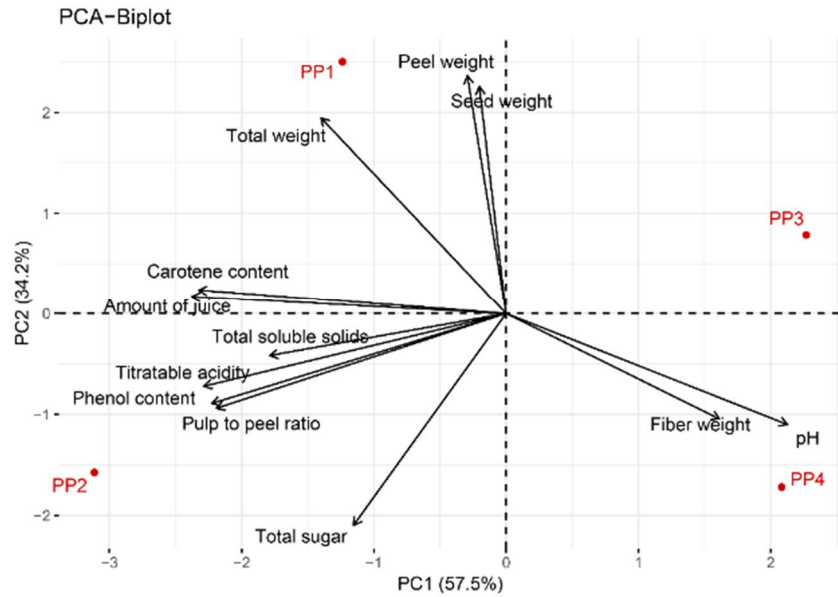


Fig. 5. Principal component analysis (PCA) of palmyra palm across various physicochemical parameters.

This study evaluated the physicochemical properties of palmyra palm germplasm to identify the most promising variety for nutritional and commercial use. Among the tested types, germplasm PP<sub>2</sub> consistently outperformed the others in key parameters, including juice yield, pulp-to-peel ratio, TSS, total sugar, TA, carotene, and phenolic content. These traits highlight its superior quality, greater sweetness, and potential health benefits. Therefore, PP<sub>2</sub> emerges as the most suitable germplasm for large-scale cultivation and commercial processing, particularly for juice and food product development. Further agronomic and postharvest evaluations are recommended to optimize its use and unlock its full economic potential.

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