Evaluation on Morphological and Quality Attributes of Mango Cultivars in Western Uttar Pradesh

ABSTRACT

The study aimed to assess the morpho-economic and biochemical attributes of twelve mango cultivars grown in western Uttar Pradesh, using pooled data from the years 2021-22 and 2022-23 and conducted at Horticulture Research Center of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, the experiment utilized a Randomized Block Design (RBD) with four replications per treatment. The cultivars included Ambika, Pusa Arunima, Dashehari-51, Kesar, Pusa Surya, Amrapali, Mallika, Burma Surakha, Neelum Chausa, Mithua Malda, Rataul, and Saurav, all planted in 10-year-old orchards with a spacing of 6x6 meters. The study aimed to evaluate the morpho-economic and biochemical attributes of twelve mango cultivars in western Uttar Pradesh, identify the most suitable cultivars for the region, and determine the cultivars with the most marketable fruit traits. Additionally, it sought to assess the genetic diversity among the cultivars for future breeding programs.

The results demonstrated significant differences in morpho-economic and quality attributes among the cultivars. Mallika, Pusa Arunima and Amrapali emerged as superior varieties, excelling in tree morpho-economic and quality attributes, while others were classified as moderate. Mallika, Pusa Arunima and Amrapaliwere identified as the highest-yielding varieties, based on the mean number of fruits per plant and fruit weight over the two-year period. Furthermore, the fruits of Mallika, Pusa Arunima, Amrapali, Rataul, and Kesar exhibited the most marketable attributes.

The findings underscore the significant genetic and environmental influences on mango attributes. Mallika andPusa Arunimaconsistently demonstrated superior performance in yield, fruit quality, and biochemical attributes, positioning it as a promising cultivar for the region. The diversity observed among the cultivars highlights the need for targeted selection and management practices to optimize mango production and quality. The study also emphasizes the importance of preserving and conserving these unique genetic resources for future breeding programs aimed at developing new, commercially viable cultivars.

Keywords: Mango, Cultivars, Fruit Yield, Morpho-economic Attributes, Quality Attributes

Introduction

Mango (*Mangifera indica* L.) is one of the most important and widely cultivated fruit crops in India (Dinesh *et al.* 2016), renowned for its delightful flavor, aroma and nutritional value (Dar *et al.* 2016; Kumar *et al.* 2023; Gautam *et al.* 2023). Mango, a fruit from the Anacardiaceae family, is a dicotyledonous species that is believed to have originated in the Indo-Burmese region (Subramanyam *et al.,* 1975; Tjiptono*et al.,* 1984). It is considered to be an allopolyploid, likely an amphidiploid and an outbreeding species with a chromosomal number of 2n=40 (Mukherjee, 1950). India is the largest producer of mango in the world with an annual production of 20.77 MT from an area of 2.35 M ha (Anon. 2021). Major mango producing states in India are Uttar Pradesh andhra Pradesh, Karnataka, Maharashtra, Bihar, Gujarat, Tamil Nadu, Odisha, West Bengal and Jharkhand. Mango is India's most important commercial fruit crop, accounting for more than 54% of global mango production (Mirta and Baldwin 1997). Western Uttar Pradesh, with its favorable agro-climatic conditions, serves as a significant region for mango production, offering a diverse range of mango varieties. This diversity not only contributes to the rich genetic reservoir but also plays a crucial role in the region's agricultural economy (Sankaran & Dinesh 2020).

The present study was conducted to evaluate the morpho-economic and quality attributes of various mango varieties in Western Uttar Pradesh. The findings confirm significant diversity among the mango cultivars examined, underscoring the need for the preservation and conservation of these unique genetic resources (Rajan *et al.* 2024). Such conservation efforts are crucial for future breeding programs aimed at developing innovative, market-driven cultivars that can meet the evolving demands of consumers and the challenges of changing environmental conditions.

Mango cultivation in Western Uttar Pradesh, while thriving, faces challenges related to inconsistent fruit quality, susceptibility to pests and diseases and the impact of climate change (Chawla *et al.* 2016; Yadav *et al.* 2013). There is a pressing need to identify and evaluate the diverse mango cultivars in this region to enhance their commercial viability and resilience. The lack of comprehensive research on the morpho-economic and quality attributes of these varieties poses a problem for farmers seeking to optimize their yields and improve fruit quality.

The significant economic importance of mango cultivation in Western Uttar Pradesh and the observed variability in mango cultivars across the region (Kumar *et al.* 2023). Understanding the diversity in morpho-economic and quality attributes is crucial for identifying superior varieties that can be promoted for commercial cultivation. Additionally, this research aims to address the gap in knowledge regarding the genetic potential of local mango varieties, which is essential for sustainable mango production.

Farmers in Western Uttar Pradesh often struggle with fluctuating mango yields, inconsistent fruit quality and vulnerability to environmental stresses. These challenges are compounded by the limited availability of well-adapted, high-quality mango cultivars. The local problem is the lack of access to mango varieties that are not only resilient to local conditions but also meet market demands in terms of taste, size and shelf life (Sivakumar *et al.* 2011).

This research aims to overcome the identified challenges by systematically evaluating the morpho-economic and quality attributes of various mango varieties. By identifying superior cultivars with desirable attributes such as disease resistance, high yield potential and excellent fruit quality (Zahid *et al.* 2022) the study will provide valuable insights for breeding programs and help in the selection of varieties that are better suited to the local conditions.

The findings from this research have the potential to transform mango cultivation in Western Uttar Pradesh by identifying cultivars that are not only more resilient but also of higher quality. This will empower farmers with the knowledge and resources to cultivate mango varieties that thrive in their local climate, leading to better yields and higher market value. Additionally, by focusing on the conservation of genetic diversity, the study ensures that the rich variety of mangoes in the region is preserved for future use, supporting long-term agricultural sustainability and contributing to the overall economic and nutritional health of the community.

Materials and Methods

The experiment was conducted Horticultural Research Centre, Sardar Vallabhbhai Patel University of Agriculture and Technology, during 2021-22 to 2022-23. Geographically, the experimental field is located at 29º04' North latitude, 77°42' East longitude and at an altitude of 237.75 meters above the mean sea level. The experimental materials for present investigation comprised of twelve mango cultivar collected from different parts of part of India. The cultivars viz. Ambika, Pusa Arunima, Dashehari-51, Kesar, Pusa Surya, Mallika, Amrapali, Burma Surakha, Neelum Chausa, Mithua Malda, Rataul and Saurav were selected for the study and periodically observed. The age of the plants varied from 8-10 years. The experiment was laid on RBD with four replications and resulting in a total of 48 trees. The crops were spaced at 6 mx 6 m. All the cultivar were provided with standard agronomic practices such as nutrient and pest management.

Observation with respect to morpho-economic and quality characters were taken during the period of observation on the selected characters are number of fruit per tree, fruit yield (kg)/tree, fruit weight (g), fruit length (cm), fruit width (cm), fruit pulp weight (g), stone weight (g), stone length (cm), kernel weight (g), kernel length (cm), kernel width (cm), acidity %, TSS (^{0}Brix), reducing sugar (%), non-reducing sugar (%), total sugar(%), totalcarotenoid (mg/100g), ascorbic acid (mg/100 g), phenolcontent (mg GAE/100 g) and total antioxidants (µmol Trolox 100g). A total of four plants were selected per replication.

The morphological characterization was done adopting standard mango descriptors developed by the IPGRI (IPGRI 2006). The number of fruits per tree was counted for each mango cultivar. The yield per tree was recorded over the study period. Fruit weight and pulp weight, stone weight and kernel weight were measured by weighing balance. The digital Vernier calipers was used to measure the fruit length, fruit width, stone length, kernel length and kernel width.

The biochemical analysis conducted by following standard protocols. Total soluble solids (TSS) were measured by using hand refractometer (AOAC, 2000). Titratable acidity, reducing and non-reducing sugar was determined by method described in AOAC (2000). Total sugars were estimated as suggested by Ranganna (1986). The total carotenoid was determined through the ranganna method (Ranganna*et. al.* 1999). The titration method was followed for the estimation of ascorbic acid in mango juice (Sadashivam and Theymoli,1987). Total phenol estimation was carried out with the Folin-Ciocalteau reagent (Malick and Singh 1980). The antioxidant (AOX) activity in the mango fruits was assessed using the CUPRAC (Cupric Reducing Antioxidant Capacity) method, as described by Apak *et al.* (2004).The acquired observations were statistically analyzed using the recommended Panse &Sukhatme (1967) standard approach.This analysis ensured the accuracy and reliability of the results, with statistical C.D. at 5% validation performed to determine the significance of differences among treatments.

Result and Discussion

Morpho-economic Attributes

The data presented in Table 1 and Figure 1 on mango revealed significant variations in fruit morpho-economic attributes across different cultivars grown under the agro-climatic conditions of western Uttar Pradesh. Among the twelve mango cultivars studied, the highest fruit yield per tree was recorded in cv. Mallika (108.82 kg) followed by cv. Pusa Arunima (81.41 kg) and cv. Amrapali (77.15 kg). The lowest fruit yield was observed in cv. Saurav (31.60 kg). The high yield observed in cv. Mallika could be due to its genetic potential for higher productivity, better adaptation to the western Uttar Pradesh climate and efficient utilization of available resources. On the other hand, the lower yield in cv. Saurav might be due to its lower genetic yield potential or lesser adaptability to the specific environmental conditions of the region. These variations in fruit yield among the mango cultivars can be attributed to several factors, including genetic diversity, adaptability to local environmental conditions and management practices (Khan *et al.* 2015).

The highest number of fruits per tree was recorded in cv. Rataul (351.19) followed by cv. Mallika (338.31) and cv. Amrapali (288.94). The lowest number of fruits per tree was observed in cv. Saurav (137.63). These variations in fruit numbers among the mango cultivars can be attributed to genetic factors, differences in flowering and fruit-setting habits and the ability of each cultivar to adapt to the specific environmental conditionsof western Uttar PradeshCultivars such as Rataul and Mallika, which showed a higher number of fruits per tree, likely possess superior genetic attributes that enhance flowering, pollination and fruit retention, thus resulting in higher productivity. On the other hand, the lower number of fruits in cv. Saurav might be due to its genetic predisposition towards lower flower-to-fruit conversion rates or its reduced adaptability to the local climate and soil conditions.Previous studies have shown that cultivar and environment interactions play a crucial role in determining the yield and quality of mango fruits. According to Makhmale*et al.* (2016), the performance of mango cultivars can vary significantly based on climatic conditions, soil type and cultural practices. Similarly, Iqbal *et al.* (2012) highlighted that the choice of cultivar is critical for optimizing fruit yield and quality in specific agro-climatic zones. This study's findings align with these observations, emphasizing the importance of selecting suitable cultivars for improved mango production in western Uttar Pradesh.

The highest fruit weight was recorded in the cultivar 'Pusa Arunima' (331.33 g), followed closely by 'Ambika' (326.55 g) and 'Mallika' (321.45 g), while the lowest fruit weight was observed in 'Rataul' (144.52 g). In terms of fruit length, 'Mallika' had the greatest measurement (12.90 cm), followed by 'Pusa Arunima' (12.63 cm) and 'Pusa Surya' (12.26

cm). The shortest fruit length was noted in 'Rataul' (8.24 cm). For fruit width, 'Mithua Malda' exhibited the largest width (7.69 cm), with 'Pusa Surya' (7.41 cm) and 'Pusa Arunima' (7.34 cm) following, whereas 'Kesar' recorded the smallest width (5.24 cm). Regarding fruit pulp weight, 'Pusa Arunima' again topped the list (248.46 g), followed by 'Mallika' (243.30 g) and 'Ambika' (218.94 g), while 'Rataul' had the lowest pulp weight (74.98 g). Other cultivars such as 'Dashehari-51', 'Kesar' and 'Burma Surakha' showed moderate performance across these parameters, reflecting a diversity of fruit quality characteristics within the region.The observed variation in mango fruit characteristics among the cultivars in Western Uttar Pradesh can be attributed to several factors, including genetic differences, environmental conditions and agricultural practices. Genetically, each cultivar has distinct attributes that determine fruit size, shape and pulp content. For instance, 'Pusa Arunima' and 'Mallika' consistently show superior fruit quality attributes due to their genetic predisposition for larger fruit and higher pulp weight.

The evaluated cultivars exhibited significant variation in stone and kernel characteristics. The lowest stone weight was recorded in the cultivar 'Rataul' (21.95 g), followed by 'Saurav' (27.19 g) and 'Amrapali' (28.75 g), while the highest stone weight was observed in 'Mithua Malda' (36.47 g). The shortest stone length was observed in the cultivar 'Rataul' (7.21 cm), followed by 'Kesar' (8.71 cm) and 'Dashehari-51' (9.31 cm), while the longest stone length was found in 'Neelum Chausa' (11.96 cm). In terms of kernel weight, the lowest was recorded in 'Rataul' (13.84 g), followed by 'Kesar' (14.90 g) and 'Saurav' (15.26 g), whereas the highest kernel weight was observed in 'Pusa Arunima' (22.63 g). The shortest kernel length was observed in the cultivar 'Kesar' (4.81 cm), followed by 'Rataul' (5.31 cm) and 'Saurav' (5.36 cm), while the longest kernel length was found in 'Neelum Chausa' (7.38 cm). In terms of kernel width, the narrowest was recorded in 'Kesar' (2.36 cm), followed by 'Dashehari-51' (2.53 cm) and 'Saurav' (2.49 cm), whereas the widest kernel was observed in 'Pusa Arunima' (3.40 cm).

The variations in stone and kernel characteristics among the mango cultivars in Western Uttar Pradesh can be attributed to genetic differences, environmental conditions and agricultural practices. The genetic diversity among the cultivars dictates their stone and kernel attributes, with 'Rataul' and 'Kesar' showing superior attributes in terms of stone and kernel size due to their genetic makeup.The subtropical climate of Western Uttar Pradesh, characterized by its seasonal temperature and rainfall patterns, influences the growth and development of mango stones and kernels.

The impact of climate change on agriculture must consider the increasing levels of atmospheric CO_2, a key driver of climate change, which plays a vital role in essential plant functions such as photosynthesis (Dusenge*et al.* 2019; Soares *et al.* 2019; Hussain *et al.* 2021). In mango cultivation, flowering has been negatively affected by irregular sequences of cool evenings and unusually warm winters, while rising average temperatures are already impacting mango production. Therefore, rapid climate change should be a significant concern for mango growers, scientists and consumers alike. The rich genetic diversity of mangoes is beneficial for breeding and selection programs aimed at adapting to climate changes (Bally & Dillon 2018). Although rising temperatures may benefit mango fruit development, they can also induce physiological changes in the fruit. High temperatures, coupled with increased light, may enhance photosynthesis and fruit size (Urban *et al.*, 2003). Increased CO_2 concentrations may further improve fruit quality by enhancing photosynthesis and increasing fruit dry mass. In non-irrigated orchards, drought is known to have both positive and negative effects on fruit quality. While drought reduces fruit size, it enhances fruit quality by increasing dry matter and sugar concentration (Léchaudel*et al.*, 2005; Liu *et. al.* 2021) in mangoes.

Biochemical Attributes

The data presented in Table 2 and Figure 2 highlighted significant variations in the biochemical attributesamong the twelve mango cultivars studied. The highest TSS was recorded in the cultivar 'Mallika' (22.03 °Brix), followed by 'Ambika' (20.46 °Brix) and 'Amrapali' (19.89 °Brix), while the lowest TSS was observed in 'Mithua Malda' (17.06 °Brix).In terms of acidity, 'Mallika' exhibited the highest acidity (0.28%), followed by 'Pusa Surya', 'Amrapali' and 'Rataul' (all at 0.26%). The lowest acidity was found in 'Pusa Arunima' (0.20%), with 'Burma Surakha' (0.21%) and 'Kesar' (0.22%) closely following. Other cultivars such as 'Dashehari-51' and 'Mithua Malda' displayed moderate acidity levels (0.25%).The variation in TSS and acidity among mango cultivars in western Uttar Pradesh can be attributed to genetic factors, environmental influences and cultivation practices. Genetically, each cultivar has unique attributes that affect its sugar content and acidity. 'Mallika' and 'Ambika,' with high TSS levels, are likely genetically predisposed to produce sweeter fruit, while cultivars like 'Mithua Malda' and 'Burma Surakha' exhibit lower sweetness.The climatic conditions in western Uttar Pradesh, characterized by its hot summers and distinct wet and dry seasons, can impact sugar accumulation and acid levels in mango fruit (Mishra *et al.* 2016). Cultivars such as 'Mallika' and 'Amrapali' may benefit from these conditions, enhancing their sweetness and flavor profile. Soil properties, including fertility and pH, also affect nutrient uptake and fruit quality.

The data presented in Table 1 and Figure 1 reveal significant variations in reducing sugar, non-reducing sugar and total sugar content among the twelve mango cultivars studied. The highest total sugar content was recorded in the cultivar 'Mallika' (20.31%), followed by 'Pusa Arunima' (18.09%) and 'Ambika' (17.85%), while the lowest total sugar content was observed in 'MithuaMalda' (12.83%).In terms of reducing sugar, 'Dashehari-51' exhibited the highest content (6.61%), followed by 'Pusa Surya' (6.33%) and 'Pusa Arunima' (6.15%). The lowest reducing sugar content was found in 'Neelum Chausa' (4.23%). For non-reducing sugar, 'Mallika' again led the cultivars (14.62%), with 'Ambika' (11.97%) and 'Amrapali' (11.83%) following closely. The lowest non-reducing sugar content was recorded in 'Mithua Malda' (7.50%).

The variation in sugar content among mango cultivars in Western Uttar Pradesh can be attributed to genetic factors, environmental influences and cultivation practices. Genetically, each cultivar has distinct sugar profiles, which determine their sweetness and flavor. 'Mallika,' with the highest total sugar content, benefits from a high non-reducing sugar level, contributing to its rich sweetness. The climatic conditions in Western Uttar Pradesh, including its warm temperatures and seasonal rainfall, can affect sugar accumulation in mango fruit. Cultivars like 'Mallika' and 'Pusa Arunima' are well-suited to these conditions, enhancing their sugar content and overall taste. Soil characteristics, such as nutrient availability and pH, also play a role in determining sugar profiles (Ahmad *et al.* 2018).

The significant variations in total carotenoid and ascorbic acid content among the twelve mango cultivars studied. The highest total carotenoid content was recorded in the cultivar 'Amrapali' (8.94 mg/100g), followed closely by 'Kesar' (8.74 mg/100g) and 'Mallika' (7.73 mg/100g), while the lowest carotenoid content was observed in 'Neelum Chausa' (1.39 mg/100g). In terms of ascorbic acid content, 'Pusa Arunima' exhibited the highest level (45.31 mg/100g), followed by 'Pusa Surya' (42.64 mg/100g) and 'Mallika' (37.94 mg/100g). The lowest ascorbic acid content was found in 'Kesar' (20.58 mg/100g).

The variation in total carotenoid and ascorbic acid content among mango cultivars in Western Uttar Pradesh can be attributed to genetic factors, environmental conditions and cultivation practices (Pandey, 2015). Genetically, each cultivar has unique characteristics that determine their levels of carotenoids and vitamin C. 'Amrapali' and 'Kesar,' with the highest carotenoid levels, are likely genetically predisposed to produce richly colored fruit with high antioxidant content.

The phenol content across the evaluated cultivars varied significantly. The lowest phenol content was observed in the cultivar 'Burma Surakha' (41.29 mg GAE/100 g) followed by 'Kesar' (50.99 mg GAE/100 g) and Pusa Surya' (52.82 mg GAE/100 g), while the highest phenol content was observed in 'Mallika' (119.73 mg GAE/100 g).Regarding total antioxidants, 'Mallika' also exhibited the highest level (1.28 µmol Trolox/100 g), followed by 'Pusa Arunima' (0.82 µmol Trolox/100 g) and 'Ambika' (0.79 µmol Trolox/100 g). The lowest total antioxidant content was found in 'Kesar' (0.42 µmol Trolox/100 g) and 'Burma Surakha' (0.42 µmol Trolox/100 g).

In Western Uttar Pradesh, environmental factors like temperature, rainfall and soil conditions significantly influence mango growth, fruit development and nutritional quality. The region's subtropical climate and soil fertility impact phenol, antioxidant, carotenoid and vitamin C levels in different cultivars, with genetic attributes also playing a role. Cultivation practices such as fertilization and irrigation further affect nutrient content and fruit quality (Sarkar *et al.* 2016; Sun *et al.* 2022; Peng *et al.* 2023). Understanding these factors is vital for selecting mango cultivars that offer superior nutritional benefits and align with consumer preferences in the region.

Conclusion

The evaluation of twelve mango varieties in this study indicates that all are promising cultivars for cultivation in Western Uttar Pradesh, with potential for inclusion in further research trials, mass multiplication programs and eventual adoption by farmers and orchardists. Among these, Mallika andPusa Arunimaemerged as particularly superior based on their morpho-economic and quality attributes, while Mallika, Pusa Arunima, Amrapali, Rataul and Kesar also demonstrated favorable marketable fruit characteristics. The study highlights the significant diversity among the mango cultivars, underscoring the importance of preserving and conserving these genetic resources. This diversity is crucial for future breeding programs aimed at developing innovative, market-driven cultivars that can adapt to changing environmental conditions and meet consumer demands. The findings contribute to the sustainable development of mango production in the region, offering valuable insights for both current and future agricultural practices.

Future Scope

Future research should focus on utilizing this genetic diversity to develop new cultivars with enhanced resilience to climate change and improved commercial traits. Additionally, targeted breeding programs can further optimize the identified superior cultivars, ensuring sustained productivity and quality in mango production for the region.

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 manuscripts.

References

A.O.A.C. Official methods of analysis. 17th Edition. Association of Official Analytical Agricultural Chemists, Gaithersburg, M.D., USA. 2000.

Ahmad I, Bibi F, Ullah H, Munir TM. Mango fruit yield and critical quality parameters respond to foliar and soil applications of zinc and boron. Plants. 2018;7(4):97.

Anonymous. National Horticulture Board, Indian Horticulture Database. Ministry of Agriculture, Government of India. 2021. www.agricoop.nic.in

Apak R, Guclu K, Ozyurek M, Karademir SE. Novel total antioxidant capacity index for dietary polyphenols and vitamins C and E, using their cupric ion reducing capability in the presence of neocuproine: CUPRAC method. Journal of Agricultural and Food Chemistry. 2004;52(26):7970-7981.

Bally IS, Dillon NL. Mango (*Mangifera indica* L.) breeding. Advances in Plant Breeding Strategies: Fruits. 2018;3:811-896.

Chawla R, Sheokand A, Rai MR, Kumar R. Impact of climate change on fruit production and various approaches to mitigate these impacts. Tropical Fruits. 2011;26.

Dar MS, Oak P, Chidley H, Deshpande A, Giri A, Gupta V. Nutrient and flavor content of mango (*Mangifera indica* L.) cultivars: an appurtenance to the list of staple foods. In: Nutritional composition of fruit cultivars. Academic Press. 2016;445-467.

Dinesh MR, Ravishankar KV, Sangma D. Mango breeding in India-Past and future. Journal of Horticultural Sciences. 2016;11(1):1-12.

Dusenge ME, Duarte AG, Way DA. Plant carbon metabolism and climate change: elevated CO2 and temperature impacts on photosynthesis, photorespiration and respiration. New Phytologist. 2019;221(1):32-49.

Gautam P, Kumar A, Prakash O, Singh J, Ali I. Advances in Production Technology of Mango. New Vishal Publication, Patel Nagar, New Delhi. 2023;9-59.

Hussain S, Ulhassan Z, Brestic M, Zivcak M, Zhou W, Allakhverdiev SI, Liu W. Photosynthesis research under climate change. Photosynthesis Research. 2021;150:5-19.

IPGRI. Descriptors for mango (*Mangifera indica* L). International Plant Genetic Resources Institute, Rome, Italy. 2006;1-71.

Iqbal M, Niamatullah M, Hussain A, Munir M, Khan I, Khan Q. Performance of selected parameters of mango cultivars in Muzaffargarh district, Punjab. Sarhad J. Agric. 2012;28(3):395-398.

Khan AS, Ali S, Khan IA. Morphological and molecular characterization and evaluation of mango germplasm: An overview. Scientia Horticulturae. 2015;194:353-366.

Kumar A, Kumar A, Prakash S, Singh S, Pandey V, Raghav DK, Pal D. Assessment of different elite mango varieties suitable for North western plain zones of Uttar Pradesh. Environment Conservation Journal. 2023;24(4):214-220.

Kumar A, Prakash O, Pandey V, Alam K, Sonkar S, Singh S, Gangwar V. The Impact of Biotechnology on Mango Enhancement: Exploring Genetic Engineering and Molecular Markers. International Journal of Environment and Climate Change. 2023;13(8):1673-1680.

Léchaudel M, Joas J. An overview of preharvest factors influencing mango fruit growth, quality and postharvest behaviour. Brazilian Journal of Plant Physiology. 2007;19:287-298.

Liu X, Peng Y, Yang Q, Wang X, Cui N. Determining optimal deficit irrigation and fertilization to increase mango yield, quality and WUE in a dry hot environment based on TOPSIS. Agricultural Water Management. 2021;245:1-13.

Makhmale S, Bhutada P, Yadav L, Yadav BK. Impact of climate change on phenology of mango-the case study. Ecology, Environment and Conservation. 2016;22(9

Malick CP, Singh MB. Plant enzymology and histo-enzymology. Kalyani Publishers, New Delhi. 1980.

Mirta S, Baldwin E. Mango. Book Chapter. 1997.

Mishra DS, Tripathi A, Nimbolkar PK. Review on physiological disorders of tropical and subtropical fruits: Causes and management approach. International Journal of Agriculture, Environment and Biotechnology. 2016;9(6):925-935.

Mukherjee SK. Mango: Its allopolyploid nature. Nature. 1950;166:196-197.

Pandey SN. Diversity in genus Mangifera L. and varietal variation and improvement in mango (*Mangifera indica* L.): A review. Progressive Horticulture. 2015;47(1):20-38.

Panse VC, Sukhatme PV. Statistical Methods for Agricultural Workers, ICAR, New Delhi. 1967

Peng Y, Fei L, Liu X, Sun G, Hao K, Cui N, Jie F. Coupling of regulated deficit irrigation at maturity stage and moderate fertilization to improve soil quality, mango yield and water-fertilizer use efficiency. Scientia Horticulturae. 2023;307:111492.

Rajan S. Phenological responses to temperature and rainfall: A case study of mango. Tropical fruit tree species and climate change. 2012;71.

Rajan S, Mishra PK, Aditya K, Sagar P, Srivastav V. On-farm conservation of traditional mango varieties by custodian farmers in Uttar Pradesh. Indian Journal of Traditional Knowledge (IJTK). 2024;23(4):372-380.

Ranganna S. Handbook of analysis and quality control for fruit and vegetable products and Ed. Tata Mc-Graw Hill publishing company Ltd, New Delhi. 1999.

Sadasivam S, Theymoli B. In Practical manual biochemistry. Tamil Nadu Agricultural University. 1987;14.

Sankaran M, Dinesh MR. Biodiversity of tropical fruits and their conservation in India. Journal of Horticultural Sciences. 2020;15(2):107-126.

Sarker BC, Rahim MA, Archbold DD. Combined effects of fertilizer, irrigation and paclobutrazol on yield and fruit quality of mango. Horticulturae. 2016;2(4):14.

Sivakumar D, Jiang Y, Yahia EM. Maintaining mango (*Mangifera indica* L.) fruit quality during the export chain. Food Research International. 2011;44(5):1254-1263.

Soares JC, Santos CS, Carvalho SM, Pintado MM, Vasconcelos MW. Preserving the nutritional quality of crop plants under a changing climate: importance and strategies. Plant and Soil. 2019;443:1-26.

Subramanyam H, Krishnamurthy S, Parpia HAB. Physiology and biochemistry of mango fruit. Advances in Food Research. 1975;21:223-305.

Sun G, Hu T, Liu X, Peng Y, Leng X, Li Y, Yang Q. Optimizing irrigation and fertilization at various growth stages to improve mango yield, fruit quality and water-fertilizer use efficiency in xerothermic regions. Agricultural Water Management. 2022;260:107296.

Tjiptono P, Lam PE, Mendoza DB Jr. Status of the mango industry in ASEAN in mango. ASEAN Food Handling Bureau. 1984;1-11.

Urban L, Le Roux X, Sinoquet H, Jaffuel S, Jannoyer M. A biochemical model of photosynthesis for mango leaves: evidence for an effect of the fruit on the photosynthetic capacity of nearby leaves. Tree Physiol. 2003;23:289-300.

Yadav S, Korat JR, Yadav S, Mondal K, Kumar A, Kumar S. Impacts of climate change on fruit crops: a comprehensive review of physiological, phenological and pest-related responses. International Journal of Environment and Climate Change. 2023;13(11):363-371.

Zahid G, Aka Kaçar Y, Shimira F, Iftikhar S, Nadeem MA. Recent progress in omics and biotechnological approaches for improved mango cultivars in Pakistan. Genetic Resources and Crop Evolution. 2022;69(6):2047-2065.

Table 1. Mean performance values of different morpho-economic attributes for twelve mango varieties based on pooled data from the years 2021-22 and 2022-23

Cultivars	Fruit Yield (kg)/Tree	Number of Fruit per Tree	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Fruit Pulp weight (g)	Stone Weight (g)	Stone Length (cm)	Kernel Weight (g)	Kernel Length (cm)	Kernel Width (cm)
Ambika	79.18	240.25	79.18	12.35	7.35	223.56	36.31	10.53	19.19	6.73	3.30
Pusa Arunima	87.35	258.13	87.35	12.65	7.40	253.19	37.23	10.75	22.69	6.48	3.43
Dashehari-51	42.49	210.75	42.49	10.30	5.78	142.13	32.99	9.38	16.56	6.70	2.55
Kesar	44.88	189.75	44.88	9.51	5.33	161.90	30.38	8.72	14.73	4.78	2.37
Pusa Surya	67.46	240.50	67.46	12.35	7.46	184.85	36.51	10.01	19.10	6.49	2.64
Amrapali	80.70	343.88	80.70	11.53	6.75	170.82	28.81	9.90	18.87	6.76	2.82
Mallika	114.55	348.88	114.55	12.95	7.10	248.38	36.24	10.23	19.40	6.86	2.98
Burma Surakha	50.00	270.50	50.00	10.18	6.28	117.66	34.06	9.48	17.19	5.88	2.85
Neelum Chausa	59.87	230.75	59.87	11.55	6.48	156.85	34.49	11.97	17.94	7.39	2.80
Mithua Malda	78.31	279.50	78.31	9.93	7.78	180.95	36.51	10.35	18.69	7.04	2.78
Rataul	52.94	358.88	52.94	8.43	6.00	76.29	21.96	7.22	13.88	5.32	2.65
Saurav	33.13	141.00	33.13	11.68	6.73	135.72	27.31	11.73	15.30	5.49	2.50
Mean	**65.91**	**259.40**	**65.91**	**11.12**	**6.70**	**171.02**	**32.73**	**10.02**	**17.79**	**6.33**	**2.81**
Min	33.13	141.00	33.13	8.43	5.33	76.29	21.96	7.22	13.88	4.78	2.37
Max	114.55	358.88	114.55	12.95	7.78	253.19	37.23	11.97	22.69	7.39	3.43
SE(d) ±	2.25	9.83	2.25	0.39	0.22	5.70	1.06	0.32	0.61	0.19	0.10
C.D. at 5%	4.71	20.52	4.71	0.81	0.47	11.90	2.21	0.67	1.27	0.40	0.20
C.V.(%)	4.19	4.64	4.19	4.26	4.08	4.08	3.96	3.90	4.19	3.67	4.21

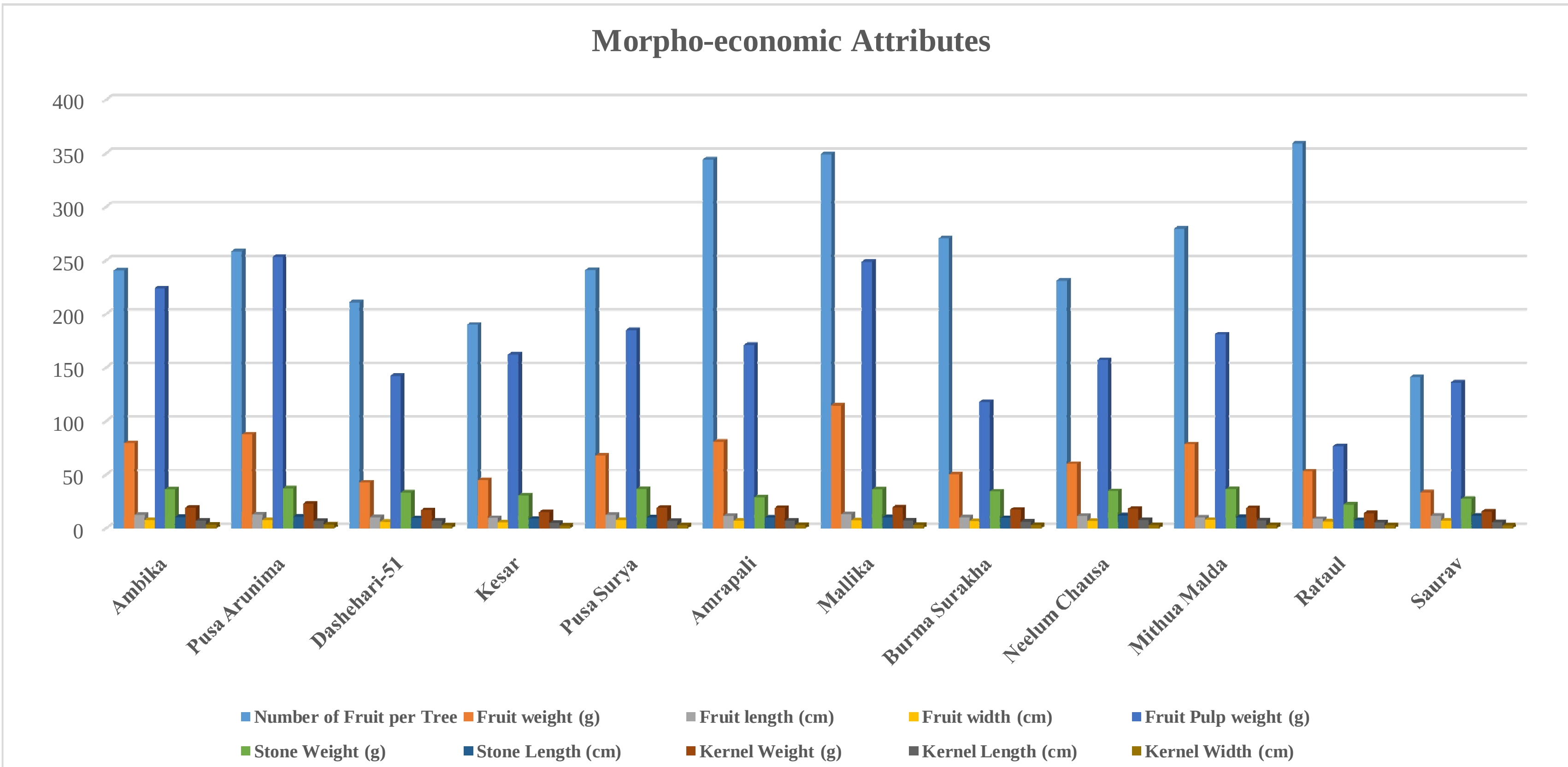

Figure 1. Mean performance values of different morpho-economic attributes for twelve mango varieties based on pooled data from the years 2021-22 and 2022-23

Table 2. Mean performance values of different biochemical attributes for twelve mango varieties based on pooled data from the years 2021-22 and 2022-23

Cultivars	TSS (°Brix)	Acidity (%)	Reducing Sugar (%)	Non-reducing Sugar (%)	Total Sugar (%)	Total Carotenoid (mg/100g)	Ascorbic acid (mg/100 g)	Phenol Content (mg GAE/100 g)	Total antioxidants (µmol Trolox 100g)
Ambika	20.48	0.23	5.26	11.97	17.86	4.30	31.76	56.27	0.79
Pusa Arunima	19.14	0.20	6.19	11.29	18.10	4.37	45.31	55.05	0.83
Dashehari-51	18.64	0.26	6.61	9.59	16.73	5.13	30.76	60.17	0.67
Kesar	17.91	0.22	4.43	8.69	13.40	8.77	20.58	51.03	0.43
Pusa Surya	19.41	0.27	6.33	9.61	16.45	3.56	42.68	52.83	0.45
Amrapali	19.90	0.27	5.37	11.82	17.85	8.95	31.96	69.13	0.76
Mallika	22.03	0.28	4.91	14.61	20.32	7.74	37.94	119.98	1.28
Burma Surakha	17.64	0.21	4.44	10.04	15.01	2.66	26.41	41.27	0.42
Neelum Chausa	18.13	0.24	4.23	8.53	13.37	1.41	26.11	85.89	0.54
Mithua Malda	17.06	0.25	4.94	7.49	12.83	3.56	33.00	54.01	0.49
Rataul	17.58	0.27	4.91	9.66	15.09	4.55	24.77	64.89	0.63
Saurav	18.88	0.26	5.71	9.75	15.99	3.12	27.83	64.10	0.66
Mean	**18.90**	**0.25**	**5.28**	**10.25**	**16.08**	**4.84**	**31.59**	**64.55**	**0.66**
Min	17.06	0.20	4.23	7.49	12.83	1.41	20.58	41.27	0.42
Max	22.03	0.28	6.61	14.61	20.32	8.95	45.31	119.98	1.28
SE(d) ±	0.54	0.01	0.17	0.35	0.54	0.16	1.05	2.55	0.02
C.D. at 5%	1.14	0.02	0.35	0.72	1.13	0.33	2.19	5.33	0.05
C.V.(%)	3.52	3.65	3.94	4.14	4.13	4.03	4.06	4.85	4.32

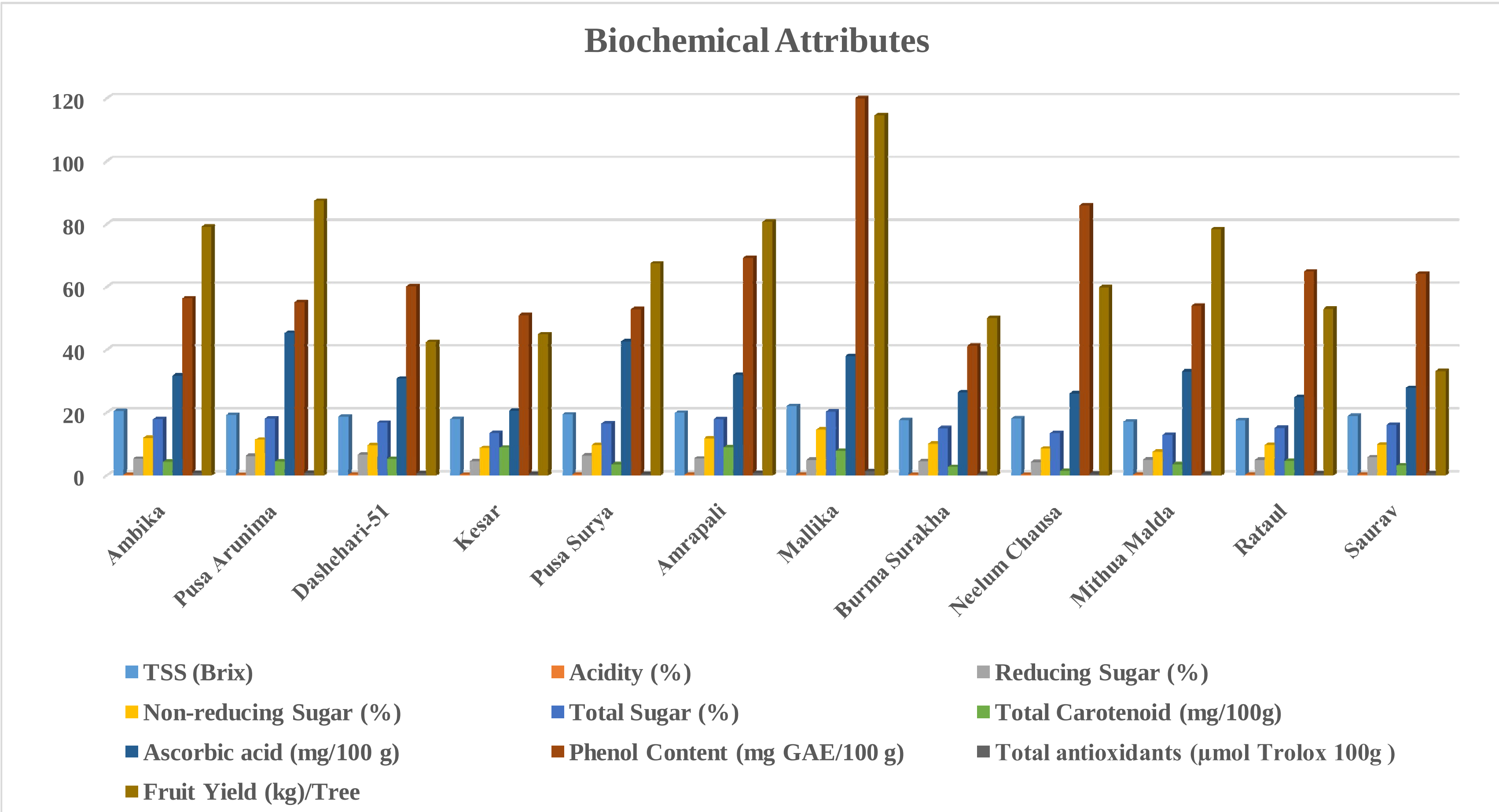

Figure 2. Mean performance values of different biochemical attributes for twelve mango varieties based on pooled data from the years 2021-22 and 2022-23