**Evaluation of wood apple genotypes for yield traits under Tamil Nadu condition**

***Abstract***

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| **Aim:** Wood apple (*Feronia limonia* L.) is a hardy, indigenous fruit crop with significant nutritional and medicinal properties. Despite its adaptability to adverse agro-climatic conditions and its utility in traditional medicine and dryland horticulture, the species remains underexploited due to limited research on its genetic potential. This study aimed to evaluate the genetic variability in yield-related traits among selected wood apple genotypes to identify superior types for varietal development.  **Methodology:** Field evaluation was carried out at the Department of Fruit Science, Horticultural College and Research Institute, Tamil Nadu Agricultural University (TNAU), Periyakulam, over five years (2019–2024). Nine genotypes (WFL-01 to WFL-09), selected from preliminary germplasm collections for their promising yield and quality traits, were assessed under a Randomized Block Design (RBD) with three replications. Morphological and yield-related parameters were recorded using standard procedures.  **Results:** Significant variability was observed among genotypes for all measured traits. Fruit length ranged from 6.80 to 11.00 cm, fruit width 6.90 to 10.00 cm, and fruit weight 150.00 to 470.00 g. Pulp weight varied from 75.00 to 340.00 g, with seed count ranging from 170 to 620. Shell thickness was between 0.28 and 0.40 cm. Yield per tree varied notably from 33.00 to 150.40 kg, and projected yield ranged from 7.20 to 30.80 t ha⁻¹.  **Conclusion:** Among the evaluated genotypes, WFL-03 demonstrated the highest performance across all yield attributes, followed closely by WFL-08 and WFL-04. The considerable variation observed suggests a high degree of genetic diversity, offering significant opportunities for selection and genetic improvement in wood apple. These findings hold practical relevance for commercial cultivation, breeding programs, and sustainable utilization of this underutilized fruit crop. |

***Keywords:*** *Wood Apple, Genetic Diversity, Yield Traits.*

1. INTRODUCTION

Wood apple (*Feronia limonia* L.), a monotypic species of the family Rutaceae with 2n = 18 chromosomes (Shukla *et al*., 2024), is an indigenous underutilized fruit tree valued for its ecological resilience and multipurpose utility. Due to its diverse medicinal, nutritional, and industrial applications from pulp, leaves, and bark are traditionally used for their therapeutic properties such as treating digestive disorders, diabetes, respiratory problems, antimicrobial, antioxidant, anti-inflammatory, and hypoglycemic properties (Bagul *et al.,* 2019; Parvez and Sarker, 2021). Commonly grown in the wild or along field margins, this drought-hardy and salinity-tolerant tree thrives in arid and semi-arid zones, especially in the degraded soils of central and peninsular India and its distribution in states like Madhya Pradesh, Chhattisgarh, Uttar Pradesh, West Bengal, and Maharashtra (Shukla *et al*., 2024), organized cultivation of wood apple remains limited due to a lack of improved varieties and agronomic standardization.

The yield potential of wood apple is influenced by a complex interplay of genotypic and environmental factors. However, due to its semi-wild status, minimal domestication, and long juvenile phase, the crop suffers from wide variability in yield related traits such as number of fruits per tree, fruit weight, and pulp recovery. With increasing demand for nutritionally rich and climate-resilient crops, there is a pressing need to identify and evaluate elite genotypes with superior yield performance and adaptability to low-input systems. Previous studies have reported significant genetic diversity among wood apple accessions for traits like tree vigor, fruit size, pulp weight, and seed number (Singh *et al*., 2016). However, these evaluations were often localized and lacked a comprehensive multigenotypic comparison under uniform conditions. In this context, yield traits such as fruit weight, number of fruits per tree, shell thickness, pulp-to-fruit ratio, and total yield per plant serve as key indicators for selection and varietal improvement (Shukla *et al*., 2025).

Therefore, the present study was undertaken to assess the diversity in yield-contributing traits among selected wood apple genotypes collected from different agro-climatic regions. The objective was to identify high-yielding and agronomically promising accessions for potential use in breeding programs and commercial cultivation.

2. materials and methods

**Experimental details**

The present investigation on the evaluation of wood apple (*Feronia limonia* L.) genotypes was carried out at Central Block (10°07'21.8"N 77°35'28.3"E), Department of Fruit Science, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam, Tamil Nadu, India, during the period 2019–2024.The 15 years old promising genotypes (WFL-01 to WFL-09) were selected from diversity-rich regions across Tamil Nadu and established under *ex-situ* field gene bank conditions. The experiment was laid out in a Randomized Block Design (RBD) with an area of 0.35 acre and spacing of 7 X 7 m with three replications and standard cultivation practices were followed.

**Observation recorded**

**Fruit length (cm) & Fruit width (cm)**

A digital caliper was used to measure the fruit length (along the longest axis) and width (perpendicular to the length) of each fruit. Measurements were taken from freshly harvested fruits to ensure accuracy and recorded to the nearest millimeter (0.1 cm) (Takahashi *et al*., 2025; Neupane *et al*., 2023)

**Fruit weight (g)**

Individual fruits were weighed using a digital top-pan balance with a sensitivity of at least 0.01 g. The balance was properly calibrated before use, and the gross weight of each fruit was recorded consistently (Guo *et al*., 2021).

**Pulp weight (g)**

Each fruit was cut open, seeds were separated manually, and the clean pulp was weighed using an electronic balance. Mean pulp weight was calculated from ten fruits per tree (Tayde *et al*., 2024)

**Number of seeds per fruit**

Each fruit was cut open carefully, and all seeds were manually extracted and placed on labeled paper towels. Seeds were then individually counted to ensure accuracy (Dowarah *et al*., 2021)

**Shell thickness (cm)**

Shell thickness was measured using a digital caliper at multiple points on the fruit, including the equator, stem end, and stylar end. The average thickness was calculated for each fruit and recorded in centimeters (Guo *et al*., 2021).

**Number of fruits per tree**

All mature fruits on each sample tree were manually counted. In trees with dense canopies, fruits on representative branches were counted, and the total number per tree was extrapolated based on the total number of branches (Malik *et al*., 2016).

**Yield per tree (kg)**

All fruits from each tree were harvested and weighed. The total weight of fruits per tree was calculated and expressed in kilograms (kg) (Raut *et al*., 2023).

**Estimated yield per hectare (tons ha-1)**

The number of productive trees per hectare was recorded. The average yield per tree (in kg) was multiplied by the tree population per hectare, and the result was converted to tons to estimate the yield per hectare (ICAR-CIAH, 2020).

Yield (t ha-1) =

**Statistical analysis**

The pooled data recorded over multiple seasons were statistically analyzed using Analysis of Variance (ANOVA) in R software (version 2.4.1), employing the agricolae package for performing mean comparisons and experimental design analysis (De Mendiburu, 2020). Treatment means were compared at the 5% level of significance using the Critical Difference (CD) method to identify statistically significant differences among wood apple genotypes.

3. results and discussion

The data presented in Figure 1. revealed a wide range of variability among the evaluated wood apple genotypes for fruit morphological and yield-related attributes, indicating the presence of significant genetic diversity that can be exploited for selection and improvement.

**Fruit length (cm)**

Fruit length varied significantly among the genotypes, ranging from 6.8 cm in WFL-01 to a maximum of 11.0 cm in WFL-03. Genotypes WFL-04 and WFL-08 also showed relatively longer fruits with lengths of 9.5 cm each. The observed wide range in fruit length among wood apple genotypes showing notable lengths is primarily attributed to their considerable genetic diversity. Such variation is a valuable resource for breeders, as it enables selection of individuals possessing desirable traits, such as longer fruit, for improvement programs. Singh *et al*. (2016) underlined the reason for this variability lies in differences in the genetic makeup among genotypes, which influence fruit growth patterns, cell division rates, and ultimately, organ size. Environmental factors, while important, play a lesser role compared to genetic determinants in perennial and tree crops like wood apple. Comparable variability has been reported in bael (*Aegle marmelos*) and wood apple (*Feronia limonia*), where fruit length ranged from 4.60 cm to 14.86 cm among genotypes (Kumar *et al*., 2024).

**Fruit width (cm)**

Fruit width ranged from 6.9 cm in WFL-01 to 10.0 cm in WFL-03, indicating moderate variation among genotypes. WFL-04, WFL-05, and WFL-08 also recorded high fruit widths (9.2–9.7 cm), which often correlate with overall fruit volume and consumer preference. The observed variation in fruit width among wood apple genotypes, ranging from 6.9 cm to 10.0 cm, is mainly attributed to underlying genetic diversity, as genotypic effects predominantly determine fruit shape and size through regulation of cell division and expansion during fruit development. This finding aligns with studies such as Singh *et al*. (2016), who reported a similarly wide range of fruit widths (5.57–15.62 cm) in wood apple from Gujarat, attributing the variability to genetic factors. Big sized fruits tend to have more pulp and better market value.

**Fruit weight (g)**

The highest fruit weight was recorded in WFL-03 (470.45 g), followed by WFL-08 (460.65 g), while the lowest was seen in WFL-01 (150.23 g). The marked variation in fruit weight among wood apple genotypes primarily reflects underlying genetic diversity that controls fruit development and biomass accumulation, with genotypes exhibiting larger fruit dimensions (length/width) also displaying greater weights due to a positive allometric relationship among these traits. Such variability is consistent with observations in other fruit crops; for instance, considerable differences in fruit weight have been documented in bael genotypes, with weight ranges of 200-1000 g attributed to both genetic makeup and environmental influences (Dhakar *et al*., 2016). A high fruit weight is desirable in breeding programs aimed at improving productivity.

**Pulp weight (g)**

Pulp weight followed a similar trend to total fruit weight. WFL-03 had the highest pulp weight (340.5 g), while WFL-01 showed the lowest (75.13 g). The substantial variation in pulp weight among wood apple genotypes directly reflects differences in overall fruit size and highlights the influence of genetic factors governing both fruit development and compositional traits. This strong positive correlation between pulp weight and fruit size has also been observed in other fruit crops such as guava and bael, larger fruits tend to furnish greater pulp mass, thereby enhancing processing efficiency and product recovery a pattern emphasized as well in wood apple by Tayde *et al*. (2024), who noted that selecting for high pulp content is crucial for developing varieties suitable for juice and pulp-based industries.

**Number of seeds per fruit**

The number of seeds per fruit ranged widely from 170 in WFL-07 to 620 in WFL-03. The wide variation in the number of seeds per fruit among wood apple genotypes in your study is mainly due to underlying genetic diversity, where each genotype’s genetic makeup influences ovule development, fertilization success, and fruit-set physiology. Genotypes with low to moderate seed content are usually preferred for pulp extraction and consumer satisfaction, as excessive seeds can reduce edible pulp proportion and complicate processing. These findings align with similar studies in wood apple (Singh *et al*., 2016), who evaluated genotypes from the Bundelkhand and Awadh regions of India reported seed numbers ranging from as low as 103 to 657 per fruit, highlighting substantial genetic effects

**Shell thickness (cm)**

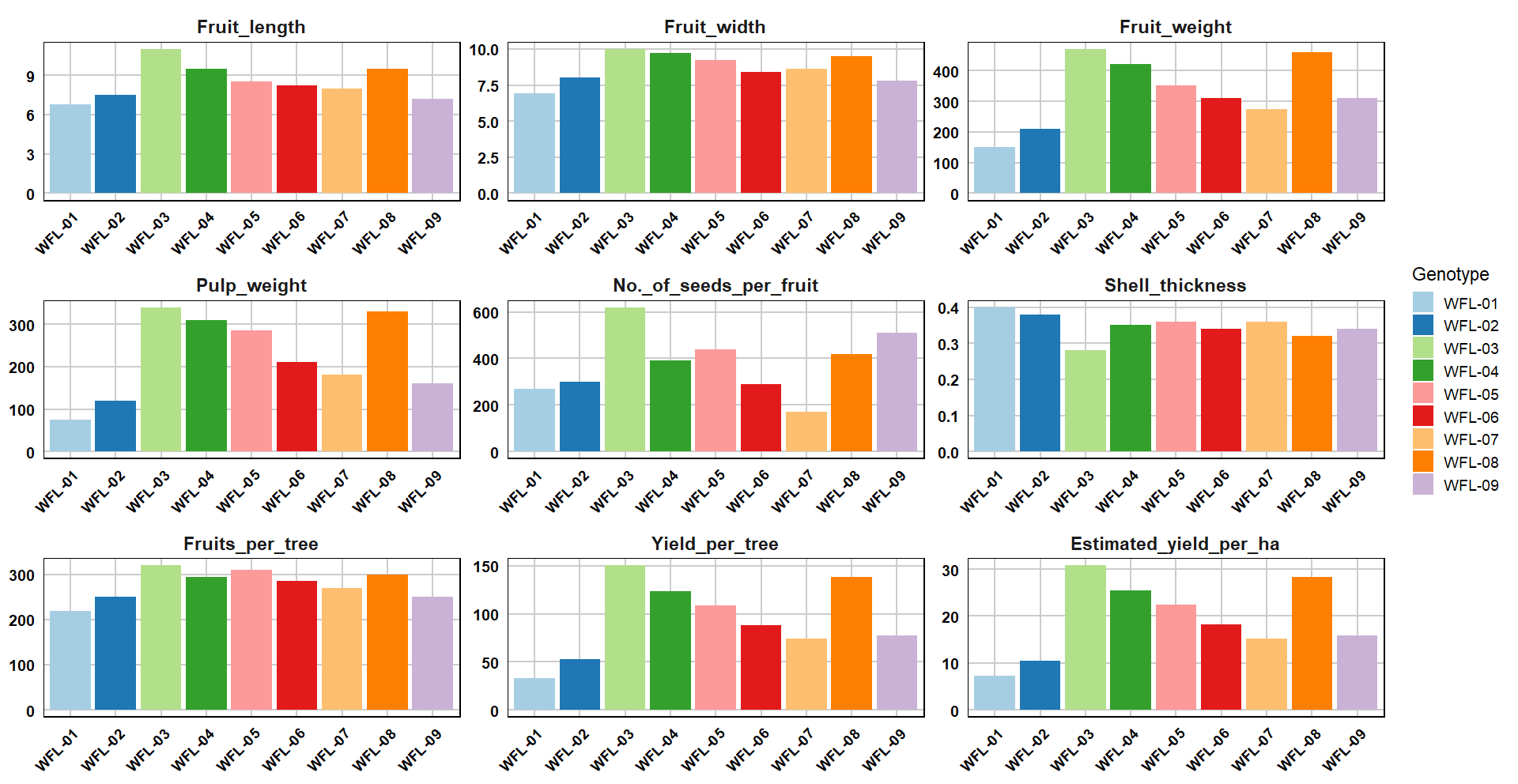
Shell thickness differed slightly but meaningfully across genotypes. The thickest shell was observed in WFL-01 (0.40 cm) and thinnest in WFL-03 (0.28 cm), which is advantageous for easier processing. The observed variation in shell thickness among wood apple genotypes is primarily reflects genetic differences that influence pericarp development and cell wall deposition during fruit maturation. Thinner shells, such as those found in WFL-03, are particularly advantageous for pulp processing industries as they reduce the effort and cost associated with shell removal and minimize processing waste. Similar patterns have been reported by Rajangam and Sankar (2022) in wood apple

**Number of fruits per tree**

The number of fruits per tree ranged from 220 (WFL-01) to 320 (WFL-03). WFL-03, WFL-05, and WFL-08 exhibited high fruit set potential, which contributes significantly to overall yield. Genotypes like WFL-03, WFL-05, and WFL-08, which exhibit higher fruit set potential, can significantly influence total yield through enhanced flower production and successful fruit retention. The variation in the number of fruits per tree among wood apple genotypes is driven by genetic differences that affect flowering capacity, fruit set, and overall reproductive potential. This genotypic variation in fruit-bearing ability under similar orchard conditions has also been documented in bael (*Aegle marmelos*), where fruit number per tree ranges widely due to inherent genetic and physiological factors regulating flowering and fruit development (Saroj *et al*., 2008). Similarly, studies on wood apple reported by Rajangam and Sankar (2022) confirm such diversity in fruit set capacity, which is often influenced by genetic controls over flowering phenology, hormone regulation, and resource allocation.

**Yield per tree (kg) and estimated yield per hectare (tons ha-1)**

Yield per tree ranged from 33.00 kg in WFL-01 to 150.40 kg in WFL-03 and the estimated yield per hectare followed the same trend as per-tree yield, ranging from 7.2 tons ha­-1 in WFL-01 to 30.8 tons ha-1 in WFL-03. The variation in yield per tree among wood apple genotypes due to genetic differences influencing multiple fruit and tree growth traits such as fruit size, number of fruits per tree, and overall tree vigor. High-yielding genotypes like WFL-03, WFL-08, and WFL-04 combine genetic potential for larger fruit size and higher fruit set, thereby significantly enhancing overall productivity. Similar genotypic variation in yield has been observed in bael (Aegle marmelos), where yield per tree varies widely (30 to over 160 kg) depending on genetic makeup, cultural practices, and environmental adaptation (Pandey *et al*., 2013). Studies on wood apple genotypes from Maharashtra also report yield variations from about 66 to 170 kg per tree, linked to morphological and physiological diversity among genotypes (Raut *et al*., 2023). Yields as high as 25–35 tons ha­-1 have been documented in elite bael and wood apple genotypes under improved orchard management (ICAR-CIAH, 2020).



**Fig. 1. Diversity of yield characteristics among wood apple genotypes**

*Test the significant at P < 0.05 and Each bar represents the mean value ± standard error (SE) of pooled data across multiple seasons.*

4. Conclusion

The evaluation of yield-related characters among the nine-wood apple (*Feronia limonia* L.) genotypes revealed considerable variation, indicating the presence of valuable genetic diversity. Among the genotypes, WFL-03 consistently outperformed others by recording the highest fruit length (11.0 cm), fruit width (10.0 cm), fruit weight (470.0 g), pulp weight (340.0 g), and number of seeds per fruit (620), shell thickness (0.28 cm) along with superior fruit count per tree (320), yield per tree (150.40 kg), and projected yield per hectare (30.80 t ha-1). This suggests that WFL-03 holds significant potential for commercial cultivation and future breeding programs aimed at improving fruit size and yield. Other genotypes such as WFL-08 and WFL-04 also exhibited promising yield traits, making them suitable for dual-purpose use in both table and processing markets. The wide variability observed in yield attributes highlights the scope for further selection and genetic enhancement in wood apple. This effort is expected to lay a strong foundation for the genetic enhancement and systematic domestication of this nutritionally significant underutilized fruit crop.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

**Competing Interests**

Authors have declared that no competing interests exist.

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