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Pummelo [*Citrus grandis* (L.) Osbeck] Diversity in India

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An extensive survey was conducted in parts of Bihar, Karnataka, Tamil Nadu, North-East Region and Andamans during 2012-14 to know the existing variability of largest sized *Citrus* spp. fruit, pummelo [*Citrus grandis* (L.) Osbeck]. The aim was to select the best genotypes suitable for large scale plantation and domestic markets. *Devenhalli* pummelo from Karnataka got GI status, indicating its importance in the region as it has small size (525 g), low acidity and high TSS (>10^0B) with red pulp. Pummelo from Yarcaud, Tamil Nadu had highest juice content (22.60 %) followed by fruits from Nagaland (21.65 %) which are larger in size (1,232.30 g). In Bihar, pummelo is valued for *Chhat Puja* and farmers maintain at least one plant in their home gardens to get fruits during festival season without any maintenance cost, and fortunately many good quality pummelo are available in some home gardens of the state. Pummelo from Bihar as Clone No. 8, 28, 31, 35, and 39 had high TSS (>10^0B) confirmed its potential for better consumer acceptance than others. The fruits of Clone No. 33 were completely seedless, were easy to serve and Clone No. 26 was suited for better consumption as it had soft cell sacs. Clone No. 1 had maximum fruit size (2,420 g) and number of segments per fruit (22.00) may be suited for better yield. The fruits of Clone No. 25, 37 and 13 are easy to peel as it has very thin rind (0.80, 1.00, 1.01 cm). Port Blair pummelo has low acidity, but due to low TSS (6.90 ^{0}B), may not be liked by consumers. *Devanhalli* pummelo from Karnataka, Manipur pummelo, Clone No. 31 and seedless pummelo of Bihar may be suited for commercial plantation and large scale consumption. If all these germplasm are propagated through air-layering and distributed to the farmers, better quality pummelo may fetch better price in national and international markets. Livelihood security will thus improve for the grower and subsequently diversity will also be maintained.

Key Words: Diversity, Home garden, Nutritional security, Pummelo

Introduction

Citrus fruits are recognized as an important component of the human diet, being sodium and cholesterol free, rich in vitamin C, folic acid, potassium, flavonoids, coumarins, pectins and dietary fibres (Dugo and Di Giacomo, 2002; Roy *et al*., 2014). 'Pummelo' a member of Rutaceae family, grown as a tropical citrus fruit, has generally been identified with the wild species *Citrus maxima* (Burm.) Merr. on the basis of morphology and molecular markers.

Pummelo is now gaining popularity in India due to its high nutritional value and antioxidant property. The pummelo plants are mostly maintained in home gardens and no commercial plantation has been started yet. The quality of pummelo in India is not homogeneous across the regions and morphological characteristics are very different and the genetic variability has not been fully reported. It has played an important role as a parent of many citrus fruits, such as lemon, oranges and grapefruits (Youseif *et al.,* 2014).

Pummelo is distributed in Bangladesh, Cambodia, Chile, India, Indonesia, Japan, Laos, Malaysia, Philippines, Thailand and Vietnam (Orwa *et al.,* 2009) and, is also grown in China (Vinning and Moody, 1997; Zhang and Shaolin, 2000), Srilanka and Nepal. In India, it is grown in home gardens in all states of India and maximum diversity is reported from North-East (NE) Region (Singh and Singh, 2003; Roy *et al*., 2014), Bihar and Bengal. Though it is the largest fruit of citrus group, it has not attained the commercial importance despite its health and nutritional benefits. The use of pummelo is more as a fresh fruit and it is valued in Bihar during *Chhat Puja,* while the high antioxidants content and other nutritional values have medicinal uses (Panmanas

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and Theamprat, 2012). In fact, popularity of pummelo lies in its greater tolerance to insect and diseases than other citrus fruits. However number of trees with good quality fruit is very negligible in comparison to the inferior ones, and even then, large variability exists in different parts of the country (Karnataka, Bihar, West Bengal, NE region, Tamil Nadu, Andaman and Nicobar Island etc.).

There is potential in India for the development of this fruit as an export crop because its thick rind makes it easy to handle and transport (suitable for distant market), and thin rind is easy to peel (suited for local consumption). According to Wen *et al.* (2010), there is an urgent need for pummelo conservation due to a decline in varietal diversity owing to loss of natural habitat, elimination of unwanted phenotypic characters and artificial selection during domestication process. *Chhat Puja,* a festival of Bihar for which pummelo is valued for, is the main sink of fruit consumption and people of Bihar who are residing in other parts of the country, purchase the fruits at any cost, during the festival which motivates farmers to conserve the diversity. Once the suitable germplasm is identified, it can be used not only during *Chhat Puja* but also as a table fruit. Further, it's red colour segments are attractive and have potential for large scale processing, juice extraction etc.

Across the country, many good quality pummelo are available in home gardens, descriptive orchards and recently *Devenhalli* pummelo from Karnataka got GI protection. Characterization of pummelo using morphological traits will help in selecting genetically potential genotypes for cultivation (increased production), marketing and their use in plant breeding programmes. The present study was, therefore, undertaken for morphological and quality characterization of pummelo germplasm grown in homestead across the country and to select germplasm of better quality for consumption, marketing and conservation.

Materials and Methods

The study was conducted at two places in India, NRC for Citrus (NRCC), Nagpur (for *Amrawati* cluster) and NRC for Litchi, Muzaffarpur, Bihar (for *Pusa* cluster) under UNEP-GEF/ TFT Project during 2012-14. At both the places as well across the country, pummelo diversity was observed, mostly in home gardens and street plantations.

To know about the pummelo variability available in the country, information was collected from the records of ADB (Asian Development Bank) and National Agricultural Technology Project (Plant Breeding) project completed at NRCC, Nagpur. Accordingly, different areas of India were surveyed and first hand information was collected from farmers to identify their preferred phenotypes, and above all, to obtain pointers to the genetic diversity. Traits, such as tree age, fruit bearing frequency, flowering, maturity period and fruit yield, were assessed based on information collected from growers. As per information provided by the community/pummelo grower, individual plants were observed. Three fully mature and healthy fruits from each tree were collected randomly from different directions of the canopy, at different locations.

The physical (fruit weight, fruit length, fruit width, rind thickness, number of segments/fruit, number of seeds/fruit) and chemical (TSS, acidity percentage) characters of fruits were recorded after thorough washing with tap water to remove adhering impurities. Fruit and seed weights were measured using electronic (digital) balance whereas fruit rind thickness was measured by slide callipers. The juice was extracted from the pulp by straining through a muslin cloth and total soluble solid content of fruits was determined with the help of a hand held refractometer and expressed in terms of degree brix and values were corrected at 20 °C. Juice acidity was estimated by titrating 2 ml juice against 0.1 N NaOH using phenolphthalein as an indicator (AOAC, 1990). The data was analyzed as per Gomez and Gomez (1984).

Result and Discussion

Large variability was observed in fruits of pummelo collected across India. All the eight quantitative characters showed significant variation indicating the strength of genetic base of the crop. Among different regions where pummelo are grown, one of the areas is Bihar, wherein pummelo with only red flesh was found, indicating the preference for red flesh over white ones. However, in other parts of the country, both white and red flesh pummelo are maintained by the community, in their home gardens. Pummelo diversity existing in different regions, based on fruit characters and their potential for commercialization, is mentioned below.

Variability of Pummelo in Bihar

Based on the information available at the community level in Muzaffarpur, Samastipur and Darbhanga districts

of Bihar, a total of 43 seedling plants of pummelo were marked and fruits were analysed for fruit physico-chemical characters (Table 1). The wide variation in physico-chemical composition of fruits, offers wide scope for breeding desirable hybrids or variants.

Large variability was observed in clones collected from Bihar and based on fruit characters, four clones (clone no. 8, 28, 31 and 35) were found superior with high TSS (> 10.50°B). These four clones had red flesh and tasted better due to sweetness.

Table 1. Physico-chemical characteristics of pummelo fruits collected from Muzaffarpur, Samastipur and Darbhanga districts of Bihar

Place of collection of fruits	*Clone no.	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Rind thickness (cm)	No. of segments per fruit	No. of seeds per fruit	TSS (^{0}B)	Acidity (%)	Pulp colour
Muzaffarpur and Darbhanga	1.	2420.00	19.50	18.60	1.52	22.00	111.00	10.10	1.10	-
	2.	468.00	9.94	10.42	1.21	11.00	52.00	8.40	1.00	-
	3.	1481.00	15.20	16.30	2.34	15.00	95.00	8.30	1.30	-
	5.	1415.00	14.60	15.80	1.36	16.00	85.00	8.80	1.20	-
	6.	542.00	10.40	9.50	1.04	16.00	8.00	10.30	1.10	-
	7.	1063.00	12.70	15.80	1.53	14.00	80.00	8.50	1.40	-
	8.	1380.00	14.05	14.78	1.82	14.00	64.00	11.50	1.60	-
	9.	1490.00	15.60	16.04	1.94	14.00	43.00	8.90	1.50	-
	10.	1838.00	17.50	19.50	3.16	14.00	36.00	8.10	1.60	-
	12.	1594.00	14.00	16.00	1.44	19.00	108.00	10.10	1.60	-
	13.	1557.00	13.50	16.02	1.01	16.00	98.00	9.60	1.40	-
	14.	1378.00	15.00	14.88	1.17	12.00	111.00	8.70	1.60	-
	15.	1358.00	14.00	13.50	1.84	15.00	112.00	9.90	1.30	-
	17.	1560.00	14.60	14.50	1.20	16.00	115.00	9.30	1.60	-
	18.	1641.00	16.80	13.60	1.06	19.00	62.00	8.00	1.40	-
	19.	2006.00	15.20	16.70	1.64	19.00	125.00	9.20	1.60	-
Pusa, Samastipur	20	1231.67	15.17	14.50	1.63	12.00	76.00	9.30	3.14	Light red
	21	1289.33	15.33	14.53	2.10	12.33	38.00	8.23	3.48	Pink
	22	2064.00	21.83	17.50	4.00	15.67	128.33	9.63	3.39	Light pink
	23	1056.00	14.83	15.13	2.50	14.67	104.67	8.63	3.27	Light red
	24	1701.33	14.33	15.23	1.50	18.00	125.67	9.00	3.59	Dark red
	25	862.67	11.03	11.83	0.80	14.08	125.33	9.17	3.43	Dark red
	26	1088.67	15.07	13.40	2.10	17.33	108.00	8.50	2.93	Light red
	27	1208.67	13.07	15.17	1.90	14.00	151.33	8.00	3.34	Light pink
	28	644.67	10.73	10.63	1.13	12.00	96.00	10.50	3.34	Light red
	29	1283.33	15.57	15.67	2.70	17.67	60.67	7.40	3.92	Light red
	30	1110.00	15.17	13.07	2.07	13.67	58.67	9.00	3.55	Very light red
	31	2238.67	16.50	17.03	1.97	14.67	82.67	11.13	3.40	Red
	32	1738.67	15.00	16.77	2.00	17.00	98.00	9.60	3.41	Red
	33	498.00	11.53	11.87	2.00	10.00	0.00	8.60	-	Light red
	34	1774.67	16.97	16.73	2.90	13.67	139.33	8.10	3.13	Red
	35	602.00	12.00	12.67	1.30	14.33	124.00	11.10	3.21	Dark red
	36	638.00	10.73	11.03	1.20	12.33	112.00	8.20	3.50	Light red
	37	750.67	12.67	11.67	1.00	13.67	54.00	9.67	3.39	Red
	38	868.67	13.33	10.67	1.07	15.67	82.00	8.80	3.54	Light red
	39	493.33	10.50	10.10	1.10	13.33	47.00	10.17	3.06	White
	40	1334.00	11.75	13.75	1.35	15.00	68.00	9.55	3.41	Dark red
	41	789.33	10.67	12.50	1.50	13.33	23.33	9.40	3.26	Dark red
	42	1207.00	16.33	14.33	2.77	14.67	19.67	8.00	3.62	Red
	43	1358.67	11.50	13.67	1.93	18.00	78.00	8.10	3.33	Light pink
	Mean	1275.58	14.10	14.28	1.74	14.98	82.64	9.13	2.58	-
	Range	468.00-2420.00	9.90-21.80	9.50-19.50	0.80-4.00	10.00-22.00	0.00-151.00	7.40-11.50	1.00-4.00	-
	SEm ±	78.34	0.40	0.38	0.10	0.39	5.93	0.15	0.16	-
	Variance	245510.30	6.62	5.77	0.46	6.05	1408.43	0.93	1.00	-
	SD	495.49	2.57	2.40	0.68	2.46	37.52	0.96	1.00	-

For better yield, fruit size is more important and clone nos. 1, 31, 22 and 19 had fruit weight more than 2000 g *i.e.*, 2420, 2238.67, 2064 and 2006 g, respectively over other genotypes. The fruit of clone no. 33 was comparatively small (498 g) but completely seedless and may be best for fresh fruit consumption by children. Clone no. 33, also had least number of segments (10.00) and clone no. 26 was tender as it had very soft cell sacs (Table 1).

Present findings indicated significant variation in number of seeds/fruit (0-151) with clone no. 6, 42, 41 and 10 of Bihar having few seeds/fruit (8, 19.67, 23.33 and 36, respectively). Clone no. 1, 24, 43, 29 had more than 17 segments/fruit. Hazarika *et al.* (2013) also reported less number of seeds (12.67-37.50) among germplasm of pummelo from Mizoram. Thin rind was observed in clone no. 25 (0.80 cm), 37 (1.00 cm), 13 (1.01 cm) and 18 (1.06 cm) whereas thick rind was found in clone no. 22 (4.00 cm) and 10 (3.16 cm). Clone no. 31 with higher fruit weight, red flesh, thin rind, high TSS (11.13°B), moderate acidity and less number of seeds per fruit can be considered a promising clone of pummelo from Bihar. The pulp of pummelo from Bihar is mostly red or dark red and may fetch better price in the market for attractive appearance and high antioxidant content. Additionally, in three pummelo collections, fruit bearing was thrice in a year *viz*., during flowering, fruit development and fruit maturity. These plants can be used in breeding programmes for availability of fruits throughout the year for consumption and other uses.

Variability of Pummelo in South India, NE Region and Andamans

In North-East region, pummelo are grown mostly in home gardens and best quality of pummelo is produced in Agartala (Tripura), Mamit (Mizoram) and Dimapur (Nagaland). In Tripura, the maximum demand was observed during *Vishwakarma Puja* (in September) and *Durga Puja* (in October), as it is offered (as *prasad*) to god. In Bihar and West Bengal, large quantity of pummelo fruits are consumed during *Chhath* and *Durga Puja* (September-October) as mature pummelo are available in these states. This creates a huge market for this fruit during the season. Like Bihar, in every household of Dimapur area of Nagaland, pummelo is grown in home gardens and is mostly maintained for domestic consumption. Best quality of pummelo is produced in villages near *Medziphema*, due to better climate and soil conditions. All accessions were seedy in nature.

Table 2 gives the physico-chemical characters of pummelo collected from NE region, Southern India and, Andaman and Nicobar Islands. The highest fruit weight (1232.30 g) was recorded in Nagaland clone with high acidity (2.52). Most of the fruits were concave with pulp colour varying from white to reddish white. Fruit juice percentage was maximum in Yercaud pummelo (22.60%) followed by Nagaland pummelo (21.65%). Least acidity (%) was observed in Port Blair pummelo (0.80) but due to low TSS (6.90°B), small fruit size (491.80g) and high rind thickness, it is not preferred by traders or consumers.

Table 2. Physico-chemical characters of pummelo fruits from NE region, Southern India and, Andaman and Nicobar Islands

Place of collection of fruits	Region	*Clone no.	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Rind thickness (cm)	Juice (%)	TSS (°B)	Acidity (%)	Pulp colour
Salem	Tamilnadu	-	741.70	11.86	12.64	1.30	19.54	7.50	1.36	-
Yercaud		-	925.00	12.36	11.48	1.44	22.60	9.00	2.10	-
Chettalli, Coorg	Karnataka	-	1023.20	13.58	14.48	1.80	20.15	7.20	1.44	White
		-	938.90	14.15	13.27	1.40	17.66	6.20	1.60	Red
Devanahalli, Bengaluru,		-	754.10	11.64	11.25	1.40	20.32	10.90	1.37	Red
		-	525.40	11.58	10.84	1.60	21.45	10.20	2.12	Red
Jonapotha,	Nagaland	-	1232.30	13.50	13.08	1.80	21.65	9.80	2.52	White
Tamenglang,	Manipur	-	999.50	12.45	11.86	1.70	19.20	12.50	1.44	Red
Port Blair	Andaman and Nicobar Island	-	491.80	10.46	10.25	2.70	18.80	6.90	0.80	Red
		Mean	847.99	12.39	12.12	1.68	20.15	8.91	1.63	-
		Range	491.80-1232.30	10.46-14.15	10.25-14.48	1.30-2.70	17.66-22.60	6.20-12.50	0.80-2.52	-
		SEm ±	80.50	0.39	0.44	0.14	0.51	0.70	0.17	-
		Variance	58323.96	1.37	1.80	0.18	2.40	4.45	0.27	-
		SD	241.50	1.17	1.34	0.42	1.55	2.10	0.52	-

*all the clones are maintained and conserved by community in home gardens at various locations

In Southern India, best quality of pummelo is produced near BIAL (Bengaluru International Airport Limited), Bengaluru, Karnataka as *Devanhalli* pummelo. Although, fruit weight is 525.40 g but it has higher TSS (>10 °Brix), moderate rind thickness and juice percentage, may be most suitable for peninsular region. Besides this, Coorg region of Karnataka also has good pummelo diversity in home gardens and in the areas of coffee plantations. It is used for home consumption due to which very less quantity is sold in the local market. Large plantation of pummelo is also maintained at IIHR Regional Centre, CHES, Chettalli and Coorg. Pummelo from Salem, Tamil Nadu has thinnest rind among pummelos of southern India and exhibits higher productivity due to tropical humid climate which facilitates marketing in nearby cities. There is a need to popularize the pummelo in southern India by highlighting the nutritive value and other benefits.

Pummelo is also grown in North-western part of India, Doon Valley of Uttarakhand and Poanta Valley of Himachal Pradesh wherein it is mostly maintained in home gardens. Limited number of fruits are sold in the local market for consumption. However, there is a need to increase consumption of fruits by generating more awareness about its health and nutritional benefits.

Present investigations revealed that there was a wide range of variation among assessed germplasm and few may be exploited for various attributes. Some like *Devenhalli* pummelo of Karnataka (for better juice percentage, high TSS and moderately thin rind with red pulp) is best for fruit consumption in peninsular region, Nagaland pummelo (for better juice percentage) and Manipur pummelo (with high TSS) may be promoted for large scale plantations in NE regions. Regarding pummelo from Bihar, clone no. 1 for yield and, clone no. 31 and 33 for fruit quality (better sized fruit, moderately thin rind, high TSS and seedlessness) may be promoted among community, orchardist of northern and eastern parts of the country for better consumption, yield and fruit quality. Despite presence of a strong genetic base, serious effort must be made to conserve the germplasm and popularize the crop both from health point of view and for livelihood security.

The present study, clearly established that many superior pummelo clones are managed by local farming communities inhabiting various agro-eco-niche as *on-farm* conservation, may help to identify best parental lines for pummelo improvement and potential clones for livelihood security. Further, breeding programme and effective management of genetic resources may help in growing the crop along with competing cash crops.

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