Indian Journal of Agricultural Sciences **95** (8): 962–967, August 2025/Article
https://doi.org/10.56093/ijas.v95i8.157326

Performance evaluation of different cultivars of mandarin (*Citrus reticulata*) under arid irrigated region of Punjab

SUBHASH CHANDER[1*], KRISHAN KUMAR[1], MANVEEN KAUR[1], H S RATTANPAL[2] and P K ARORA[1]

Dr. J C Bakhshi Regional Research Station (Punjab Agricultural University, Ludhiana), Abohar, Punjab 152 116, India

Received: 1 October 2024; Accepted: 26 June 2025

ABSTRACT

The present study was carried out during 2022 and 2023 at Dr. J C Bakhshi Regional Research Station (Punjab Agricultural University, Ludhiana), Abohar, Punjab to evaluate the comparative performance of PDKV mandarin-5 (a clone of Nagpur mandarin), Nagpur mandarin, Kinnow and the recently recommended low seeded Kinnow mutant, PAU Kinnow 1. Kinnow displayed larger canopy volumes (21.9 and 25.5 m^3) and higher fruit yield (32.5 and 65.6 kg/tree) during the two years. PAU Kinnow-1 showed on par yield to Kinnow. The lowest yield in both years was recorded in Nagpur mandarin. Among the fruit quality attributes, higher total soluble solids (TSS) were recorded in PAU Kinnow-1 (10.8 ºB and 11.0 ºB) during both years. Nagpur mandarin and PDKV-5 recorded TSS in the range of 7.1–7.8 ºB. PAU Kinnow-1 and Kinnow also had higher juice content. Nagpur Mandarin in both years recorded highest ascorbic acid content (31.6 and 39.7 mg/100 ml juice). The lowest seed number (~ 3/fruit) was noted in PAU Kinnow-1. The results indicated that PAU Kinnow-1 due to its high yield potential (comparable to Kinnow) and superior fruit quality attributes (low seed content, high TSS and high juice content) holds promise for further area expansion under citrus fruits in Punjab.

Keywords: Mandarin, North-West India, Quality, Varietal evaluation, Yield

Citrus is one of the most widely cultivated fruit crops, thriving in tropical and sub-tropical regions between 40° N and 40° S latitude. India ranks as the world's third-largest citrus producer, after China and Brazil, with approximately 1.09 million hectares of citrus cultivation yielding 14.2 million metric tonnes annually (Anonymous 2023a). Citrus fruits provide immense health benefits due to abundance of ascorbic acid, minerals (K and Ca), dietary fibres and antioxidants (Zibaee *et al.* 2020). Commercially important citrus groups are mandarins, sweet oranges, limes, lemons, grapefruits, and pummelos. Mandarin (*Citrus reticulata*) is the second most significant species worldwide and covers 42.46% of India's citrus cultivation (Anonymous 2023b). In India, popular mandarin varieties include Kinnow, Nagpur Mandarin, Coorg Mandarin, and Khasi Mandarin (Tripathi *et al.* 2016). In Punjab, citrus is grown on 55,000 hectares, yielding 1.34 million metric tonnes, with mandarins accounting for 87% of the total citrus area. About 70% of the total Punjab citrus is being grown in Fazilka district alone (Abohar and surrounding) that represents arid irrigated zone.

[1]Dr. J C Bakhshi Regional Research Station (Punjab Agricultural University, Ludhiana), Abohar, Punjab; [2]College of Horticulture and Forestry, Punjab Agricultural University, Ludhiana, Punjab. *Corresponding author email: subhashghorela@pau.edu

Kinnow (*Citrus reticulata* Blanco) is a widely grown mandarin in Punjab for its high yield, good flavour and high juice content, but it has high seed number (12–25). The Punjab Agricultural University has recently recommended a low seeded Kinnow mutant. In central India, the loose-skinned Nagpur Mandarin is the preferred variety. In recent, a new cultivar, PDKV-5, has also been recommended by PDKV, Akola for Maharashtra state. However, the performance of these varieties has not been determined under north Indian conditions. The performance of a fruit variety particularly in terms of yield and fruit quality is influenced by inherent genetic traits of the varieties, soil characteristics, and the agro-climate of the specific growing area (Wegayehu *et al.* 2016, Ayele *et al.* 2017, Fikre and Mensa 2021). Varietal evaluation studies are crucial for identifying cultivars suitable for a specific environmental condition. Therefore, in the present study, we aimed to compare the performance of Kinnow, PAU-Kinnow 1, Nagpur Mandarin, and PDKV-5 Mandarin varieties under the arid irrigated region of Punjab for fruit yield and quality parameters.

MATERIALS AND METHODS

Description of the study area: The present study was carried out during 2022 and 2023 at Dr. J C Bakhshi Regional Research Station (Punjab Agricultural University, Ludhiana), Abohar, Punjab. The climate of the study area is classified as arid to semi-arid type, and is placed under agro-climatic region–V of Punjab. The orchard soil was sandy loam in texture; medium in organic carbon (0.3%) having *p*H 7.9 and EC 0.12 dS/m.

Planting material and their management: Four mandarin varieties i.e. PDKV-5 (a high yielding clone of Nagpur Mandarin), Nagpur Mandarin, Kinnow and PAU Kinnow-1 (low seeded Kinnow mutant) were evaluated in this study. The plants of these varieties were prepared by budding on rough lemon rootstock. One-year old plants were planted in 2017 at the spacing of 6 m × 6 m. The plants were raised under uniform orchard management practices and irrigated with canal water using drip irrigation system. The NPK fertilizers were applied into soil and Zn and Mn were given through foliar sprays as per PAU package and practices for cultivation of citrus fruits (Anonymous 2023b). There were nine plants per variety and three plants constituted a replication.

Data collection: The data for growth, yield and quality parameters were recorded for two fruiting seasons (2022 and 2023).

Growth parameters: The vegetative parameters were recorded during October month each year. Plant height was measured from base to the top of the plant and girth of stem was measured just above the bud union. Canopy volume (CV) was calculated using the formula:

$$CV\ (m^3) = 4/3\ \pi\ r^2\ h$$

Where π, 3.14; r, Radius from average canopy diameter (m) and h, Height from the point of first emerged branch to top (Westwood *et al.* 1963).

Fruit yield parameters: The fruit yield was estimated in terms of number of fruits/tree and also as kg/tree. In addition to this, yield efficiency was also estimated by computing yield (kg) per unit trunk cross-sectional area (TCSA, cm^2) and per unit canopy volume (m^3). TCSA was calculated using the formula (Westwood *et al.* 1963).

$$TCSA = Girth^2/4\pi$$

Fruit quality parameters: For physical and biochemical quality determination, fruits were harvested at optimum maturity during January month. Thirty fruits were randomly taken with ten fruits representing a replication. The data were recorded on fruit length, fruit breadth, fruit weight, peel thickness, peel weight (%), juice content, total soluble solids (ºB), titratable acidity (% citric acid equivalent) and ascorbic acid content (mg/100 ml juice). Fruit length (cm), fruit breadth (cm) and peel thickness (mm) was measured using digital vernier calliper. The fruit weight (g) was determined on electronic balance. The fruit peel including rag was removed, and juice was extracted, which was expressed as per cent of total fruit weight. Total soluble solids (ºB) was measured using digital refractometer. Titratable acidity and ascorbic acid of fruits were determined following standard procedures (AOAC 2005).

Statistical analysis: Statistical analysis for the studied parameters was done separately for each individual year. The data was subjected to analysis of variance and the differences among treatment means were determined at 5% significance level. All the data were analysed using OPSTAT (Sheoran *et al.* 1998).

RESULTS AND DISCUSSION

Plant growth: The mandarin plants differed significantly for plant height and canopy volume (Table 1). During both years (2022 and 2023), higher plant height (2.9 and 3.3 m) was recorded for PDKV-5 Mandarin. It was significantly higher than Kinnow and PAU Kinnow-1 in both the years ($p<0.05$) (Table 1). Genotypic differences have been reported as the reason for growth differences among mandarins (Tripathi *et al.* 2016). Kinnow exhibited a larger canopy volume (21.9 and 25.5 m^3) in both years ($p<0.05$), likely due to its greater tree spread in N-S and E-W directions, which contributed to the overall canopy expansion. In 2023, PAU Kinnow-1 and PDKV-5 showed canopy volumes similar to Kinnow, indicating that these varieties can achieve comparable growth under arid irrigated conditions. The larger canopy volume in Kinnow suggested better light interception and a greater availability of photosynthates. In citrus, the variation in plant height and canopy among different varieties was attributable to differences of their genetic makeup under the prevailing environmental and edaphic conditions (Barbora *et al.* 2019, Borah *et al.* 2023). In terms of stem girth, no significant differences were observed among the four mandarin varieties, suggesting a more uniform pattern in trunk growth across the different types. Generally, stem girth is largely influenced by mineral nutrition, which affects photosynthesis, reducing carbohydrate and protein production, thereby limiting the tree growth (Taiz and Zeiger 2002).

Table 1 Comparison of different mandarins for plant growth attributes

Varieties	Plant height (m)		Canopy volume (m^3)		Stem girth (cm)	
	2022	2023	2022	2023	2022	2023
PDKV-5	2.9	3.3	18.5	24.5	41.6	46.8
Nagpur mandarin	2.7	3.1	15.8	21.4	40.7	46.3
Kinnow	2.5	2.6	21.9	25.5	41.7	46.4
PAU Kinnow 1	2.5	2.6	18.6	24.1	40.2	45.6
CD (p=0.05)	0.3	0.4	2.2	1.9	-	-
F test (p=0.05)	s	S	s	s	ns	ns

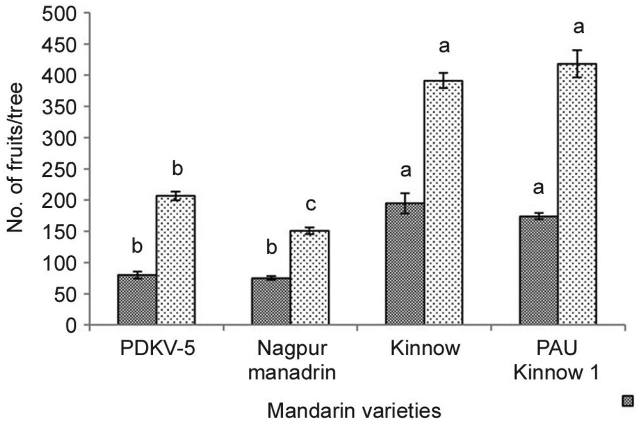

Fig. 1a Number of fruits/tree in different mandarins.

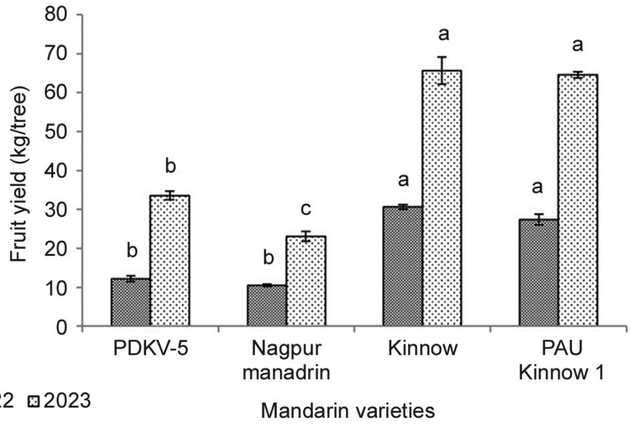

Fig. 1b Fruit yield (kg/tree) of different mandarins.

Fruit yield: The yield was compared based on the number of fruits/tree, and kg/tree. In addition to it, the yield efficiency was also computed per unit transverse cross section area (kg/cm^2) and per unit canopy volume (kg/m^3). During both the years (2022 and 2023), there was a significant variation in the average number of fruits per tree among the four mandarin varieties (p<0.05). Kinnow Mandarin produced a significantly higher number of fruits compared to Nagpur Mandarin and PDKV-5 Mandarin in both years (p<0.05), suggesting that Kinnow may possess superior reproductive traits such as higher flower retention and better fruit set. Interestingly, PAU Kinnow-1 (174, 418 fruits) bore statistically similar numbers of fruits to Kinnow (195, 393 fruits) during the mentioned period (Fig. 1a), indicating that despite minor variations, these two varieties exhibit comparable fruit-bearing capacity. This could be attributed to similar phenological patterns or adaptive responses to local climatic conditions. In 2023, the PDKV-5 (206.7) too recorded significantly higher number of fruits than Nagpur Mandarin (150.7) (Fig. 1a). The number of fruits/tree is directly influenced by several factors, including the flowering pattern, effective pollination, favourable weather conditions, and the specific characteristics of the cultivar (Patel *et al.* 2023).

Like fruit number, the yield of Kinnow (30.6 and 65.6 kg/tree) and its mutant, PAU Kinnow-1 (27.6 and 64.6 kg/tree), was statistically similar in both years (Fig. 1b). However, these varieties exhibited significantly higher yields compared to Nagpur Mandarin and PDKV-5 Mandarins in both years. This suggested that Kinnow and its mutant have superior productivity under the given environmental and cultivation conditions. The yield of PDKV-5 and Nagpur Mandarin was comparable in 2022, but in 2023, the yield of PDKV-5 (30.6 kg/tree) surpassed that of Nagpur Mandarin (27.4 kg/tree), possibly indicating a better adaptation of PDKV-5 to the prevailing conditions. This highlighted the importance of genotype-environment interaction in influencing yield performance, with specific cultivars showing greater stability or response to changing conditions across different years. Similar findings were reported by Viera *et al.* (2020) in passion fruit, where the interaction between genotype and environment proved to be a key factor in determining fruit yield in the cultivars. Further PDKV-5 is a clonal selection of Nagpur Mandarin for high yield, which was verified in this study. The variation in yield of mandarin clones has also been reported earlier (Tripathi *et al.* 2016).

The yield efficiency per unit trunk cross-sectional area (kg/cm^2 TCSA) was recorded significantly higher in Kinnow Mandarin (0.22, 0.38) and PAU Kinnow-1 Mandarin (0.21, 0.39) compared to the other two varieties during both years (p< 0.05) (Fig. 2a). Varieties that exhibit higher yields per unit of TCSA demonstrate superior efficiency in resource utilization, including water and nutrients, and more effective canopy management. This comparison is crucial for identifying high-performing cultivars that can optimize production without excessive vegetative growth, which may otherwise compete for resources needed for fruiting.

The relationship between TCSA and yield efficiency has also been studied in several other crops and is considered a reliable indicator of tree's productivity potential (Chander and Kurian 2019). For instance, in citrus, Dalal and Brar (2012) found a positive correlation between TCSA and yield efficiency, while Kumar and Pandey (2010) in banana and Kumar *et al.* (2019) in plum also reported similar findings demonstrating the significance of this metric in perennial crop species. Similarly, the yield efficiency in terms of canopy volume (kg/m^3) was found to be higher for Kinnow Mandarin during both years, with values comparable to PAU Kinnow-1 (Fig. 2b). This suggested that the genetic potential of Kinnow and PAU Kinnow-1 to bear more fruits likely resulted in their higher overall yield and yield efficiency. A larger canopy volume typically corresponds to a greater leaf area, which enhanced the tree's photosynthetic capacity (Liu *et al.* 2021). This increased photosynthesis may have directly contributed to higher fruit production, as the tree can produce more carbohydrates to support fruit growth and development. Additionally, a well-developed canopy structure can improve light interception and distribution within the tree (Chander *et al.* 2022). This not only aids in maximizing photosynthetic efficiency but also improves the microclimate within the canopy, potentially leading to better fruit quality and more uniform ripening. Hence,

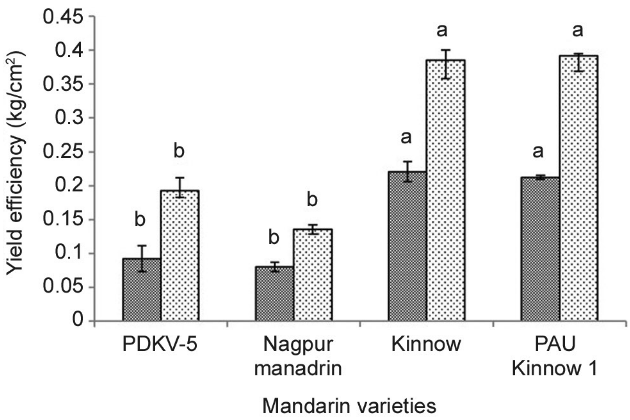

Fig. 2a Yield efficiency (kg/cm^2 TCSA) of different mandarins.

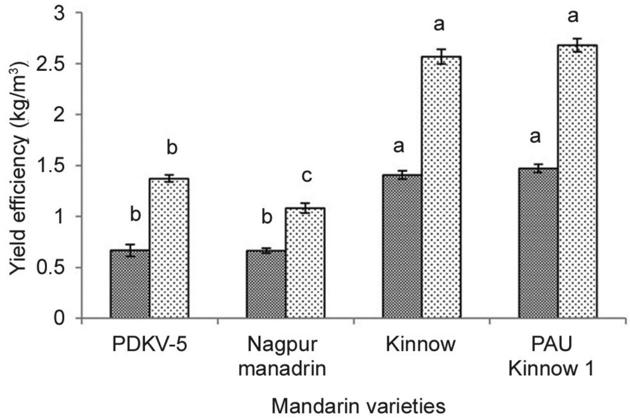

Fig. 2b Yield efficiency (kg/m^3 canopy volume) of different mandarins.

the higher yield efficiency observed in Kinnow and PAU Kinnow-1 may be attributed to their significantly larger canopy volume compared to Nagpur mandarin and PDKV-5 mandarins. Previous research supports these findings, with Samant *et al.* (2020) recording higher mango yields in trees with larger canopy volumes.

Fruit quality: The fruit characteristics of the evaluated mandarin varieties exhibited significant variation (Fig. 3). The findings revealed that Kinnow Mandarin consistently produced larger weight fruits (165.4 and 168.8 g) compared to the other varieties during both years (p<0.05). This suggests that Kinnow has a genetic predisposition for larger fruit size, which could be an advantage for markets where bigger fruits are preferred. PDKV-5 Mandarin also demonstrated favourable fruit characteristics, with a higher fruit weight than Nagpur Mandarin during both years, indicating that it performs well in terms of fruit size

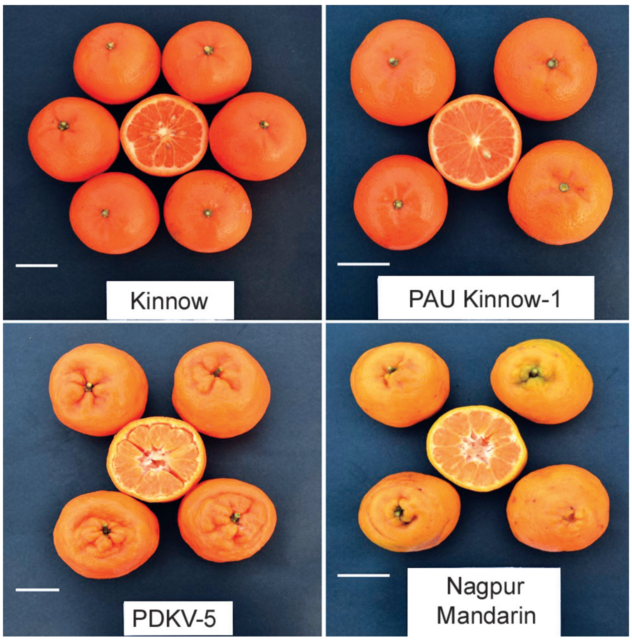

Fig. 3 Fruits of different mandarin varieties. The bars denote to 5.0 cm size.

compared to the traditionally grown Nagpur Mandarin. The lowest fruit weight in both years (140.2 and 153.2 g) was recorded in Nagpur Mandarin. However, in 2023, the fruit weights of Nagpur Mandarin (153.2 g) were statistically similar to PAU Kinnow-1 Mandarin (154.5 g) (Table 2). A significant difference was observed in fruit length among the mandarin varieties (p< 0.05), with PDKV-5 consistently showing the highest fruit length (6.4 and 6.6 cm) during both years. This suggests that PDKV-5 might have a genetic advantage in terms of vertical fruit growth. In contrast, no significant variation in fruit breadth was noted across the different varieties during either of the year (Table 2).

Nagpur Mandarin exhibited a higher peel weight (28.4% and 31.6%) in both years, indicating a larger peel compared to other varieties. Juice content varied significantly across the mandarin varieties during both fruiting seasons (p<0.05). Kinnow produced notably higher juice content (51.5% in 2022 and 57.0% in 2023), demonstrating its superior juiciness. In contrast, the significantly lower peel weight observed in PAU Kinnow-1 in 2023 likely contributed to its relatively higher juice content, suggesting a negative association between peel weight and juice yield. These findings emphasize the influence of cultivar traits, such as peel weight on juice production, which is a critical factor for both consumer preference and industrial processing.

Seedless cultivars are often favoured in commercial production and trade, as they not only make fruit consumption easy but also increase their processing potential (Rattanpal *et al.* 2019). Lowest number of seeds (3.2 and 3.3/ fruit) was recorded in PAU Kinnow 1 in both the years. PAU Kinnow 1, bud mutant of Kinnow with less number of seeds is recommended for cultivation in Punjab (Rattanpal *et al.* 2019).

The phytochemical composition of various citrus cultivars varies depending on the cultivar, soil type, fertilizer, climate, and even different parts of the same fruit (Guo *et al.* 2023). In the present study, significant difference for fruit TSS was recorded among the mandarin varieties during both years (p<0.05). During 2022, the TSS of Kinnow (10.5°B) and PAU Kinnow-1 (10.8 °B) was statistically similar but higher than PDKV-5 (7.1 °B) and Nagpur Mandarin (7.2 °B)

Table 2 Fruits physico-chemical attributes of different mandarins

Varieties	Fruit length (cm)		Fruit breath (cm)		Fruit weight (g)		Fruit juice (%)		Number of seeds		Peel weight (%)		TSS (ºB)		Acidity (%)		Ascorbic acid (mg/100 ml)	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
PDKV-5	6.4	6.6	9.7	7.2	153.3	162.4	47.2	52.3	5.1	4.9	25.4	29.0	7.1	7.4	1.20	1.00	28.7	36.8
Nagpur mandarin	5.8	6.5	8.8	7.1	140.5	153.2	47.1	53.4	4.5	4.7	28.4	31.6	7.2	7.8	1.10	0.90	31.6	39.7
Kinnow	6.1	6.3	9.7	7.3	165.4	168.8	51.3	55.8	24.6	24.6	26.1	29.4	10.5	10.6	0.90	0.89	21.1	32.8
PAU Kinnow 1	6.0	6.2	9.9	7.2	157.1	154.5	51.5	57.0	3.2	3.3	26.3	26.3	10.8	11.0	0.89	0.87	20.1	30.6
CD (p=0.05)	0.2	0.1	-	-	7.8	5.4	2.8	2.1	2.0	2.2	-	1.6	0.7	0.3	0.04	0.10	2.2	2.8
F test (p=0.05)	s	s	ns	ns	s	s	s	s	s	s	ns	s	s	s	s	s	s	s

(Table 2). During 2023, PAU Kinnow-1 (11.0 ºB) had significantly higher TSS over all mandarins including Kinnow (10.6 ºB) (Table 2). The TSS of Nagpur Mandarin in Nagpur conditions under different plant densities (6 m × 6 m, 6 m × 3 m, 4 m × 4 m, 4 m × 2 m and 2 m × 2 m) ranged from 9.15–9.57, which is higher than that obtained in our study (Ladaniya *et al.* 2021). Bhatnagar *et al.* (2015) recorded variations in TSS of Nagpur Mandarin from 7.66 at Lolra to 11.83 at Parvkheri villages of Jhalawar district, indicating that geographical conditions influence the TSS variations in citrus. Mesejo *et al.* (2024) compared the TSS of Clemnules clementine and Valencia sweet orange grown under two different climates: arid (Morocco) and mediterranean (Spain) climate. The fruits under arid climate possessed lower TSS. The mean number of days above 35ºC temperature were higher under arid climate than the Mediterranean climate. The researchers found the significant negative correlation between the duration of such days and TSS. Similarly, the role of agro-climate in variation of total soluble solids (TSS) has also been noted in mango (Singh *et al.* 2013, Kishore *et al.* 2015).

Like TSS, differences in titratable acidity were also recorded among the mandarin varieties during both the years (p<0.05). During both the years, higher amount of titratable acidity (1.2 and 1.1%) was recorded in PDKV-5 Mandarin. The titratable acidity of Kinnow (0.90 and 0.89%) and PAU Kinnow-1 (0.89 and 0.87%) was statistically similar in both the years. Ladaniya *et al.* (2021) recorded 0.78% acidity in fruits of Nagpur Mandarin planted at 6 m × 6 m spacing at Nagpur conditions, which is lower than that of our study. Mesejo *et al.* (2024) compared the acidity of citrus fruits under two different climates: arid (Morocco) and mediterranean (Spain) climate. The arid climate tended to increase the acidity of the citrus fruits, proving positive correlation of higher temperature with acidity percentage. Hence, reduction in TSS and increase of acidity in two Nagpur Mandarin types in our conditions may be due to the influence of arid climate, while Kinnow and PAU-Kinnow 1 seems adapted to the conditions.

Citrus fruits are relished for their vitamin C (ascorbic acid) content, which has significance for good health. Nagpur Mandarin stood out for its high ascorbic acid content (31.6 and 39.7 mg/100 ml juice), significantly higher than the other varieties. PDKV-5 also demonstrated elevated levels of ascorbic acid (28.7 and 36.8 mg), though slightly lower than Nagpur Mandarin. The high ascorbic acid content in Nagpur Mandarin might be attributed to the influence of arid climate. The stressful conditions of drought enhances ascorbic acid content (Zheng *et al.* 2022). Climatic factors play a critical role in the accumulation of ascorbic acid in citrus fruits, as reported by Zheng *et al.* (2022), highlighting the interplay between genotype and climate in determining fruit nutritional quality.

In conclusion, Kinnow and its low-seeded mutant, PAU Kinnow-1, demonstrated superior performance in terms of yield, with better fruit quality, particularly higher total soluble solids (TSS), compared to Nagpur Mandarin and PDKV-5 Mandarin under the arid climate. PAU Kinnow-1, with its limited number of seeds (approximately 3 per fruit) and superior internal quality (high TSS), offers a significant advantage for growers and consumers alike. With yields comparable to Kinnow, PAU Kinnow-1 holds strong potential for expanded cultivation.

ACKNOWLEDGEMENT

The authors are thankful to the Project Coordinator, ICAR-AICRP on Fruits for providing the planting material and financial support.

REFERENCES

Anonymous. 2023a. *Horticultural Statistics at a Glance* 2021. https://agricoop.gov.in

Anonymous. 2023b. *Package of Practices for Cultivation of Fruits*, 3rd edn, pp. 21–23. Punjab Agricultural University, Ludhiana, Punjab.

AOAC. 2005. *Official Methods of Analysis*. Latimer J W and Horwitz W (Eds). AOAC International Press, Washington D C.

Ayele L, Etissa E, Dagnew A, Assefa W, Kebede G, Girma M, Firde K and Ayalew M. 2017. Development of hermaphrodite papaya (*Carica papaya* L.) varieties for production in Ethiopia. *Academic Research Journal of Agricultural Science and Research* **5**(7): 561–69.

Bhatnagar P, Singh J and Jain S K. 2015. Physico-chemical variations in fresh 'Nagpur' mandarin fruits of Jhalawar district. *HortFlora Research Spectrum* **4**(4): 293–300.

Borah L, Borah M and Kakoti R K. 2023. Review of the general characteristics of Khasi Mandarin (*Citrus reticulata* Blanco.) for evaluation of an elite germplasm. *The Pharma Innovation Journal* **12**(12): 2174–77.

Barbora A C, Saikia J, Kakoti R K, Deka S, Hazarika B and Gogoi A. 2019. Survey, selection and evaluation of elite Khasi Mandarin (*Citrus reticulata* Blanco.) genotypes for growth, yield, quality and biotic stress tolerance under climatic conditions of north-eastern region. *International Journal of Pure and Applied Bioscience* **7**(1): 469–74.

Chander S and Kurian R M. 2019. Effect of crop load, fruit position and shoot vigour on yield and quality of *Annona atemoya* × *Annona squamosa* in India. *The Journal of Horticultural Science and Biotechnology* **94**(4): 507–12.

Chander S, Kurian R M, Satisha J, Upreti K K and Laxman R H. 2022. Advancing fruiting season in *Annona* cv. Arka Sahan through pruning. *Journal of Horticultural Sciences* **17**(2): 316–24.

Dalal R P S and Brar J S. 2012. Relationship of trunk cross-sectional area with growth, yield, quality and leaf nutrient status in Kinnow mandarin. *Indian Journal of Horticulture* **69**: 111–13.

Fikre G and Mensa A. 2021. Evaluation of improved hermaphrodite papaya (*Carica papaya* L.) varieties at Arba Minch, Southern Ethiopia. *International Journal of Agricultural Research, Innovation and Technology* **11**(2): 69–71.

Guo H, Zheng Y J, Wu D T, Du X, Gao H, Ayyash M, Zeng D G, Li H B, Liu H Y and Gan R Y. 2023. Quality evaluation of citrus varieties based on phytochemical profiles and nutritional properties. *Frontiers in Nutrition* **18**(10): 1165841.

Kishore K, Singh H S, Kurian R M, Srinivas P and Samant D. 2015. Performance of certain mango varieties and hybrids in east coast of India. *Indian Journal of Plant Genetic Resources* **28**(03): 296–302.

Kumar D and Pandey V. 2010. Relationship of pseudo-stem cross-sectional area with bunch weight, fruit quality and nutrient status in banana cv. Rasthali (Pathkapoora-AAB). *Indian Journal of Horticulture* **67**: 26–29.

Kumar D, Srivastava K K and Singh S R. 2019. Correlation of trunk cross sectional area with fruit yield, quality and leaf nutrient status in plum under north-west Himalayan region of India. *Journal of Horticultural Sciences* **14**(1): 26–32.

Ladaniya M S, Marathe R A, Murkute A A, Huchche A D, Das A K, George A and Kolwadkar J. 2021. Response of Nagpur Mandarin (*Citrus reticulata* Blanco) to high density planting systems. *Scientific Reports* **11**(1): 1–11.

Liu F, Song Q, Zhao J, Mao L, Bu H, Hu Y and Zhu X G. 2021. Canopy occupation volume as an indicator of canopy photosynthetic capacity. *New Phytologist* **232**(2): 941–56.

Mesejo C, Martínez-Fuentes A, Reig C, El-Otmani M and Agustí M. 2024. Examining the impact of dry climates temperature on citrus fruit internal ripening. *Scientia Horticulturae* **337**: 113501.

Patel J J, Sharma D K, Patel A M and Barot D C. 2023. Growth and yield performance of different exotic mango cultivars under South Gujarat. *The Pharma Innovation Journal* **12**(12): 2255–58.

Rattanpal H S, Singh G and Gupta M. 2019. Studies on mutation breeding in mandarin variety Kinnow. *Current Science* **116**(3): 483–87.

Samant A P, Warang O S, Kulkarni M M and Bhingarde R T. 2020. Relationship between plant canopy volume, leaf area index and yield in mango (*Mangifera indica* L.) cv. Alphonso. *International Journal of Current Microbiology and Applied Sciences* **11**: 859–63.

Sheoran O P, Tonk D S, Kaushik L S, Hasija R C and Pannu R S. 1998. Statistical software package for agricultural research workers. Recent Advances in Information Theory, Statistics and Computer Applications by D S Hooda and R C Hasija. Chaudhary Charan Singh Haryana Agriculture Unjversity, Hisar, pp. 139–43.

Singh T K, Singh J and Singh D B. 2013. Performance of mango varieties in Kymore plateau of Madhya Pradesh. *Progressive Horticulture* **45**(2): 268–72.

Taiz L and Zeiger E. 2002. *Plant Physiology*, 3rd edn, pp. 484. Sinauer Associates, Inc., Publishers.

Tripathi P C, Karunakaran G T, Sakthivel H R, Sankar V and Kumar R S. 2016. Evaluation of Coorg mandarin (*Citrus reticulata*) clones for yield and quality. *The Indian Journal of Agricultural Sciences* **86**(7): 901–05.

Viera W, Brito B, Zambrano E, Ron L, Merino J, Campana D and Alvarez H. 2020. Genotype × environment interaction in the yield and fruit quality of passion fruit germplasm grown in the Ecuadorian Littoral. *International Journal of Fruit Science* **20**(3): 1829–44.

Wegayehu A, Lemma A, Asmare D, Edossa E, Girma K, Mikiyas D and Merkebu A. 2016. Variability, association and path coefficient analysis of yield and yield components of dioecious papaya genotypes in Ethiopia. *International Journal of Research in Agriculture and Forestry* **3**(10): 8–14.

Westwood M N, Reimer F C and Quackenbush V L. 1963. Long term yield as related to ultimate tree size of three pears varieties grown on rootstocks of five *Pyrus* species. *(In) Proceedings of American Society for Horticultural Science*, Vol. 82, pp. 103–08.

Zheng X, Gong M, Zhang Q, Tan H, Li L, Tang Y, Li Z, Peng M and Deng W. 2022. Metabolism and regulation of ascorbic acid in fruits. *Plants* **11**(12): 1602.

Zibaee E, Kamalian S, Tajvar M, Amiri M S, Ramezani M, Moghadam A T, Emami S A and Sahebkar A. 2020. Citrus species: A review of traditional uses, phytochemistry and pharmacology. *Current Pharmaceutical Design* **26**(1): 44–97.