

The growth and quality of fruit of three pummelo (*Citrus maxima* (Burn.) Merr.) accessions

S Susanto¹, D Hermansah¹, and F Amanda¹

¹Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University, Jl. Meranti, Kampus IPB Darmaga, Bogor 16680, Indonesia.

E-mail: slmtsanto@gmail.com

Abstract. Indonesia is rich with pummelo (*Citrus maxima* (Burn.) Merr.) germplasm, but its development is still very limited. Pummelo development efforts are directed to the availability of superior cultivars. The objective of this research was to gain information the developmental and quality differences of fruit of three pummelo accessions. This research was conducted at Cikabayan Research Station, IPB from December 2015 to October 2016. The research used a randomized complete block design with single factor named accession (Accession 1, Accession 2 and Accession 3) consisting of five replication. The results showed that fruit growth of all accessions continued to increase in early development phase, but fruit grew slowly in the maturity period. Accession 1 showed a higher in fruit volume and weight than the other accessions. The content of fruit juice of accession 1 was significantly higher than the Accession 3 but having no difference with Accession 2. Among accessions did not show significant different on the peel color, edible portion, and sugar content (TSS). The acid content of accession 2 was higher compared to the other accessions. Accession 1 was the better accession based on the criteria of fruit performance and internal quality.

1. Introduction

Pummelo (*Citrus maxima* (Burm.) Merr.) is an Indonesian native fruit plant with high economic value. Pummelo spread in various regions in Indonesia and has a various of cultivars such as Bali Red, Cikoneng, Nambangan, Raja, Ratu, and Pangkep. Germplasm of pummelo is very diverse in Indonesia with different local names. Only a few pummelo cultivars are developed although not less than 14 pummelo cultivars are well known by fruit growers. At recent, East Java, Central Java, Aceh and South Sulawesi are as the main centers of pummelo cultivation area [1].

Pummelo grows well in the tropics so it is potential to be developed in various area in Indonesia. The other advantage of the pummelo as having a bigger size, a fresh taste, and longer shelf life up to 4 months [2]. However, pummelo development area is still very limited. Nationally, pummelo production is still low in 2014 and 2015 reached 141,296 tons and 111,753 tons, respectively, or around 5% of national citrus production [3].

Superior cultivars of pummelo assembled or selected from various available germplasm accessions are one of the decisive success factors for its development. [4] Reported that the 'Nambangan' cultivar is one of the most widely cultivated pummelo in Indonesia. [5] Stated that pummelo fruit contains some fairly high antioxidant compounds, such as phenol and flavonoids. Pummelo having red juice color, fresh taste and seedless is several criteria of pummelo fruit preferred by consumers and potentially to be developed.



Efforts in development of pummelo plantation are directed at the availability of superior cultivars that produce adequate flowering to ensure high productivity and fruit quality. Superior cultivars can be obtained through germplasm selection, crossing and biotechnology utilization. Identification of differences among pummelo accessions can be seen based on the characteristics of the fruit, including size and shape of the fruit, seed number, color and texture of flavedo (epicarp), thickness and color of albedo (mesocarp), color and flavor fruit flesh, and aroma of essential oil. This research was done to observe growth and quality of the fruit of three pummelo accessions.

2. Materials and methods

The research was conducted at Cikabayan Research Station, IPB from December 2015 to October 2016. Fruit quality analysis was carried out at Postharvest Laboratory, Department of Agronomy and Horticulture of IPB. The plant materials used in this research is 4-year-old of three different accessions of pummelo cultivated with spacing of 4 m x 3 m. All trees bear fruit for the second year.

The research used a randomized complete block design with one factor of accession (accession 1 (A1), accession 2 (A2), and accession (A3)). Each treatment consisted of five replications with each experimental unit using 20 pummelo fruit samples. The data was analyzed using F test to search the significant effect among the treatments tested. If there was a significant effect, then continued with Least Significance Different (LSD) at the level of $\alpha = 5\%$.

The research was preceded by maintenance of pummelo plantation includes weed control and organic and anorganic fertilizer application with dose of 10 kg for organic fertilizer and 5 kg NPK for anorganic fertilizer per plant. Setting ratio of the number of leaves to fruits (100:1) was performed after fruitlet reach a diameter of around 1-2 cm, which will be achieved at around 3 weeks after anthesis. Fruit bagging was done at 4 week after anthesis (WAA) with fruit diameter ± 3.5 cm. All pummelo fruit were harvested at the age of 19 WAA.

The variables observed for this research includes flowering, fruit setting, fruit development and fruit quality. Flowering observations includes flowering time and number of flowers and fruit set. The development of fruit was measured by observing the growth of fruit diameter measured every two weeks. Quality of fruit is divided into external quality and internal quality of fruit. External qualities includes peel pigment, peel smoothness, peel thickness, fruit softness and fruit weight. Internal quality includes the number of seeds, TSS, TA, vitamin C, and flavonoid contents.

The fruit peel pigment was measured by spectrophotometry [6]. Peel smoothness was expressed in percent ratio of peel surface having smooth performance with the total peel surface of fruit. Fruit softness was carried out by an electric penetrometer (MK VI). Fruit volume was measured using principle of Archimedes by put pummelo fruit into a container contain full of water. Fruit weight was measured using analytical scales and expressed in grams (g). Fruit peel thickness was measured using average of peel thickness from two sides of fruit cross diameter [2]. Edible part was obtained from the ratio of fruit flesh weight (g) to fruit weight (g).

Internal quality of fruit consists of fruit juice content (%) obtained from the ratio of weight of fruit juice (g) to the weight of the fruit flesh (g). Total soluble solids (TSS) observed by put a drop of juice on the hand refractometer and read in units of °Brix. Total titratable acidity (TA) was measured using 0.1 N NaOH titration method with phenolphthalein indicator solution.

3. Results and discussion

3.1. Flowering and fruiting

Among three accessions, there was no significant difference on the number of flowers, fruit set and number of fruit per tree, which showed each in the range of 1346-1640 flowers, 2.3%-2.6% and 32-41 fruit per plant (table 1). Fruit growth characteristics was different among accessions, resulted in different fruit diameter on several weeks observation (figure 1). Accession 3 tended to grow slower than Accession 1 and 2 up to 14 WAA. At 16-19 WAA accession 1 had significantly greater fruit diameter than that of Accession 2 and 3. Fruit of all accessions grew faster up to 16 WAA, and then gradually grew slower in the 3 weeks after. Generally, fruit grow faster in early fruit development

stage as result of cell division and enlargement phase, and will then slowdown in the maturation phase. [7] Stated that pummelo fruit grew rapidly at the beginning of growth after two months of anthesis and begins to slow down in the maturation phase until fruit ready for harvest.

Table 1. Flower number and fruitsetting.

Accessions	Flower Number per Plant	Fruitset (%)	Fruit Number per Plant
A1	1391,3 a	2,3 a	32 a
A2	1640,0 a	2,5 a	41 a
A3	1346,1 a	2,6 a	35 a

Values followed by different letters in the same column show significantly different based on the LSD at the 5% level.

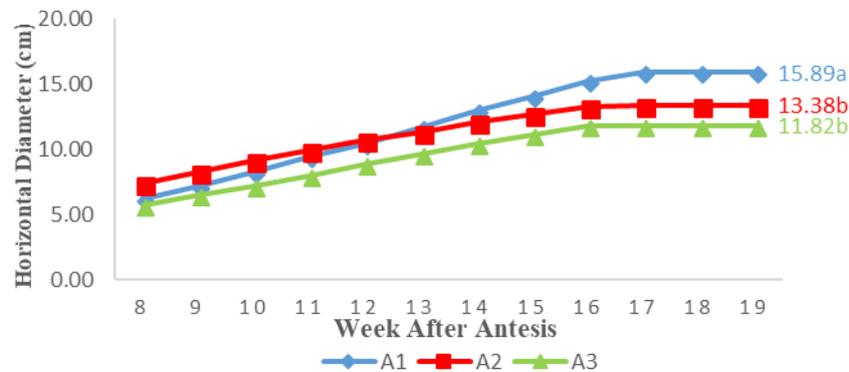


Figure 1. Fruit growth of three pummelo accessions.

3.2. Fruit quality

There was no significant difference among accessions on peel smoothness, softness, edible portion, chlorophyll content, and TSS, but having significant difference on fruit volume, fruit weight, peel thickness, fruit diameter, juice content and acid contents. Fruit peel smoothness levels among accessions did not show significant difference because all fruit were bagged with plastic film to avoid pest attacks. Fruit peel softness of Accession 3 was significantly higher than Accession 1 but did not differ significantly with Accession 2 (table 2). Fruit softness is generally associated with fruit maturity level and cultivar. Pummelo belongs to hard-skinned fruit, in the early stadia the development of fruit peel will be hard and slightly soft at the maturation stage [8].

The fruit volume showed significant difference among accessions. Accession 1 was the accession with the largest volume of fruit compared to other accessions. The volume of fruit indicated the size of the fruit, the greater the volume of fruit the greater the size of the fruit. The fruit development pattern of Accession 1 compared to the other accessions was shown in figure 1. [9] Reported that there was a positive correlation between the accumulation of leaf carbohydrates to the weight and volume of the fruit.

Table 2. Peel smoothness, softness and fruit volume.

Accessions	Smoothness (%)	Softness (mm 50 g ⁻¹ 5 detik ⁻¹)	Fruit Volume (ml)
A1	67,42a	17,610b	1717,33a
A2	58,26a	21,786ab	1027,28b
A3	57,74a	23,423a	1096,87b

Values followed by different letters in the same column show significantly different based on the LSD at the 5% level.

The fruit weight of the Accession 1 showed the highest compared to Accessions 2 and 3. This was related to the availability of assimilates produced by the source for fruit enlargement and sink capacity, resulting in variation in fruit weight on the three accessions. Variations in pummelo fruit weight also can occurred in the same accession due to the difference in nutritional status and environmental condition [10]. The peel thickness of accession 3 was lower than other accessions. Peel thickness related with fruit size, the bigger fruit tended to have thicker peel. The size of the fruit on Accession 1 was the largest and has thickest peel. The size of the fruit and the thickness of the peel had a linear relationship, the larger fruit size will be followed by a thickening of the peel of the fruit and vice versa [11]. The edible portion did not show significant difference among accessions. Edible portion of all accessions was around 60% of the weight of fruit (table 3). [7] reported that edible portion of pummelo cultivar Nambangan approximately half of the fruit weight. The edible portion of the various pummelo fruit cultivars ranged 50-65% depend on the fruit component of each accession such as peel thickness and the presence of seeds [1].

Table 3. Fruit weight, peel thickness and edible portion.

Accessions	Fruit Weight (g)	Peel Thickness (cm)	Edible Portion	
			(g)	(%)
A1	1128,73a	1,73a	658,26a	58,12a
A2	816,40b	1,67a	461,46b	60,99a
A3	810,27b	1,29b	489,33b	60,42a

Values followed by different letters in the same column show significantly different based on the LSD at the 5% level.

Table 4. showed the observation of fruit peel color by measuring the chlorophyll pigment content. Chlorophyll is a pigment that causes a green color in flavedo or fruit peel. The green color pigment will be high during the fruit development period but will decrease during the ripening period. The peel chlorophyll pigment consists of chlorophyll a and chlorophyll b. Chlorophyll a and chlorophyll b did not show any significant difference among accessions. The average value of the total amount of chlorophyll a is about twice that of the average value of chlorophyll b. Chlorophyll of the fruit peel will be degraded at the maturation stage of fruit which causes the concentration of chlorophyll on the fruit peel to decrease [12]. The degradation of chlorophyll content on the peel of the fruit impact on the peel color of the fruit, the lower the concentration of chlorophyll the green peel of the fruit will be younger. Visually peel color of all accessions showed the yellowish green color at harvest (figure 2).

Table 4. Peel chlorophyll content.

Accessions	Chlorophyll a (mg g ⁻¹)	Chlorophyll b (mg g ⁻¹)	Total (mg g ⁻¹)
A1	0,06a	0,03a	0,09a
A2	0,05a	0,02a	0,07a
A3	0,04a	0,02a	0,06a

N Values followed by different letters in the same column show significantly different based on the LSD at the 5% level.

The juice content, TA, and TSS/TA ratios were significantly different among accessions, but had no significant effect on TSS content (table 5.). The content of juice in accession 1 was significantly higher than the juice content of Accession 3, but having no significant difference with the juice content of Accession 2. The percentage of fruit juice content is related to water availability during cultivation and cultivar [13]. The color of the fruit flesh of Accession 1 and Accession 2 were red while in Accession 3 was yellowish red (figure 2).

The total soluble solid content was not significantly different among accessions. This showed that the level of sweetness of fruit juice each accession was relatively similar in around 8-9 °Brix. The total soluble solid content of various pummelo cultivars ranged from 8-11 °Brix [1]. This indicated that the degree of sweetness in the three accessions observed was moderate.. The level of sweetness was not only influenced by plant genetic but also factors such as climatic conditions, cultivation techniques and fruit maturity level. Further observation showed that Accession 2 was the accession with the highest total titratable acidity (TA) compared to other accessions. The high TA content causes the fruit to be more acidic and vice versa. This acid content also indicated the maturity level of fruit, the mature fruit having lower acid content than that of immature fruit.

Table 5. Juice content, total soluble solids (TSS), and titratable acidity (TA).

Aksesi	Juice Content (%)	TSS (°Brix)	TA (%)	Rasio TSS/TA
A1	65,56a	9,03a	0,43b	21,10a
A2	63,23ab	8,70a	1,05a	8,28b
A3	60,60b	9,12a	0,67b	13,61b

Values followed by different letters in the same column show significantly different based on the LSD at the 5% level.



Figure 2. Fruit Appearance and Cross Section of three pummelo accessions.

4. Conclusion

Accession 1 was significantly higher in diameter, volume and fruit weight as compared to the other accessions. The content of fruit juice in Accession 1 was also significantly higher than Accession 3 but having no difference from Accession 2. Peel color, edible portion, and sugar content showed no difference among accessions. Acid content in Accession 2 was significantly higher than other accessions. Overall, Accession 1 was a better accession based on criteria of fruit performance and internal quality.

References

- [1] Susanto S, Rahayu A and Tyas K N 2016 *Pamelo Indonesia dan Kajian Ekofisiologisnya* (Bogor: IPB Press)
- [2] Susanto S 2004 Perubahan kualitas buah jeruk besar (*Citrus grandis* (L) Osbeck) yang disimpan dan dibiarkan di pohon *J. Hayati* **11** pp 25-28

- [3] [BPS] Badan Pusat Statistik 2016 Produksi Buah-Buahan di Indonesia Periode 2011–2015 (<https://www.bps.go.id/site/resultTab> 24 November 2016)
- [4] Rahayu A 2012 Karakterisasi dan Evaluasi Aksesori Pamelon (*Citrus maxima* (Burm.) Merr.) Berbiji dan Tidak Berbiji Asli Indonesia *Disertasi* (Bogor: Institut Pertanian Bogor)
- [5] Toh J J, Khoo H E and Azrina A 2013 Comparison of antioxidant properties of pummelo [*Citrus grandis* (L) Osbeck] varieties *Int. Food Res. J.* **20** pp 1661–1668.
- [6] Sims D A and Gamon J A 2002 Relationships between leaf pigment content and spectral reflectance across a wide range of species, leaf structures and developmental stages *Remote Sensing of Env.* **81** pp 337–357.
- [7] Mahardika I B K and Susanto S 2003 Perubahan kualitas buah beberapa kultivar jeruk besar (*Citrus grandis* L. (Osbeck) selama periode pematangan *J. Hayati* **10** pp 106-109.
- [8] Muramatsu N, Takahara T, Ogata T and Kojima K 1999 Changes in rind firmness and cell wall polysaccharides during citrus fruit development and maturation *J. Hort. Sci.* **34** pp 79–81.
- [9] Kalsum U 2015 Perbaikan Kualitas Jeruk Pamelon (*Citrus maxima* (Burm.) Merr.) melalui Pengaturan Nisbah Jumlah Daun:Buah dan Pemberongsongan Buah *Thesis* (Bogor: Institut Pertanian Bogor)
- [10] Rahman M M, Rabbani M G, Khan A S M M R, Ara N and Rahman M O 2003 Study on physio-morphological characteristics of different local pummelo accessions *J. Biol Sci.* **6** pp 1430–1434
- [11] Oliveira E M S and E D Resende 2012 Yield of albedo flour and pectin content in the rind of yellow passion fruit *Ciênc. Tecnol. Aliment. Campinas* **32** pp 492–498
- [12] Rodrigo J M, Alquézar B, Alós E, Lado J and Zacarías L 2013 Biochemical bases and molecular regulation of pigmentation in the peel of citrus fruit *J. Sci. Hort.* **30** pp 1–17
- [13] Keshani S, Chuah L A, Nourouzi M M, Russly A R and Jamilah B 2010 Optimization of concentration process on pomelo fruit juice using Response Surface Methodology (RSM) *Int. Food Res. J.* **17** pp 733–742

Acknowledgement

The authors would like to thank Kementerian Riset, Teknologi dan Pendidikan Tinggi for providing research funding through the Hibah Kompetensi Scheme in 2015.