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RESEARCH ARTICLE

Morphological variations in *Citrus limon* (L.) Burm.f. (Assam Lemon) of Kokrajhar district of BTR, Assam

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Abstract

The present study documents five varieties of *Citrus limon* (L.) Burm. f. focusing on their morphological characters at vegetative and fruiting stage. The variety names are attributed according to the growing localities viz. Chandamari, Rupati Nwgwr, Patharghat, Basugaon and Dhauliguri. The collection has been done through field survey and visiting different lemon growing localities including lemon orchards of Kokrajhar district. The study highlights the importance of understanding morphological traits like leaf shape, size, fruit dimensions and overall growth habit of different lemon varieties commonly grown in Kokrajhar district of Bodoland Territorial Region (BTR), Assam. It also highlights the crucial role that lemon plays in maintaining the immune system and protection against infections like SARS-COV-2. By studying and examining these characteristics, suitable rootstock with high-yielding lemon varieties that are suited to the local climate can be identified and how it can be used for large scale cultivation in the near future. The comprehensive report resulting from this study provides valuable insights into the morphological characteristics and data by understanding the specific traits of these lemon varieties that will ultimately benefit the agricultural sector as well as development of lemon industry in the region.

Key words: *Citrus limon* (L.) Burm.f.; Characterization; Diversity; Identification; Variety.

1. Introduction

Citrus limon (L.) Burm f. commonly known as lemon, is a species of small evergreen tree or shrub belonging from the flowering plant family-Rutaceae. Swingle (1943) have divided Citrus into two subgenera, Citrus (formerly Eucitrus) and Papeda. In this context, (Bhattacharya and Dutta, 1956) have published the importance of Assam citrus in the book titled- "*Classification of the Citrus Fruits of Assam*" and that the species belongs to the subgenus *Citrus*. It is native to South-Asia (Aiyappa and Srivastava, 1965; Randhwa and Srivastava, 1986) specifically in the Northeast India where it has been grown since time immemorial (Singh, 1981; Kumar, 2019). It is to be mentioned that lemon has recently gained importance in Bodoland Territorial Region (BTR) of Assam because of its increasing demand for its refreshing flavor along with its ascorbic acid content that boost the immune system and protects from infection like SARS-COV-2 (Gogoi, 2024). On the other hand, the agro-climatic condition of Kokrajhar district is suitable for growing lemon varieties and it is also found to be grown in forest areas besides cultivated land (Gogoi and Basumatary, 2017). The Kokrajhar district is important in regards to *Citrus* genetic resources (Annual Report, 2021-2022). Hence, a study has been undertaken for germplasm collection and identification of lemon varieties which are grown at various localities of Kokrajhar district as per the objective of the Department of Biotechnology, Govt. of India sponsored project titled "Scientific approaches to develop Biopesticide for controlling Citrus diseases and standardize the products obtained from *Citrus limon* (L.) Burm f." The present study aims to explore the specific morphological traits exhibited by *Citrus limon* in Kokrajhar, investigating how local climate, soil conditions and water availability may influence these attributes. The exploration of these morphological characteristics is thus essential for both scientific understanding and its practical implementation.

2. Methodology

2.1. Study area

The Kokrajhar district is situated in the western part of Assam lying between latitude 26° 24' 3.85" N longitudes 90° 16' 22.30" E. The district covers total geographical area of 3,169.22 km2, with total forest coverage of 1,719 km2 (approx.), accounting to about 55% of land area. A thorough exploration survey was conducted in eleven selected sites of Kokrajhar district, namely Chandamari, Rupati Nwgwr, Patharghat, Basugaon, Dhauliguri, Banargaon, Tipkai, Dotma, Kachugaon, Jharbari, Saralpara etc during 2023-2024, to collect the samples of various lemon varieties (Figure 1). Agro-climatic conditions of Kokrajhar district are suitable to grow lemons and its exploration has been made to collect specimen for both live and herbarium preservation.

2.2. Germplasm collection and Identification

Following the method as suggested by (Lawrence, 1951; Jain and Rao, 1976), morphological characters such as tree height, leaf and fruit shape, size, and internal characters of a mature fruit were recorded after thorough study along with the local agro-climatic conditions. Germplasm including lemon fruits were collected from different geographical locations (Figure 1) and planted in the nursery (Biotech Hub, Science College, Kokrajhar) following the method of Rajput and Haribabu (1995) and UPOV/TF/83/3. The samples were analysed for various morphological features of the leaf and fruit such as its shape, size and overall plant morphology for identification of their taxa. A comprehensive report detailing the morphological characteristics on the basis of two years study has been recorded.

3. Result

Assam lemon - *Citrus limon* (L.) Burm.f. has been considered as one of the most important tropical fruits since prehistoric times and it is beyond doubt that the said plant species is endemic to Assam as well as North-eastern states of India. The agro-climatic

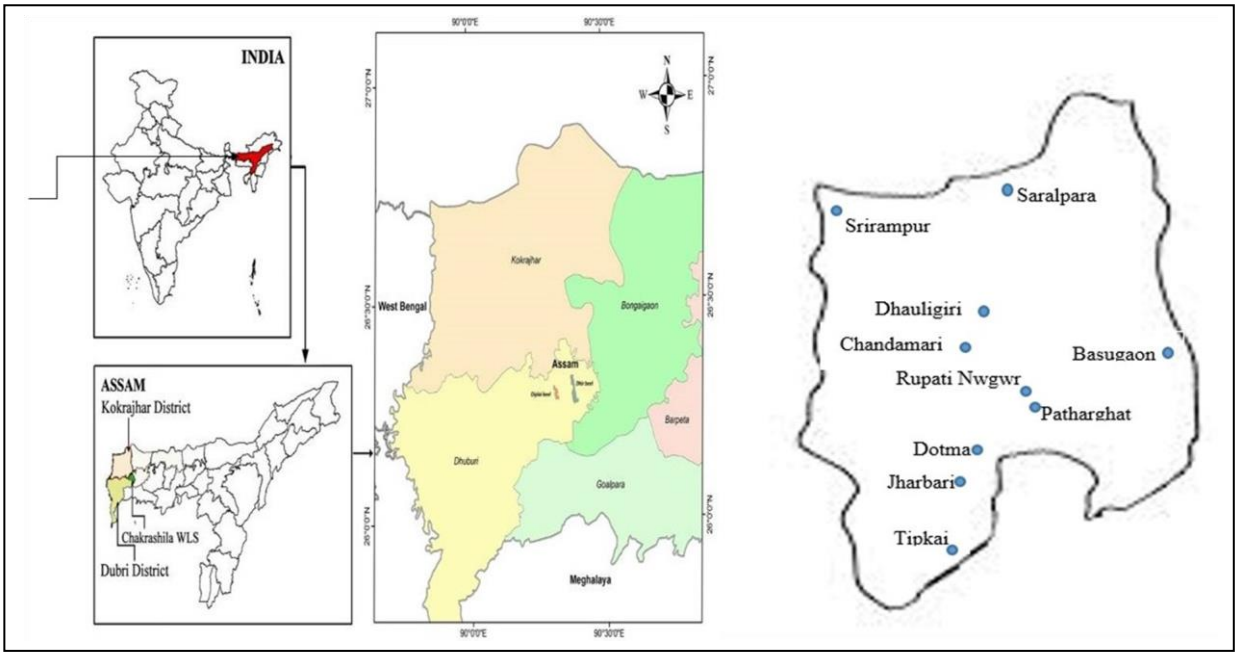

Figure 1. Showing different locations of Kokrajhar district from where *Citrus limon* (L.) Burm.f. variety has been collected.

conditions of Assam particularly adjacent areas to Arunachal Pradesh, Nagaland and Meghalaya are suitable to grow lemon varieties along with other citrus species and some pockets of Kokrajhar district, BTR, Assam has gained attention in regards of lemon distribution. Due to cross pollination and apomictic reproduction leads to creation of variations. The result of the past two-year study at various stages viz. habit, fruiting, fruit while become mature and fruit anatomy through transverse and longitudinal sectioning has revealed variations among the studied lemon varieties. Findings are presented in Figure 2, Table 1 and major morphological characters observed are as follows-

Variety-1 (Figure 2: A, B, C, D and Table 1) observed at Chandamari area of Kokrajhar district (Figure 1). Plant is a shrub, height 6-8 ft., dense foliage, straggling brush, dropping and thorny; Leaf medium large, ovate-oblong, 11.5 cm long and 5.5 cm broad; Fruit grown in cluster (2-4), ovate-oblong, gradually narrowed towards base, surface uneven, 10cm long, 5.8 cm diameter and average weight 136 g; Juice vesicle crystal white, acicular, juice abundant and good flavor; Rind thin, about 0.2 cm thick; Fruit axis hollow, 0.8 cm large; Fruiting season almost throughout the year.

Variety-2 (Figure 2: E, F, G, H and Table 1) is grown at Rupati Nwgwr (Figure 1). Plant is shrub, height 5-7 ft., dense foliage, straggling brush, dropping and thorny; Leaf evergreen, medium large, 12 cm long and 7.1 cm breadth; Fruit ovate-oblong, surface smooth, areola present at the base and pointed apex, average weight 203.9 g, length 10.03 cm and diameter 6.3 cm; Juice vesicle crystal white, acicular, juice abundant and good flavor; Rind white, thin and 0.1-0.3 cm thick; Fruit axis hollow and 1.2 cm large; Seed may or may not present; Fruiting season almost throughout the year but main crop from May to October.

Variety-3 (Figure 2: I, J, K, L and Table 1) collected from Patharghat (Figure 1). Plant is small tree about 8-14 ft. height, branch strait and lower one drooping, thorny; Leaf evergreen, medium large, 10.6 cm long and breadth 4.9 cm; Fruit oblong, surface slightly rough, average weight 77.5 g, length 7 cm and diameter 5 cm; Rind thick, thickness 0.3-0.5 cm; Juice vesicle crystal clear, acicular, juice abundant, sour and spice flavored; Axis solid, 0.8 cm large; Seed present; Fruit grown in solitary and fruiting season almost throughout the year. Variety 4 (Figure 2: M, N, O, P and Table 1) is grown at Basugaon area of Kokrajhar district (Figure 1).

Plant is small tree, height 8-14ft, dense foliage, straggling brush, dropping and thorny; Leaf evergreen, medium large, 14 cm long and 7.7 cm breadth; Fruit spherical, surface smooth, green yellow when ripe, apex pointed, average weight 92.95 g, 7.5 cm long and 5.4 cm diameter; Juice vesicle yellow-white, short and stout, juice abundant, sour but scented like cardamom; Rind thick, thickness 0.4 cm; Fruit axis solid, 0.7 cm large; Seed present. Fruit grown in solitary or cluster (2-3); Fruiting season May to November.

Variety-5 (Figure 2: Q, R, S, T and Table 1) has been collected from Dhauliguri village (Figure 1). Plant is small tree, 10-12 ft height, branch straight and thorny; Leaf evergreen, medium large, length 15.3 cm and 6.8 cm width; Fruit ovate-oblong, surface bumpy with prominent apex, average weight 311.6 g, length 12.2 cm and 7.4 cm diameter; Rind thick, white and thickness ranges from 0.4 to 0.6cm; Fruit axis solid, 1.1cm large; Juice vesicle white, short and stout, juice abundant and sour; Seed present; Fruiting season April to October

4. Discussion

Among different Citrus species grown in Assam as well as North Eastern States of India (Govinda and Ghosh, 1997; Govinda and Yadav, 1999; Singh, 1981; Singh, 1999), *Citrus limon* (L.) Burm f. has gained tremendous prominence due to its distinct aroma and attractive flavor. The said lemon fruit has gained the due attention during Covid-19 pandemic period worldwide. The reason behind its ever-increasing demand is the presence of high-quality nutrients along with ascorbic acid that maintains the immune system functioning and protects human beings from Corona virus (SARS-Cov-2) infection (Gogoi, 2021). Subsequently, Geographical Indication (GI) has been awarded to Assam lemon in 2019 by Registrar of Geographical Indication, Govt. of India and the Government of Assam has notified the Assam lemon as the state fruit of Assam on 13th February, 2024.

Lemon is called by various names in India: limbu, limu, nimbu (Hindi), Ritey-ape (Arunachal Pradesh) and nemu (Assam). The names in different languages have a striking phonetic resemblance with the words limun, limuna and li-mung (Bhattacharya and Dutta, 1951 and 1956). Regarding nomenclature, the earlier workers have considered limes, lemons and citron within the same species - *Citrus medica* Linn. Roxbourgh (1832) has placed limes under a separate species *C. acida* which has been accepted by Lushington (1910) and Brandis (1874). Swingle (1913) has

Figure 2. Presented the habit, fruiting stage, mature fruit and internal features of five varieties of *Citrus limon* (L.) Burm f. of Kokrajhar, BTR, Assam.Variety-1, Chandamari (A, B, C, D); Variety-2, Rupati Nwgwr (E, F, G, H); Variety-3, Patharghat (I, J, K, L); Variety-4, Basugaon (M, N, O, P); Variety-5, Dhauliguri (Q, R, S, T).

Table 1. Morphological characters of leaf and fruit of five varieties of *Citrus limon* (L.) Burm.f. collected from different locations of Kokrajhar, BTR, Assam.

Sl. No.	Lemon growing locality	Morphological character of the fruit			Fruit axis (cm)	Leaf character	
		Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)		Leaf length (cm)	Leaf width (cm)
1	Chandamari	10	5.8	136	0.8 (hollow)	11.5	5.5
2	Rupati Nwgwr	10.03	6.3	203.9	1.2 (hollow)	12	7.1
3	Patharghat	7	5	77.5	0.8 (solid)	10.6	4.9
4	Basugaon	7.5	5.4	92.95	0.9 (solid)	14	7.7
5	Dhauliguri	12.2	7.4	311.6	1.1 (solid)	15.3	6.85

established the position of lime as an independent species and named it as *Citrus aurantifolia* (Christm.) Swin. On the other hand, (Swingle, 1943) reports that lemon have been variously named by different taxonomists, *C. medica* var. *limon*, L.; *C. limon* (Linn.) Burm.f.; *C. limonia* (*vulgaris*), Risso (1813); *C. limonum*, Brandis (1874); *C. medica*, Roxburgh (1832). The oldest name *Citrus limon* (L.) Burm. (1741-1750), has been accepted as the true sour lemons without any contradiction (Tanaka, 1937; Swingle, 1943; Webber, 1943). As it has been mentioned in the introductory part of the article, after thorough exploration across the district, it has been observed to be grown in some pockets (Figure 1 and Map), but there were variations among the lemon varieties/cultivars that grow in the wild and domestic conditions. Among the five collected *Citrus limon* (Linn.) Burman varieties/cultivars (Plate-I & Table 1), Variety-3 and Variety-4 has been observed to be grown in backyard or forest as a semi-wild plant with high adaptation in the local ecosystem. The fruit of these two varieties has less market demand although the fruits were found to be highly aromatic. Variety-5 (Plate-I and Table 1) is not usually sold in the market but it flourished well within short period of time. On the other hand, Variety-1 and Variety-2 (Plate-I and Table 1) were used for large scale cultivation, with optimum production and good market demand. Considering its commercial importance in local as well as global market, the prevailing *Citrus limon* diversity in Kokrajhar district is a valuable genetic resource that can be utilized for the growth of lemon industry in future. It is to be mentioned that (Chetiya and Bharadwaj, 2018) has been emphasized in their research article that such diversity plays an important role in selection of suitable cultivars. The present study has provided clear evidence on diverse lemon varieties are grown in the district soil.

5. Conclusion

Altogether five distinct sour lemon varieties are found to grow in Kokrajhar district and the names are attributed according to the growing localities of the district. Diverse lemon varieties are valuable genetic resource that can be considered as source material for selecting either suitable cultivar or root stock. The diverse lemon varieties that are found at Kokrajhar can be ascertained with thorough characterization, identification and corroborated with DNA sequencing. Meanwhile, lemon holds a prominent position in the agricultural landscape of Kokrajhar district, significantly contributing to both local economy and culture. The regions favourable climate and fertile soil enhance the growth of this citrus variety, leading to develop variations that are vital for research and its improvement.

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Author's contributions

All authors contributed equally to the conception, research design, data collection and manuscript finalization.

Declaration of conflict of interest

The authors report no conflict of interest.

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