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Qualitative and quantitative parameters of fruit in different Pummelo (*Citrus grandis* L. Obseck) genotypes grown in Konkan conditions

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Abstract
The present investigation entitled "Qualitative and quantitative parameters of fruit in different pummelo (*Citrus grandis* L. Obseck) genotypes grown in Konkan conditions" was carried out during during 2019-2021 at College of Horticulture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, District-Ratnagiri. The experiment was carried out in different pummelo genotypes *viz.*, T_1 (PAG-1), T_2 (NRCC-2), T_3 (NRCC-3), T_4 (NRCC-5), T_5 (AWF), T_6 (ARF) and T_7 (DPLP-2). These genotypes were studied for different morphological, physical and chemical parameters of flower, fruit and seeds. Qualitative parameters of fruit like flowering month, harvesting month, fruit axis, cross section shape of axis, nature of oil gland, fruit shape, fruit shape at apex and base, skin colour, surface texture, pulp colour, seed shape, seed surface and seed colour were varied slightly. The main flowering was observed in the month of December-January. After beginning of flowering, six to seven months were essential for maturation of fruits. The genotype PAG-1 had early flowering and least maturity period required for fruit. While quantitative parameters were mostly variated. In which physical parameters includes fruit weight, pulp weight, rind weight and peel weight of different pummelo genotypes were ranged between 492.2-1036.04 g, 164.29-620.89 g, 198.02-379.66 g and 66.93-147.38 g per fruit, respectively. Also, fruit diameter, fruit length and rind thickness varied from 348.76-598.36 mm, 125.59-207.69 mm and 16.19-37.22 mm per fruit, respectively. Chemical parameters of fruits were also showed more variation. The Pummelo genotype NRCC-3 had maximum TSS (12.41°B) and good ascorbic acid content (54.46 mg/100g). NRCC-2 recorded maximum reducing sugar (2.13%). ARF had highest acidity (1.04%) and lowest pH (3.19). The investigation revealed that the different pummelo genotypes under study possess variation in flower, fruit and seed parameters. Hence, the present study will contribute in conservation of Pummelo genotypes.

Keywords: *Citrus grandis* L., Pummelo, genotypes, physical and chemical analysis

Introduction
Citrus belongs to family Rutaceae, falls under sub-family Aurantioideae. There are mainly six species of the genus citrus *viz., C. sinensis, C. limon, C. aurantifolia, C. paradisi, C. reticulata* and *C. maxima*. Botanically pummelo is known as *Citrus maxima* (*C. grandis* Osbeck), (2n = 18). In the western world, it is identified mainly as the principle ancestor of grape fruit. It has biggest fruit among the citrus species (Ben, 2010) [5]. It is a natural monoembryonic species. It's also found growing in unattended wild lands as well. It is known to have originated from South-East Asia. Pummelo widely distributed in Bangladesh, Cambodia, India, Japan, Thialand and Vietnam. China is the largest acreage of pummelo and second in production next to USA (Scora, 1975) [18]. In India, this plant is commercially grown on the Northern as well as N - E states**.** It required altitude of 1500 m above mean sea level. Very little pummelo cultivation has been started in recent past. This fruit abundantly found in very limited scale but trees are found in N-E states, N-W Himalayan region, Eastern Uttar Pradesh, Karnataka and Kerala region. It is commercially grown in part of Karnataka (Anonymous, 1999) [2].
Konkan region has and humid weather. Commercial cultivation of citrus is not traditional in this region although *C. medica, C. maxima, C. Limon*, species of citrus grows well in Konkan region. In Konkan region, mostly pummelo is grown as a crop of kitchen garden. It is found to be regular bearing but, it does not require any special horticultural practice like bahar treatment. As Konkan region has potential areas, for large scale pummelo cultivation, in the future, provided that market outlets are clearly defined.
Pummelo fruit is having several bioactive compounds in fruits having antioxidant properties are carotenoid, polyphenolic, anthocyanin and vitamins. Pummelo has the highest antioxidant

content and function as an anticancer agent (Ani and Abel, 2018) [1]. High antioxidant activity is also good for diet. In pummelo, naringin is the dominant flavonoid compounds that found in flavedo and juice. Pummelo is one of the nutritious fruits which is rich in calcium, phosphorous, potassium and fiber. The fruits also contain vitamin A, vitamin B and vitamin C. It is low calories fruit and 100 gm edible portion provides 40 calories. The fruits are rich in Thiamine (B_1), Riboflavin (B_2) and Niacin (B_3). Pummelo rind when squeezed and inhaled can help to treat nausea (Anonymous, 2019) [3].

The characterization of germplasm is an important stage in the certification program, improvement and conservation of genotypes, and monitoring of the genetic quality. This type of analysis is not only simple but also least cost. Till today, yet, very limited research has been carried out on analysis of morphological properties of pummelo all over the world. Morphological characterization of pummelo genotypes, its classification and proper utilization are the essential steps to promote this fruit crop in Konkan region. Morphology based characterization mostly used was given by Swingle and Reece (1967) and Tanaka (1977) [20, 21]. Morphological investigation is important to access the diversity and classification of pummelo germplasm. So, characterization of different germplasm of pummelo is very important to know the suitability of these germplasms for cultivation under Konkan condition.

The objective of present research work was to study the morphological parameters of seven genotypes which will be useful for distinguishing them and help in improvement and conservation of such promising genotypes.

Material and Methods

The survey was conducted during the flowering and fruit maturity season. Sampling of tree and flowers started in Feb 2020 and finished in April 2020. Leaves and fruits parameters were undertaken from October to February during 2020. Research was conducted at nursery No-4, College of Horticulture Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (MS), India.

Plant material

The material for present study consisted of seven genotypes. The genotypes were of same age and no special cultural practices have been followed. Sampling of 5 flowers, 5 fruits and 5 seeds were carried out randomly from each selected tree. In this respect 17 qualitative and 19 quantitative morphological, physical and chemical characteristics were selected for present research work. These all parameters are as follows and some of the qualitative characters are illustrated with figures.

Qualitative parameters

All fruits for observation were taken from periphery of the tree as prescribed for citrus by the International Plant Genetic Resource Institute (Anonymous, 1999) [2]. Fruit parameters were studied for fruit axis (solid, semi-hollow, hollow), cross section shape of axis (round), nature of oil gland (conspicuous and strongly conspicuous), fruit shape (spheroid, ellipsoid, pyriform, oblique, obolid, ovoid) (Fig. 1), shape of fruit apex (acute, rounded, truncate) (Fig. 2), fruit base shape (convex, truncate, necked) (Fig. 3), colour of fruit (yellow, yellow green, light yellow, orange red), pulp colour (white pink, pink white, pink, white) and smooth surface texture. Seed parameters like seeds shape (semi-deltoid) (fig. 4), seed surface (wrinkled and smooth) and cream seed colour.

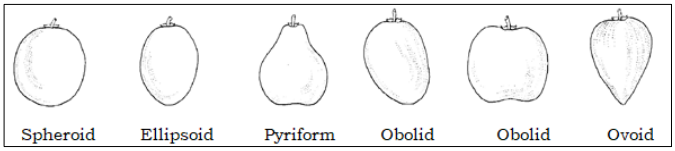


Fig 1: Fruit shape

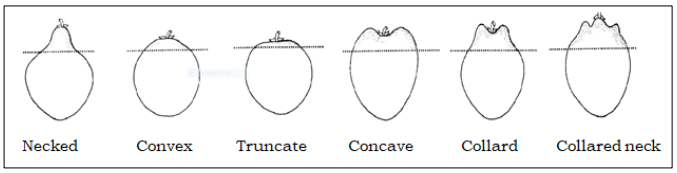
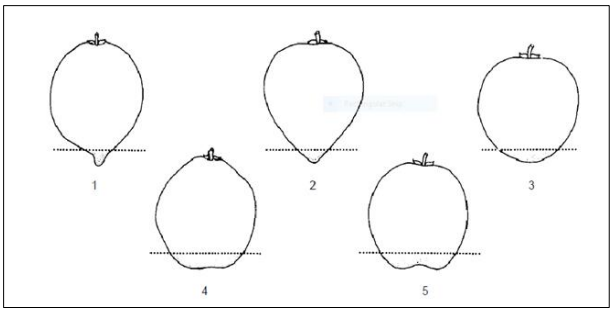


Fig 2: Fruit apex shape



1. Mammiform 2. Acute 3. Rounded 4. Truncate 5. Depressed

Fig 3: Fruit base shape

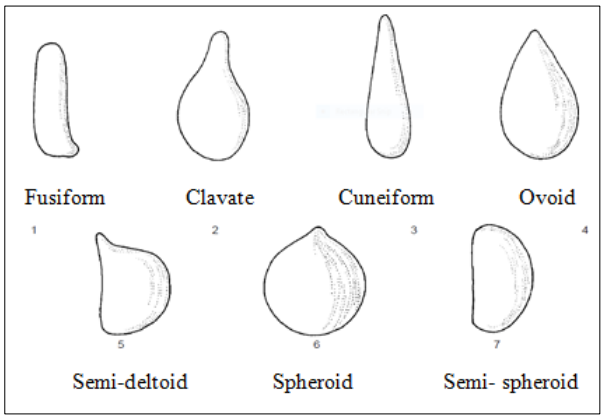


Fig 4: Seed shape

Chemical parameters

Chemical description was studied for TSS (ºB), pH, Acidity (%), Ascorbic acid (mg/100g), total and reducing sugars (%), calcium (mg/100g), phosphorous (mg/100g) and potassium (mg/100g). Some important formulae are enlisted below for calibration of chemical parameters:

$$1)\ \text{Acidity (\%)} = \frac{\text{Burette reading x N of NaOH x 0.064}}{\text{Wt. of sample taken}} \times 100$$

$$2)\ \text{Reducing sugar (\%)} = \frac{\text{100 x 0.05(Glucose value) x 250}}{\text{Burette Reading x Wt. of sample taken}}$$

$$3)\ \text{Total sugar (\%)} = \frac{100 \times 100\ (\text{Volume made}) \times 0.05\ (\text{Glucose Value}) \times 250}{\text{Burette Reading} \times \text{Wt. of sample} \times 50\ (\text{filtrate taken})}$$

$$4)\ \text{Ascorbic acid (mg/100gm)} = \frac{5 \times V2}{V1 \times 5} \times \frac{100}{\text{Weight of sample}} \times 100$$

Data analysis

Quantitative data was statistically analyzed and mean, range, standard error, critical difference and coefficient of variation was calculated. Result of respective parameter was declared as a significant or non-significant.

Result and Discussion

1. Flower parameters and harvesting month

Qualitative parameters like flowering season, flower type, colour of open flower, inflorescence type and colour of anthers are given in Table 1. The significantly early flowering was observed in PAG-1 i.e., during the month of December. It was followed by genotype NRCC-3 in the month of December-January. Other pummelo genotypes (NRCC-2, NRCC-5, AWF, ARF and DPLP-2) were flowered in the month of January. There was no variation in given parameters like flower types, inflorescences type, colour of open flower and colour of anthers of all genotypes of pummelo. All the pummelo genotypes had bisexual types of flowers, axillary umbel cyme type of inflorescences, white colour of open flower with green spot and yellow colour of anthers, respectively. (Table 1). Gaikwad *et al.* (2015) [7], Hoque *et al.* (2015) [10], Mia (2016) [13] and Salunkhe (2018) [16] showed same finding as per the current investigations.

2. Fruit parameters

2.1 Physical parameters

Qualitative fruit parameters like fruit shape, shape of fruit apex, shape of fruit base, fruit surface texture, fruit skin colour and pulp colour showed slight variation. PAG-1 and NRCC-2 had spheroid fruit shape while remaining (NRCC-3, NRCC-5, AWF, ARF and DPLP-2) had pyriform fruit shape. Most of the genotypes had convex type of fruit base. Truncate fruit base was observed in NRCC-2 and AWF, except NRCC-5 had necked fruit base. All the genotypes showed truncate fruit apex, except PAG-1 had rounded fruit apex. Smooth fruit surface texture was observed in all pummleo genotypes. Fruit skin colour showed wide variation like yellow, light yellow, orange red and yellow green fruit skin colour. White pink, pink white, pink and white pulp colour variation in genotypes (Table 2). Gaikwad (2015) [7], Kore *et al.* (2017) [11] and Salunkhe (2018) [16] recorded analogous results.

Genotypes PAG-1 and NRCC-3 showed solid fruit axis. While, NRCC-2 had semi-hollow fruit axis. The rest of the genotypes (NRCC-5, AWF, ARF and DPLP-2) had hollow type of fruit axis. All genotypes had round cross section shape of axis. Conspicuous nature of oil gland was observed in PAG-1 and NRCC-3 although, strongly conspicuous oil gland nature was noticed by the rest of the genotypes. All the pummelo genotypes had wrinkled seed surface except NRCC-5 showed smooth seed surface. Creamy seed colour and semi-deltoid seed shape were found in all pummelo genotypes (Table 3). As per the conclusions reported by Singh and Singh (2006) [19], Malik *et al.* (2006) [12], Hassan *et al.* (2008) [9], Sanabam *et al.* (2012) [17], Gaikwad *et al.* (2015) [7] and Salunkhe (2018) [16] were similar with present research work.

Quantitative parameters like fruit weight, pulp weight, rind weight and peel weight of pummelo genotypes were showed variation. It varied from 492.2-1036.04 g, 164.29-620.89 g, 198.02-379.66 g and 66.93-147.38 g per fruit, respectively. While the fruit weight, pulp weight and rind weight were found peak in AWF and peel weight was noticed highest in DPLP-2 (Table 4). Similar observation was reported by Paudyal and Haq (2008) [14], Ara *et al.* (2008) [4], Haque *et al.* (2009) [8] and Gaikwad *et al.* (2015) [7].

The variation in fruit diameter, fruit length and rind thickness fluctuated from 348.76-598.36 mm, 125.59-207.69 mm and 16.19-37.22 mm, respectively. The fruit length and rind thickness were higher in NRCC-5 while fruit diameter was highest in NRCC-3. Number of seeds Weight of twenty seeds of fruit varied from 40.67 to 84 per fruit and 5.29 g to 15.68 g per fruit, respectively. AWF and ARF had maximum number of seeds as well highest seed weight. (Table 5). The result of present investigation is in close conformity with the result of earlier research workers such as Singh and Singh (2006) [19], Ara *et al.* (2008) [4] and Roy *et al.* (2014) [15] in pummelo.

2.2 Chemical parameters

The pummelo genotype NRCC-3 had maximum TSS (12.41°B) and good ascorbic acid content (54.46 mg/100g). Significant variation in TSS and ascorbic acid of pummelo fruit varied from 8.56°B to 12.41°B and 48.39 mg to 54.46 mg per fruit, respectively. NRCC-2 recorded maximum reducing sugar (2.13%) ranged between 1.71 and 2.13 per cent. ARF had highest acidity (1.04%) and lowest pH (3.19). So, acidity reflects inversely proportional to the pH of the fruit. The variation in pH and acidity of fruit ranged between 3.19 to 4.03 and 0.43 to 1.04 per cent, respectively. Among the all genotypes calcium, phosphorous and potassium were varied from 18 mg to 26 mg, 18.67 mg to 29.33 mg and 60 mg to 70 mg per fruit, respectively. In which, calcium, phosphorous and potassium content were found maximum in DPLP-2 (26 mg/100g), ARF (29.33 mg/100g) and PAG-1 (70 mg/100g), respectively. (Table 6 and 7). Similar observations were reported by Haque *et al.* (2009) [8], Gaikwad *et al.* (2015) [7] as well as Czech *et al.* (2020) [6].

Table 1: Flower parameters and harvesting month

Treatments	Flowering season	Harvesting month	Flowering type	Inflorescences type	Colour of open flower
PAG-1	December	July	Bisexual	Axillary umbel cyme	White (green spot)
NRCC-2	January	July-August	Bisexual	Axillary umbel cyme	White (green spot)
NRCC-3	December-January	August	Bisexual	Axillary umbel cyme	White (green spot)
NRCC-5	January	August	Bisexual	Axillary umbel cyme	White (green spot)
AWF	January	August	Bisexual	Axillary umbel cyme	White (green spot)
ARF	January	July-August	Bisexual	Axillary umbel cyme	White (green spot)
DPLP-2	January	July	Bisexual	Axillary umbel cyme	White (green spot)

Table 2: Fruit shape, shape of fruit base, shape of fruit apex, fruit skin colour, fruit surface texture and pulp colour of pummelo genotypes

Treatment	Fruit shape	Shape of fruit base	Shape of fruit apex	Fruit skin colour	Fruit surface texture	Pulp colour
PAG-1	Spheroid	Convex	Rounded	Yellow	Smooth	White pink
NRCC-2	Spheroid	Truncate	Truncate	Light yellow	Smooth	Pink white
NRCC-3	Pyriform	Convex	Truncate	Light yellow	Smooth	Pink white
NRCC-5	Pyriform	Necked	Truncate	Yellow	Smooth	Pink
AWF	Pyriform	Truncate	Truncate	Orange red	Smooth	Pink
ARF	Pyriform	Convex	Truncate	Yellow green	Smooth	White
DPLP-2	Pyriform	Convex	Truncate	Yellow green	Smooth	Pink

Table 3: Fruit axis, cross section shape of axis, nature of oil gland and seed parameters of pummelo genotypes

Treatments	Fruit axis	Cross section shape of axis	Nature of oil glands	Seed shape	Seed surface	Seed colour
PAG-1	Solid	Round	Conspicuous	Semi – deltoid	Wrinkled	Cream
NRCC-2	Semi hollow	Round	Strongly Conspicuous	Semi – deltoid	Wrinkled	Cream
NRCC-3	Solid	Round	Conspicuous	Semi – deltoid	Wrinkled	Cream
NRCC-5	Hollow	Round	Strongly Conspicuous	Semi – deltoid	Smooth	Cream
AWF	Hollow	Round	Strongly Conspicuous	Semi – deltoid	Wrinkled	Cream
ARF	Hollow	Round	Strongly Conspicuous	Semi – deltoid	Wrinkled	Cream
DPLP-2	Hollow	Round	Strongly Conspicuous	Semi – deltoid	Wrinkled	Cream

Table 4: Fruit weight, pulp weight, rind weight and peel weight of pummelo genotypes

Treatments	Fruit weight (g)	Pulp weight (g)	Rind weight (g)	Peel weight (g)
PAG-1	855.26	323.07	362.49	137.71
NRCC-2	492.20	195.45	198.02	79.94
NRCC-3	704.37	379.63	203.82	116.83
NRCC-5	760.78	408.13	255.67	68.503
AWF	1036.04	620.89	379.66	146.84
ARF	691.25	218.94	314.29	66.93
DPLP-2	681.83	164.29	313.94	147.38
Mean	745.97	330.06	289.70	108.68
Range	492.20-1036.04	164.29-620.89	198.02-379.66	66.93-147.38
Result	Sig.	Sig.	Sig.	Sig.
SE ±	27.97	19.07	20.18	9.064
C.D. at 5%	86.03	59.41	62.16	27.93

Table 5: Fruit diameter, fruit length, rind thickness, no. of seeds/fruit and weight of 20 seeds of pummelo genotypes

Treatments	Fruit diameter (mm)	Fruit length (mm)	Rind Thickness (mm)	No. of seeds/Fruit	Weight of 20 seeds (g)
PAG-1	452.61	154.57	16.20	64.27	5.29
NRCC-2	348.76	125.59	16.43	40.67	9.39
NRCC-3	598.36	135.90	16.19	53.80	11.79
NRCC-5	365.84	207.69	37.22	71.67	5.80
AWF	512.51	146.45	29.80	84.00	11.85
ARF	480.40	141.16	22.70	47.67	15.68
DPLP-2	361.63	126.59	25.38	81.67	6.23
Mean	445.73	148.28	23.42	63.39	9.43
Range	348.76-598.36	125.59-207.69	16.19-37.22	40.67-84	5.29-15.68
Result	Sig.	Sig.	Sig.	Sig.	Sig.
S.E. ±	2.838	7.113	1.221	3.38	1.12
C.D. at 5%	8.841	22.16	3.81	10.41	3.44

Table 6: Chemical parameters of pummelo genotypes

Treatments	TSS (ºB)	Total sugars (%)	Reducing sugars (%)	Non reducing sugars (%)	Ascorbic acid (mg/100 gm)
PAG-1	11.37	3.15	1.95	1.19	51.30
NRCC-2	10.56	3.87	2.13	1.73	50.09
NRCC-3	12.41	3.40	1.76	1.64	54.46
NRCC-5	10.69	2.46	1.71	0.74	49.49
AWF	8.56	2.98	1.86	1.12	51.86
ARF	10.99	3.16	1.81	1.35	48.39
DPLP-2	10.23	3.88	1.96	1.92	52.11
Mean	10.69	3.27	1.88	1.39	51.1
Range	8.56-12.41	2.46 -3.88	1.71-2.13	0.74-1.92	48.39-54.46
Result	Sig.	Sig.	Sig.	Sig	Sig.
S.E. ±	0.26	0.16	0.09	0.16	0.53
C.D. at 5%	0.81	0.51	0.27	0.49	1.63

Table 7: Chemical parameters of pummelo genotypes

Treatments	Acidity (%)	pH	Calcium (mg/100g)	Phosphorous (mg/100g)	Potash (mg/100g)
PAG-1	0.67	3.92	18	20	70
NRCC-2	0.77	3.78	20	25	68
NRCC-3	0.43	3.91	24	19.67	66.34
NRCC-5	0.48	3.41	20.67	21	65
AWF	0.46	4.03	24.67	22.67	61.67
ARF	1.04	3.19	23	29.33	61.67
DPLP-2	0.62	4.01	26.00	18.67	60
Mean	0.64	3.75	22.43	22.33	64.67
Range	0.43-1.04	3.19-4.03	18-26.00	18.67-29.33	60-70
Result	Sig.	Sig.	Sig.	Sig.	Sig.
S.E. ±	0.024	0.03	0.67	1.22	0.69
C.D. at 5%	0.076	0.09	2.04	3.81	2.16

Conclusion

Furthermore, this research also identified NRCC-3 (National Research Centre for Citrus) and from local genotypes, AWF (Anjarle white fleshed) and DPLP-2 (Dapoli) as promising genotypes for both qualitative and quantitative parameters over the rest of the genotypes.

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