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Comparative Analysis of Physical and Biochemical Traits in Seeded and Seedless Kinnow Mandarins in Pakistan

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Abstract

This study evaluated the physical and biochemical qualities of low-seeded and seeded 'Kinnow' mandarins cultivated in Pakistan's Punjab region. Using a randomized complete block design, twenty trees of each variety were sampled, and five fruits from each tree were analyzed for parameters such as fruit weight, peel weight, seed count, peel thickness, juice content, TSS, titratable acidity, and vitamin C. Results indicated that seeded fruits had significantly higher weight (170 g vs. 155 g), peel weight (47.43 g vs. 34.50 g), rag weight (58.20 g vs. 41.14 g), peel thickness (4.09 mm vs. 2.70 mm), and seed count (27 vs. 4) compared to seedless fruits. Conversely, seedless fruits exhibited a higher TSS:TA ratio (15.08 vs. 9.36), reflecting better flavor, and had higher juice content (66.91% vs. 64.14%). Furthermore, vitamin C content was significantly greater in seeded fruits (73.5 mg/100 g). Overall, seed presence influenced key physical and biochemical traits, impacting fruit quality and consumer preferences.

***Keywords**: Seedless, Kinnow, Low seeded, Vitamin C*

Introduction

Pakistan is rich in natural resources, offering excellent conditions for fruit production due to its efficient irrigation system and highly fertile soils. Citrus, a major fruit crop in Pakistan, belongs to the Rutaceae family and is believed to have originated in Southeast Asia, particularly Indonesia and China. It is one of the most prominent horticultural fruit crops in the world. Citrus is widely cultivated across the globe under both subtropical and tropical climates, where environmental and soil conditions are highly favorable for optimal growth and yield (Shah et al., 2022).

Citrus fruits are widely recognized as a nutritious and healthy part of the diet. Their flavors are among the most preferred worldwide. Citrus fruits and their products are known to be rich sources of dietary fiber, minerals, and vitamins essential for growth and development. They contain numerous vital nutrients such as calcium, potassium, folate, copper, flavins, vitamin B6, niacin, thiamin, and compounds with a low glycemic index. Folate, in particular, is a crucial vitamin for the production and growth of new cells. It plays an essential role in the synthesis of DNA, RNA, and red

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blood cells. A single glass of orange juice can provide approximately 75 micrograms of folic acid. Pectin, the dominant type of fiber found in citrus, constitutes about 65–70% of the total dietary fiber content (Uthman & Garba, 2023).

In Pakistan, around 80% of citrus production is comprised of 'Kinnow' mandarins. Most citrus cultivation takes place in the Punjab province, with the Sargodha district recognized as the top producer. This region is particularly known for the widespread cultivation of 'Kinnow' mandarins. Due to its high quality and flavor, 'Kinnow' has strong export potential in international fresh fruit markets. Pakistan exports approximately 230,000 tons of 'Kinnow' annually to countries such as Russia, as well as to Southeast and Central Asia. These exports generate an estimated foreign exchange income of 132.7 million US dollars. Central Punjab provides ideal conditions for 'Kinnow' production, including a favorable climate, fertile soil, sufficient water supply, and suitable topography (Ahmad et al., 2024).

Globally, the total production of 'Kinnow' mandarins is about 27,879 thousand tons. The leading producers include China (15,195 thousand tons), the USA (15,673 thousand tons), Mexico (10,643 thousand tons), Spain (1,976 thousand tons), Egypt (760 thousand tons), Japan (1,067 thousand tons), Morocco (1,047 thousand tons), Iran (706 thousand tons), South Korea (779 thousand tons), Thailand (671 thousand tons), and Turkey (750 thousand tons). Pakistan ranks 11th among the world's 'Kinnow' mandarin producers (Asim et al., 2024).

To improve the quality of 'Kinnow' fruits and trees, plants are being developed through both natural and induced variations. These variations affect several traits, including the number of developed and undeveloped seeds, which in turn influence grafting success and overall plant performance. Notably, the nucellus of 'Kinnow' exhibits approximately 80% regeneration ability, making it a valuable source for propagation. However, the limited availability of suitable scions and rootstocks poses a challenge in developing new varieties. This becomes a significant hurdle in meeting international market demands, which require improved fruit quality and higher yields. As a result, new 'Kinnow' varieties are often obtained through chance seedlings and bud mutations rather than controlled breeding programs. 'Kinnow' mandarins enjoy high demand in both local and export markets due to their distinctive aroma, high juice content, rich vitamin C levels, delicious taste, and excellent nutritional value (Khan et al., 2025).

Seedless fruits are highly appealing to both growers and consumers. Seedless varieties such as grapes and watermelons are in high demand, with about 80% of the grapes and watermelons consumed today being seedless. Generally, seedless fruits tend to have a longer shelf life compared to seeded ones, as seeds can sometimes produce hormones that restrict fruit development. In some cases, the taste of seedless

fruits, such as tomatoes, is reported to be superior to that of seeded varieties(Chahal & Kumar, 2024).

In the case of 'Kinnow' mandarins, screening for low-seeded or seedless fruits is typically based on the presence of a stylar ring and the narrowness of new leaves on shoots and sprouts. Narrow leaves are associated with low ovule viability. The number of seeds in 'Kinnow' mandarin varies significantly, ranging from 0 to 52 seeds per fruit. Clones derived from seedless fruits often exhibit distinct vegetative characteristics. While 'Kinnow' mandarins are naturally highly seeded, seedless strains have been developed through techniques such as embryonic seedling selection and bud radiation (Zhao et al., 2024).

Unfortunately, seedless 'Kinnow' is not currently produced on a commercial scale in Pakistan due to limited access to targeted international markets, which are primarily confined to Middle Eastern countries. Globally, about 61% of exported orange and mandarin varieties are seedless. The major export markets for Pakistani 'Kinnow' include Dubai, Oman, Kuwait, Bahrain, Saudi Arabia, and Malaysia. Despite its typically high seed content, seedless strains of 'Kinnow' (containing 0–6 seeds per fruit) have been successfully created through bud radiation and embryonic seedling techniques (Sebastian et al., 2025).

Materials and Methods

Experimental Site and Design

The present study was conducted at the Experimental Fruit Garden, Square No. 32, University of Agriculture, and Faisalabad, Pakistan. Laboratory analyses were carried out in the Pomology Laboratory, Institute of Horticultural Sciences, University of Agriculture, and Faisalabad. The experiment was laid out using a randomized complete block design (RCBD) with two treatments: seeded (T2) and seedless (T1) 'Kinnow' mandarins. Twenty trees of each type were selected, and five fruits were randomly collected from each tree, making a total of forty fruits. Uniformly ripe fruits were harvested randomly from all four sides of the trees and transported to the laboratory for analysis. Each replication consisted of five fruits. The selected fruits were analyzed for various physical and biochemical parameters.

Physical Characteristics

Physical attributes of the fruits were recorded to evaluate differences between seeded and seedless 'Kinnow' mandarins. Fruit weight (g) was measured by weighing five randomly selected fruits per tree using a digital weighing balance. Fruit diameter (mm) was recorded at the equator using a vernier caliper, and the average value was calculated. Peel weight (%) was determined by manually removing and weighing the peel, and the percentage was calculated as the ratio of average peel weight to average

fruit weight multiplied by 100. Rag weight (%) was similarly calculated using the ratio of average rag weight to fruit weight. Juice weight (%) was determined by extracting and sieving juice, then expressing it as a percentage of the average fruit weight. Peel thickness (mm) was measured using a vernier caliper and averaged across replications. The number of seeds per fruit was determined by manually extracting and counting seeds from each fruit segment (Ikram et al., 2024).

Biochemical Characteristics

Biochemical parameters were assessed using freshly extracted juice from each fruit sample. Total soluble solids (TSS) were measured using a digital refractometer (ATAGO RS-5000, Japan) and expressed as °Brix at room temperature. Titratable acidity (%) was determined by titrating diluted juice against 0.1 N NaOH using phenolphthalein as an indicator, and calculated using the formula: (NaOH used × 0.0064 / ml of juice) × 100. The TSS/acid ratio was obtained by dividing the TSS value by titratable acidity. Ascorbic acid content (mg 100 g^{-1}) was estimated according to the method described by Ignat et al. (2011), involving titration with 2,6-dichlorophenolindophenol dye after dilution with 0.4% oxalic acid. Reducing sugars, non-reducing sugars, and total sugars (%) were determined following Lane and Eynon's method as described by Picó (2012). Reducing sugars were calculated by titrating Fehling's solution with juice aliquots until a brick-red endpoint, while non-reducing sugars were computed by subtracting reducing sugars from total sugars using the formula: 0.95 × (Total sugars − Reducing sugars). Total sugars were estimated after hydrolyzing non-reducing sugars with hydrochloric acid, followed by neutralization and titration against Fehling's solution. Freshly prepared standard invert sugar and Fehling's solutions were used throughout the analysis (Kumar et al., 2024).

Statistical Analysis

Data were analyzed using analysis of variance (ANOVA) under RCBD with factorial arrangements using Statistix 8.1 software. Means were compared using the Least Significant Difference (LSD) test at a 5% probability level, following the method of Ibrahim and Abdullahi (2023).

Results and Discussions

This study assessed the physical and biochemical characteristics of seeded and seedless 'Kinnow' mandarin fruits. Significant variations were observed between the two treatments in several traits affecting quality, yield, and marketability.

Physical Characteristics

Fruit Weight (g)

Fruit weight is a critical determinant of consumer preference and export quality. Seeded fruits exhibited significantly higher weight (170 g) than seedless fruits (155 g) ($p \leq 0.05$). These findings align with previous reports Altaf et al. (2008), indicating seed presence positively correlates with fruit mass.

Peel Weight (g)

Thin and smooth peels are preferred for better market acceptance. Seedless fruits had significantly lower peel weight (34.5 g) than seeded fruits (47.4 g), supporting the findings of Altaf et al. (2014).

Juice Percentage (%)

Although not statistically significant, seedless fruits recorded a higher juice yield (66.91%) compared to seeded fruits (64.14%). These findings deviate from Altaf et al. (2014), who reported higher juice yield in seeded fruits.

Rag Weight (g)

Rag weight, which represents the internal fibrous portion, was significantly higher in seeded fruits (58.2 g) than seedless ones (41.1 g) ($p \leq 0.05$). Similar outcomes were noted by Altaf et al. (2014), indicating seeds contribute to rag development.

Peel Thickness (mm)

Peel thickness is an important factor in peelability and consumer appeal. Seedless fruits had significantly thinner peels (2.7 mm) compared to seeded fruits (4.09 mm), in contrast to Singh and Singh (2004), who found greater peel thickness in seedless varieties.

Fruit Diameter (mm)

Larger fruit diameter is preferred in commercial markets. Seeded fruits exhibited significantly greater diameter than seedless fruits, corroborating Altaf et al. (2008), who reported Kinnow fruit diameters ranging between 52–85 mm.

Number of Seeds

Seeded fruits had significantly more seeds (average 27) than seedless ones (average 4), with high variability in seed number (0–54 per fruit) consistent with Altaf et al. (2014).

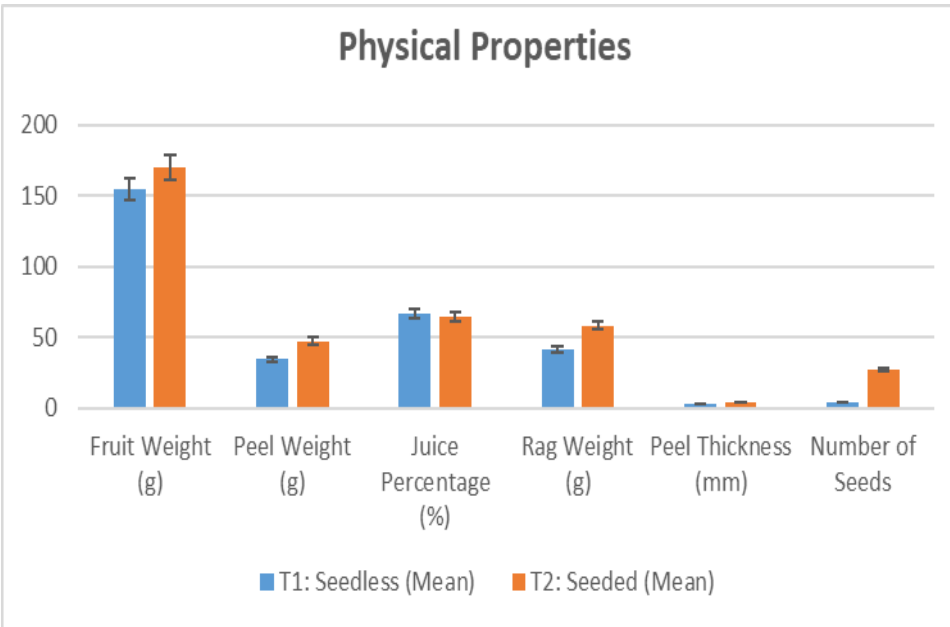
Table 5: *Comparison of Physical Characteristics of Seedless (T1) and Seeded (T2) Kinnow Mandarin Fruits*

Parameter	T1: Seedless (Mean)	T2: Seeded (Mean)	P-Value	Significance
Fruit Weight (g)	155	170	0.0368	* Significant
Peel Weight (g)	34.5	47.43	0.049	* Significant
Juice Percentage (%)	66.91	64.14	0.5525	Not Significant
Rag Weight (g)	41.14	58.2	0.0003	** Highly Significant
Peel Thickness (mm)	2.7	4.09	0.0004	** Highly Significant
Number of Seeds	4	27	0	** Highly Significant

Biochemical Characteristics

Total Soluble Solids (TSS)

Figure 1: *Physical Properties of Kinnow*



No significant difference was observed in TSS between seeded (11.31%) and seedless (11.32%) fruits. These values align with earlier findings (Din et al., 2012), which reported TSS ranging from 10.57–13%.

Titratable Acidity (TA)

Significant differences in TA were observed, with seeded fruits exhibiting higher acidity (1.21%) than seedless ones (0.75%) ($p \leq 0.05$). These results reflect trends reported by McCollum and Hearn (2011).

TSS/TA Ratio

This parameter, which determines fruit taste and balance, was significantly higher in seedless fruits, indicating a sweeter flavor profile, which enhances market acceptability.

Ascorbic Acid (Vitamin C)

Vitamin C content was significantly higher in seeded fruits (73.5 mg/100g) than in seedless ones (50.6 mg/100g). This finding aligns with Pila et al. (2010), who reported similar variations among different mandarin varieties.

pH

pH values were significantly different between treatments; seedless fruits had lower pH (2.88), while seeded fruits showed higher pH (4.75), consistent with Din et al. (2012). The lower pH in seedless fruits may enhance vitamin C stability.

Total Sugars (%)

Total sugar content was significantly higher in seeded fruits (10.18%) compared to seedless fruits (6.93%), confirming findings by Altaf et al. (2014).

Reducing Sugars (%)

Reducing sugar levels were significantly higher in seeded fruits (4.20%) than in seedless ones (3.13%), similar to previous reports (Altaf et al., 2014).

Non-Reducing Sugars (%)

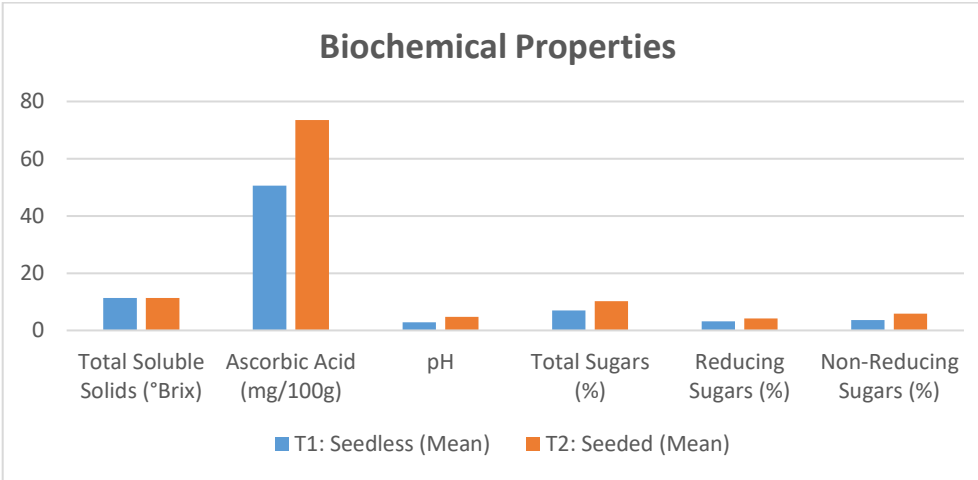
Seeded fruits exhibited a higher percentage of non-reducing sugars (5.91%) compared to seedless fruits (3.61%), confirming the trend that seeded fruits generally have greater sugar accumulation.

Table 2: *Comparison of Biochemical Characteristics of Seedless (T1) and Seeded (T2) Kinnow Mandarin Fruits*

Parameter	T1: Seedless (Mean)	T2: Seeded (Mean)	P-Value	Significance
Total Soluble Solids (°Brix)	11.315	11.308	0.5156	ns Not Significant
Titratable Acidity (%)	Lower (exact not given)	Higher (exact not given)	0.0031	* Significant
TSS/TA Ratio	Higher	Lower	0.0001	** Highly Significant

Ascorbic Acid (mg/100g)	50.6	73.5	0	** Highly Significant
pH	2.88	4.75	0	** Highly Significant
Total Sugars (%)	6.93	10.18	0	** Highly Significant
Reducing Sugars (%)	3.13	4.2	0.0025	* Significant
Non-Reducing Sugars (%)	3.61	5.91	0	** Highly Significant

Figure 2: *Biochemical Properties of Kinnow*



Conclusion

This study evaluated physical and biochemical traits of seedless and seeded *Kinnow* mandarins. Seeded fruits exhibited significantly higher average fruit weight (170 g), peel weight (47.43 g), rag weight (58.20 g), peel thickness (4.09 mm), and seed count (27 seeds/fruit) compared to seedless counterparts (155 g, 34.50 g, 41.14 g, 2.70 mm, and 4 seeds/fruit, respectively). Juice content was higher in seedless fruits (66.91%) than seeded (64.14%). Seedless *Kinnow* also showed a superior TSS:TA ratio (15.08 vs. 9.36), indicating better flavor, though total soluble solids were similar (11.31%). Ascorbic acid content was significantly higher in seeded fruits (73.5 mg/100 g) compared to seedless (50.6 mg/100 g). These findings highlight that while seeded fruits excel in size and nutrient density, seedless *Kinnow* offers superior marketable and consumer-preferred qualities, favoring its potential for export-oriented cultivation.

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