



MORPHOLOGICAL CHARACTERIZATION OF EXPORTABLE ZARA AND COLOMBO LEMONS IN BANGLADESH

Md Nabirul Islam¹, Md Monjurul Islam², Md. Nazrul Islam³, Md. Razzab Ali⁴, Md. Humayun Kabir³ and AFM Jamal Uddin^{3*}

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Abstract

Citrus fruits, particularly Zara and Colombo lemons, are vital commercial crops in Bangladesh, grown in Sylhet and Narshingdi districts respectively, and exported to Europe and the Middle East. Despite their apparent differences, these lemons are often considered the same by exporters and buyers, causing confusion among growers. Though, both fruits are marketed internationally under the name Zara Lemon. Notably, Zara lemons are more susceptible to Canker, while Colombo lemons are more prone to Scab. This study aims to clearly identify and differentiate these lemons to improve horticultural and business practices. Experiments were conducted in Joyentapur and Gowainghat Upazilas (Sylhet district) for Zara Lemons, and in Belabo and Shibpur Upazilas (Narshingdi district) for Colombo Lemons, focusing on morphological features such as trunks, branches, leaves, flowers, and internal structures during January to June 2021. The findings revealed distinct differences: Zara lemons had an average height of 3.66 ± 0.45 m, stem diameter of 27.94 ± 0.19 cm, canopy radius of 12.19 ± 0.51 m, and first branch height at 22.86 ± 0.21 cm, with 7.50 ± 0.47 branches per plant. In contrast, Colombo lemons exhibited an average height of 3.04 ± 0.11 m, stem diameter of 24.13 ± 0.25 cm, canopy radius of 9.14 ± 0.29 m, and first branch height at 114.30 ± 0.45 cm, with 4.25 ± 0.23 branches per plant. Zara lemons typically had 4 petals per flower, occasionally 5, and their edible skin averaged 211.00 ± 82.60 g, compared to Colombo's 118.00 ± 35.81 g. These results confirm that Zara and Colombo lemons are morphologically distinct, necessitating accurate identification for optimal management.

Key words: Identification, Susceptibility, European Union, Middle East, and Export.

Introduction

Citrus (family Rutaceae) is one of the most widely cultivated and consumed fruit crops globally (Denaro *et al.* 2020), and citrus fruit is abundant in a significant number of nutritional components that contribute to the human diet (Liu *et al.* 2012). Numerous citrus varieties, including lemons, are grown all over the world (Strano *et al.* 2017). In Bangladesh, the total acreage under citrus fruits in the fiscal year 2020–21 was about 162242.69 acres while the total production is around 181604.46 MT (BBS 2021). Year after year, citrus fruit output in Bangladesh increases significantly. Among the citrus in Bangladesh, Zara and Colombo lemon is the leading seasonal high-value cash crop of the Sylhet and Narshingdi districts of Bangladesh and play a role in exporting earnings. Citron (*Citrus medica*) is called “Zara Lebu” in Bangladesh. India is commonly considered as the origin location of Citron, specifically the Himalayas (Liu *et al.* 2012). Zara lemon lemons are exported from Bangladesh mainly to Europe. The countries of the European Union, and the Gulf region such as Kuwait, Saudi Arabia, UAE, and Qatar are potential markets for Zara Lemon of Bangladesh (Annon. 2021). Bangladesh exported about 183.77 metric tons of lemons, with an export value of 459.7 thousand USD, in 2021 (Ali *et al.* 2023). Commercial and homestead cultivation of lemons could considerably improve the livelihoods of the rural people in Bangladesh (Sarker *et al.* 2017). The scientific classification of Zara and Colombo lemons are *Citrus Medica* and *C. limon*, respectively. Citron developed in Assam, central India & Western Ghats of India (Kalpesh *et al.* 2012). It is also available in Japan, China, Bangladesh, Arabia, Australia, tropical & subtropical areas, in the month of October to January (Beatriz *et al.* 2005). *C. medica* has distinct physiological characteristics and unique morphological attributes (Hodgson, 1967). Height of about 8 to 15 ft. (2 to 5 m). One of the distinguishing features of *C. medica* is its petioles, or leaf stems, the citron fruit is usually ovate or oblong, narrowing towards the stylar end. However, the citron's fruit shape is highly variable, it blooms several times a year, and the fruit's inner flesh is minimal with an acidic profile (Mansour *et al.* 2012). Flowers are deeply aromatic, adding a sensory delight to their environment (Webber, 1967). It can be propagated using grafting (Khan and Khan, 2016). *C. medica* necessitates protection

*Corresponding Author Email: jama14@yahoo.com

¹Secretary, The Ministry of Housing and Public Works, Bangladesh

²Advisor, Bangladesh Fruits, Vegetables and Allied Products Exporters Association

³Professor, Department of Horticulture, Sher-e-Bangla Agricultural University,

⁴Professor, Department of Entomology, Sher-e-Bangla Agricultural University

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from frost to ensure its healthy growth and fruit-bearing capability (Morton, 1987).

The citron reaches (4–5 kg) if not picked before fully mature (HortScience, 2005). Its rich content is essential nutrients and health-enhancing fruit (Mansour *et al.* 2012). It can use antibacterial, and antifungal activities (Chhikara *et al.* 2018) But in the propagation of *C. medica* L., the semi-hardwood method is often used (Singh *et al.* 2013; Singh 2017). *C. medica* is often grown or cultivated for their fruit production mainly for medicinal and ritual purposes rather than for food (Morton, 1987). It uses various traditional medicinal preparations for the treatment of asthma, arthritis, and stomachache (Perry, 1980). This peel is eaten with rice in Bangladesh, fresh, or salad like cucumber or tomato. This fruit is weighted from 250 g to 3.5 kg or more. However, the exportable size is limited to 500-600 g. The lemon and orange are peeled to consume their pulpy and juicy segments but the citron's pulp is dry, containing a small quantity of insipid juice. Flowers of *C. medica* are beneficial to cure vomiting and effective in tumours, Asthma, cough & hiccough (Kirtikar and Basu 1993). European Countries are the only importing destination for *C. medica* from Bangladesh (Annon. 2019). Among Europe countries, the United Kingdom (UK) is the major importer of *C. medica*, BFVAPEA (2020) it is amounting 92% of the whole export, and the rest is exported to other EU countries. 2018-2019 exported were 13.20 thousand MT and earning value was 4.62 million US \$.

The fertile land for *C. medica* production is the Northeastern region including Sylhet and Narasinghdi district of Bangladesh. One of the main crops produced by farmers in that area is Zara Lemon (*C. medica*). They produce and supply *C. medica* to exporters for exporting to the different destinations of the world year-round. However, due to the prevalence of quarantine pests and disease in fruits of *C. medica* from Bangladesh, importing countries have imposed different trade barriers and to avoid extra hazards in foreign trade, sometimes the government of Bangladesh has imposed self-ban (BFVAPEA, 2020). The organization also pointed out that due to the aggregation of Sylheti Bengalese in the UK and as they love to have Zara Lemon in their meal as a deletions fruit, *C. medica* is the most favorite import item there.

Despite the significance of Zara and Colombo lemons, these varieties are not properly identified and differentiated through rigorous scientific study in Bangladesh. This lack of differentiation causes misunderstandings in production practices and export activities, leading to export restrictions and bans from importing countries. This study aims to differentiate Zara and Colombo lemons based on physical plant and fruit characteristics to resolve these issues.

Materials and Method

This study was conducted between January and June 2021 in selected regions of the Sylhet and Narshindi Districts of Bangladesh, specifically targeting the Jaintapur and Sador Upazilas in Sylhet and the Shibpur and Belabo Upazilas in Narshindi, aiming to collect and differentiate Zara and Colombo lemons from local farmers' fields. A structured sampling method was employed: one union from each Upazila was randomly chosen, resulting in a total of 20 gardens being sampled (five gardens per union). From each garden, five lemons of each variety were collected, resulting in a total of 100 lemons per variety.

The study focused on meticulously recording the physical characteristics of these lemons, including their length, width, rind chamber count, weight of edible skin, number of seeds, and juice content. For detailed measurements, twenty lemons from each variety were randomly selected. The data collected was then compiled and statistically analyzed using Microsoft Excel. This analysis allowed for the calculation of mean values and standard errors for the various parameters, facilitating a clear identification of the morphological differences between Zara and Colombo lemons.

Results and Discussion

1. Plant characteristics

To identify differences between Zara and Colombo Lemons plants and their leaves and fruits, different plant characteristics were keenly observed, and data were collected and analyzed with statistical methods (Table 1).

(a) Plant height: Zara Lemon displayed an average height of 3.66 ± 0.45 m, whereas Colombo Lemon exhibited an average height of 3.04 ± 0.11 m. These findings Zara Lemon generally reaches greater heights while displaying a somewhat larger variation. Strano *et al.* (2017) also documented similar variances in plant height and canopy radius among different citrus varieties, supporting the current study's results.

(b) Stem diameter: Zara Lemon showcased an average stem diameter of approximately 27.94 ± 0.19 cm, while Colombo Lemon demonstrated a slightly smaller stem diameter, averaging about 24.13 ± 0.25 cm, align with the findings of Hodgson (1967), who reported that these traits are indicative of a more robust growth habit.

(c) Canopy radius: The horizontal spread of the plants was analyzed. Zara Lemon boasted an average canopy radius of 12.19 ± 0.51 m, whereas Colombo Lemon 9.14 ± 0.29 m.

(d) Height of the first branch from the ground: Furthermore, the height of the first branch from the ground, indicative of branching patterns, was examined. Zara Lemon positioned its first branch at an average height of 22.86 ± 0.21 cm. whereas Colombo Lemon found an average height of 114.30 ± 0.45 cm

(e) Number of branches: Finally, the number of branches per plant was considered. Zara Lemon exhibited an average of 7.50 ± 0.47 Colombo Lemon was 4.25 ± 0.23 branches per plant



Table 1. Plant characteristics of Zara and Colombo Lemon

Parameters	Zara Lemon	Colombo Lemon
Plant height (m)	3.66±0.45	3.04±0.11
Stem diameter (cm)	27.94±0.19	24.13±0.25
Canopy radius (m)	12.19±0.51	9.14±0.29
Height of the first branch from the ground (cm)	22.86±0.21	114.30±0.45
Branch number/plant	7.50±0.47	4.25±0.23

2. Leaf characteristics

The leaf characteristics of Zara and Colombo lemon varieties differ in several parameters as presented in Table 2. of leaves in Zara per branch (31 ± 0.22) is higher than in Colombo lemon (20 ± 0.42). The color of Zara lemon leaves possesses a light green hue, while the leaves of the Colombo lemon are characterized by a deeper green color.. The Zara lemon's petioles are shorter (1.27 ± 0.08 cm) than the Colombo lemon (2.03 ± 0.11 cm). In both leaves, no wing was observed. Interestingly, when considering the overall leaf length inclusive of the petiole, Zara lemon leaves are notably longer (17.78 ± 0.37 cm) than that of Colombo (13.97 ± 0.19 cm). Width of Zara lemon leaves is broader, measuring 8.89 ± 0.03 cm, compared to the slightly narrower Colombo lemon leaves at 7.52 ± 0.05 cm. The overall leaf length and width differences corroborate the observations made by Kalpesh *et al.* (2012), who reported that these measurements are essential for distinguishing citrus varieties. The broader and longer leaves of Zara lemons suggest a potential for greater photosynthetic efficiency, a trait also noted in previous studies of *C. medica* (Morton, 1987). Morphology of leaf tip of Zara lemon leaves either pointed or round-shaped tips, whereas Colombo lemon leaves are consistently round. These morphological details, particularly the pointed or round tips in Zara lemons and the consistent round tips in Colombo lemons, provide further clarity in differentiating the two varieties, supporting the findings of Beatriz *et al.* (2005) and Abobatta (2019) on the significance of leaf morphology in citrus identification. Furthermore, leaf orientation between the two lemon varieties diverges, with Leaves of Zara lemons oriented oppositely and that of Colombo lemon adopting an alternative. For instance, Hodgson (1967) also noted that leaf number, color, and shape are critical distinguishing features in citrus taxonomy. The higher leaf count per branch in Zara lemons compared to Colombo lemons aligns with similar observations made by Strano *et al.* (2017) in different citrus varieties, indicating a robust foliar growth in Zara lemons.

Table 2. Leaf characteristics of Zara and Colombo Lemon

Parameters	Zara Lemon	Colombo Lemon
Leaf no./branch	31 ± 0.22	20 ± 0.42
Leaf color	Light green	Deep green
Length of leaf petiole (cm)	1.27 ± 0.08	2.03 ± 0.11
Leaf length with petiole (cm)	17.78 ± 0.37	13.97 ± 0.19
Leaf width (cm)	8.89 ± 0.03	7.52 ± 0.05
Leaf tip	Pointed and/or round shape	Round round
Leaf orientation	Opposite	Alternative

3. Spine characteristics

The spine characteristics of Zara and Colombo lemon varieties exhibited distinct variations, as delineated in Table 3 The Zara lemon has a higher average number of spines per branch (23 ± 0.78) than the Colombo lemon, (4.0 ± 0.69) spines per branch. Spines of the Zara lemon were notably larger, measuring 3.56 ± 0.11 cm, whereas the Colombo lemon spines were shorter, at 1.27 ± 0.19 cm. About spine positioning, Zara lemon spines were uniquely positioned at the bud, maintaining a 90-degree angle with the branch. Conversely, the spines on the Colombo lemon were aligned in the upward direction from the bud position. The distinction between these varieties was further accentuated by the color of their spine tips: while Zara lemon spines culminated in a brown hue, those of the Colombo lemon were green in color. Differences between the Zara and Colombo lemon varieties, enriching the comprehensive understanding of their phenotypic features.

Table 3. Spine characteristics of Zara and Colombo Lemon

Parameters	Zara Lemon	Colombo Lemon
Spine no./branch	23 ± 0.78	4 ± 0.69
Spine size	3.56 ± 0.11	1.27 ± 0.19
Spine position	Bud position (90° angle with branch)	Bud position (upward direction)
Spine tip	Brown in color	Green in color

4. Flower characteristics:

The flower characteristics of the Zara and Colombo lemon varieties were delineated in Table 4, revealing significant differences in certain attributes. Zara lemon has 4 petals per flower, with instances of 5 petals being rare. In contrast, the Colombo lemon consistently displayed 5 petals per flower. At the young stage, the petals of both varieties were purple. Zara lemon flowers transformed to having both their inner and back petals turn white having a light purple line, whereas the Colombo lemon's mature flowers retained a light purple color on their back petals, while the inner petals were white. Zara lemon predominantly exhibited a racemose arrangement with fewer instances of solitary structures. On the other hand, the Colombo lemon was characterized by a higher prevalence

of solitary inflorescences and relatively lesser racemose arrangements. The distinctions in inflorescence arrangements observed in Zara and Colombo lemons corroborate earlier research by Noelle *et al.* (2006), which highlighted variations in floral structure and organization across citrus species. These distinctions showed differences in the floral morphology of the Zara and Colombo lemon varieties, deepening the comprehensive understanding of their unique phenotypic traits.

Table 4. Flower characteristics of Zara and Colombo Lemon

Parameters	Zara Lemon	Colombo Lemon
Petal no./fruit	4 petals/flower common, 5 petals rare	5 petals/flower common
Petal color	Purple at the young stage Inner and back are both white at the mature stage	Purple at the young stage Inner white but back light purple color in mature stage
Inflorescences Structure	Less solitary, more racemose	More solitary, less racemose

5. Fruit Characteristics:

(a) Fruit length and fruit width of Zara and Colombo lemon

The length and width of the Zara and Colombo lemons are documented in Table 5. Averaging these dimensions, the typical length of a Zara lemon was found to be 21.47 ± 1.39 cm. On average, the length of the Colombo lemon was determined to be 13.45 ± 1.36 cm. These findings are consistent with previous research conducted by Strano *et al.* (2017), who also reported variations in citrus fruit size among different varieties. Additionally, the observed differences in lemon length align with the broader understanding of citrus fruit morphology documented by Denaro *et al.* (2020) and Liu *et al.* (2012), emphasizing the importance of such variations in distinguishing citrus species.

Table 5. Fruit length and width of Zara and Colombo Lemon

Lemon Variety	Average Fruit length (cm)	Average Fruit width (cm)
Zara	21.47 ± 1.39	26.24 ± 1.25
Colombo	13.45 ± 1.36	16.03 ± 0.67

(b) Fruit thalamus, shape, color, fruit end, rind number, weight of Zara and Colombo lemon

The thalamus of the Zara lemon fruit was observed to be less prominent, contrasting with the distinct prominence noted in the Colombo lemon (Table 6). Morphologically, the Zara lemon bore a smooth yet irregularly rough skin with an irregular fruit shape but the slender shape is dominant. In a single plant of Zara lemon, different shapes and sizes of fruits were available. In contrast, the Colombo lemon was distinguished by a distinct ridge in its skin and assumed a more oval shape in its lower portion. But in the case of Colombo, the shape of the fruits in a single and all other plants in a garden is the same.

The Zara lemon presented a lighter green hue, while the Colombo lemon exhibited a deeper green shade. The terminal end of the Zara lemon was bluntly pointed, a feature that differed from the gradually sharply pointed end of the Colombo lemon. Zara lemon has an average of 10.43 ± 0.53 chambers, while the Colombo lemon was found to have a slightly higher count at 13.67 ± 0.25 chambers. Hodgson (1967), who have also reported variations in chamber count among different citrus varieties. This characteristic could serve as a valuable marker for distinguishing between Zara and Colombo lemons.

The weight range of the Zara lemon is from 300g to a hefty 1400g. While Colombo lemon was generally lighter, with weights ranging from 170g to 350g., corroborates earlier findings by Carvalho *et al.* (2005) and Beatriz *et al.* (2005), who have highlighted the variability in fruit weight among citrus varieties. Zara lemon's edible skin averaging 211.00 ± 82.60 g, substantially more than the Colombo lemon's average weight of 118.00 ± 35.81 g., as documented by previous studies on citrus fruit anatomy and composition (Chhikara *et al.*, 2018).

Table 6. Fruit characteristics of Zara and Colombo Lemon

Parameters	Zara Lemon	Colombo Lemon
Fruit thalamus	Less prominent	Prominent
Fruit shape	Smooth, irregular rough skin, slender shape	Distinct ridge in skin, lower portion oval shape
Fruit color	Light green	Deep green
Fruit end	Bluntly pointed	Shape pointed
Number of rind chamber/fruit	10.43 ± 0.53	13.67 ± 0.25
Fruit weight (g)	300-1400	170-350
Weight of edible skin/fruit (g)	211.00 ± 82.60	118.00 ± 35.81

6. Seed characteristics of Zara and Colombo lemon

The Zara lemon was observed to have an average seed count of 8.67 ± 0.89 per fruit, which was notably lower than the Colombo lemon's average of 17.57 ± 2.19 seeds per fruit (Table 7). The Zara lemon seeds exhibited a light brown hue, contrasting starkly with the Colombo lemon seeds, which were characteristically white.

7. Amount of juice, skin thickness, and node characteristics of Zara and Colombo lemon

Zara lemons contain approximately 37.71 ± 11.28 ml of juice per fruit. In contrast, the "Colombo" variety is juicier,



providing an average of 46.67 ± 10.41 ml of juice fruit⁻¹. This suggested that the Colombo Lemon typically yielded more juice than its Zara counterpart (Table 8). Studies such as those by Denaro *et al.* (2020) and Liu *et al.* (2012) have similarly noted that juice content is a critical parameter for consumer preference and marketability. Strano *et al.* (2017) also discussed juice yield variations among citrus varieties, emphasizing its relevance to both growers and consumers.

"Zara" lemons feature a skin thickness of 1.68 ± 0.71 cm, which is considerably thicker than the "Colombo" variety, which averages a thickness of 1.00 ± 0.21 cm. The thicker skin of Zara lemons compared to Colombo lemons is consistent with the physiological characteristics documented by Hodgson (1967), who reported that skin thickness can vary significantly among citrus species and is influenced by genetic and environmental factors. This study's findings on skin thickness further corroborate the work of Beatriz *et al.* (2005), who observed that thicker-skinned citrus varieties often have less juice, aligning with the lower juice content found in Zara lemons.



Fruits of Zara lemon



Fruits of Colombo lemon



Intersection of Zara lemon



Intersection of Colombo lemon

Table 7. Seed characteristics of Zara and Colombo Lemon

Parameters	Zara Lemon	Colombo Lemon
Seed number	$8.67 \pm .89$	17.57 ± 2.19
Seed color	Light Brown	White



Seed of Zara lemon



Seed of Colombo lemon

Table 8. Amount of juice, skin thickness, and node characteristics of Zara and Colombo lemon

Lemon variety	Zara Lemon	Colombo Lemon
Amount of juice fruit ¹ (ml)	37.71±11.28	46.67±10.41
Skin thickness (cm)	1.68±0.71	1.00±0.21
Node	Single-leaf rare and double-leaf common	Single leaf
	Single spine rare and double spine common	Single spine
	Spine in every node	Some nodes are spineless

8. Growing area and insect pest infestation of Zara and Colombo lemon

Zara lemons predominantly grown in the Sylhet region, displayed a lower vulnerability to black spot infestation (Table 9). Additionally, this variety was found to have a high incidence of canker but showed lower levels of scab and leaf miner infestations. Contrarily, Colombo Lemons, chiefly cultivated in the Narshingdi area, exhibited a higher susceptibility to black spots. In the survey areas under Narshingdi, this variety showed no signs of canker but was highly infested with scab and leaf miners.

Table 9. Growing area and insect pest infestation of Zara and Colombo lemon

Lemon variety	Zara Lemon	Colombo Lemon
Growing area	Sylhet	Narshingdi
Insect pest infestation	Less infested by black spot, High canker, Less Scab infestation, less leaf miner infestation	High infestation of Black spot, no canker, high scab infestation, high leaf miner infestation

Conclusion

Morphological characterization of Zara and Colombo lemons in Bangladesh is crucial, as these export crops are primarily consumed by the Bangladeshi diaspora in the UK, Europe, and the Middle East. Zara lemons, previously exported on a large scale, faced a ban due to Canker, while Colombo lemons, though different, were exported under the same name and are susceptible to Scab. Both crops now face export restrictions due to these diseases. This study highlights the differences between these varieties and recommends targeted care at the production and business levels. Zara lemons, with higher export demand, offer significant economic potential, warranting further research to address these challenges.

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