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Diversity of quantitative, qualitative, and vitamin C content characteristics in F5 generation of *Capsicum baccatum*

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Abstract. *Rahmi HA, Syukur M, Sukma D, Aisyah SI. 2024. Diversity of quantitative, qualitative, and vitamin C content characteristics in F5 generation of chili pepper* Capsicum baccatum *species. Biodiversitas 25: 2878-2886.* Chili is a popular vegetable worldwide, and Indonesia is one of the largest chili producers. However, the cultivation of *Capsicum baccatum* species is still uncommon in Indonesia. This study aimed to assess the diversity and heritability of yield and yield quality of F5 populations of *C. baccatum.* This study was conducted at the Experimental Field of Perumahan Alam Sinar Sari, Bogor. The experiment followed a randomized complete block design (RCBD) using 12 genotypes with three replications and four sample plants per replication. The F5 populations of the following genotypes were used: 4k-6p, 4k-7p, 7m-4q, 2m-2m, 7m-3q, 7m-3m, 7m-2q, 2m-2q, 7m-8m, 7m-1m, Bishop Crown, and Lemon Drop. The observations included quantitative, qualitative character,vitamin C contents, and soluble solids. The results showed that the fruit weight per plant ranged from 37.73 to 94.24 grams, while the number of fruits per plant ranged from 11.46 to 30.95. Fruit length ranged from 2.65 to 6.08 cm, and fruit diameter ranged from 15.70 to 41.43 mm. The weight per fruit ranged from 3.43 to 14.89 grams. Brightness or L* values ranged from 19.06 to 41.93, a* values ranged from 5.62 to 31.49, and b* values ranged from 22.90 to 57.45. The chroma value ranged from 30.87 to 64.20, and the hue value ranged from 46.54 to 80.23. The analysis of vitamin C content showed a range of 12.20 to 17.74 mg/20 g, and the test results of soluble solids ranged from 8.77% to 13.49%. All quantitative characters showed high heritability, indicating a strong genetic influence on these characters. The qualitative observations were analyzed, and the results showed that the 12 *C. baccatum* chilies had similarity coefficients ranging from 0.0 to 0.5. The similarity analysis resulted in grouping the 12 genotypes of *C. baccatum* into four main groups.

Keywords: Ascorbic acid, bishop crown, CIELab, lemon drop, soluble solids

INTRODUCTION

Chili (*Capsicum* sp.) is one of the most popular vegetables in the world. Chili is a horticultural product that has a high economic value, as it is essential to the community. Chilies have many benefits due to the presence of capsaicinoids, carotenoids, phenolic compounds, vitamin C, vitamin E, and other natural antioxidants that are good for human health and as food preservatives (Carvalho et al. 2015; Mokhtar et al. 2015; Calixto et al. 2016). Although 35 species of chili have been found, only five species are commercially cultivated, namely *C. annuum, C. frustescens, C. chinense, C. pubescens, and C. baccatum* (Liu et al. 2023). Of these five species, only two are most cultivated: *C. annuum* and *C. frustescens* (Fernández-Bedmar and Alonso-Moraga 2016). Chili cultivation is expanding due to increasing of demand and its benefits. Further development is required for the *C. baccatum* species in cultivation.

Capsicum baccatum is a valuable crop for disease resistance (Cremona et al. 2018) and is essential in future functional foods (Perla et al. 2016). The diversity of *C. baccatum* is at the highest levels of variability in Bolivia (Silvar and García-González 2016), including Peru, with production of 45,470 tons per year (Gomez 2016). *C. baccatum* is widely cultivated in the upper Madeira River Valley region in Amazonia, Bolivia, and Brazil (Clement et al. 2016). *C. baccatum* originally grow at an altitude of 2,000-4,000 m above sea level for the *C. baccatum* var. *pendulum* and *C. baccatum* var. *umbilicatum.* In contrast, *C. baccatum* var. *baccatum* and *C. baccatum* var. *praetermissum* grow at altitudes less than 500 m. The average temperature for *C. baccatum* plants is between 5ºC-27ºC. The average rainfall for the most common *C. baccatum* is about 500-1,500 mm per year (Albrecht et al. 2012). Vitamin C content in some chili genotypes varies between 43-247 mg/100 g (Olatunji and Afolayan 2018). Therefore, 123 genotypes of *C. baccatum* originating from 22 countries showed the vitamin C content in range of 2.54 to 50.44 mg/100 g FW, and the spiciness level of these chilies was between 30,000 SHU and 50,000 SHU (Perla et al. 2016).

Among the five cultivated *Capsicum* species, the diversity of *C. baccatum* has been identified as a potential candidate in chili breeding programs (Ou et al. 2015). Genotypic diversity in chili species is shown by significant differences in plant and fruit morphological characteristics (Padilha et al. 2016). *C. baccatum* var. *pendulum* peppers are widely cultivated by local farmers in Brazil under the names "dedo-de-moça" and "cambuci" (Leite et al. 2016;

Cardoso et al. 2018). Although *C. baccatum* has diverse fruit shapes, unique flavors, and distinct aromas, it is not a well-known chili species outside of South America (Kanal et al. 2021). Despite this potential, *C. baccatum* is not widely recognized for germplasm variation compared to other species (Albrecht et al. 2012). One C*apsicum* species not widely cultivated in Indonesia is *C. baccatum*, which requires breeding development.

The formation of new varieties using genetic diversity is fundamental for breeding to produce plants with superior properties (Swarup et al. 2021). The increase in the productivity and quality of chili has led to the development of improved varieties, making it an urgent need. The process of assembling new superior varieties must have good performance criteria, high yields, and the ability to remain stable in various environments (Dia et al. 2016). The development of *C. baccatum* species as a chili pepper has a high potential to be developed in Indonesia. *C. baccatum* has many important genes for breeding (Manzur et al. 2015). Exotic chili species that have yet to be widely researched and have attracted the interest of many breeders (Mavi et al. 2021). Several studies have been conducted on interspecific crosses of *C. baccatum*, for examplethe crossing between Lemon Drop as the female parent and Bishop Crown as the male parent (Mavi et al. 2021; Costa et al. 2021). The development of *C. baccatum* species as a chili has high potential in Indonesia, which includes analyzing inheritance associated with production levels, both qualitative and quantitative characteristics. Therefore, this study aimed to provide information on the evaluation of diversity, heritability, yield characteristics and quality of *C. baccatum* F5 generation.

MATERIALS AND METHODS

This study was conducted at the Perumahan Alam Sinar Sari Experimental Field, Bogor. Plant materials used were 10 F5 generation namely genotypes 4k-6p, 4k-7k, 7m-4q, 2m-2m, 7m-3q, 7m-3m, 7m-2q, 2m-2q, 7m-8m, and 7m-1m, with Bishop Crown and Lemon Drop for comparison. The experiment used a randomized complete block design (RCBD) using 12 genotypes with three replications per genotypes and four sample plants per replication.

Observations of quantitative and qualitative characteristics were made based on the descriptors of *C. baccatum* plants issued by IPGRI (1995) and PPVT (2006). Quantitative observations included fruit weight per plant (g), number of fruits per plant (fruit), fruit length (cm), fruit diameter (mm), weight per fruit (g), CIELab value using portable colorimeter WR10, Chroma, Hue, Soluble solids (%), and vitamin C analysis (College of Science method (2011)). Qualitative observations included characteristics such as number of locules, depth of locule grooves, fruit longitudinal cut shape, fruit transverse cut shape, fruit surface texture, ripe fruit color, and fruit tip shape.

Vitamin C was measured on the third harvest with 4 samples in 3 replicates using a modified method from the College of Science (2011). Initially, 20 g of fresh chili fruit was weighed, followed by stalk removal and placement in a blender with 10 mL of sterile distilled water. After obtaining a smooth texture, the solution was put into a 100 mL measuring tube, and sterile distilled water was added to a volume of 100 mL. Subsequently, four Erlenmeyers were prepared in each replicate per genotype. A solution of 25 mL of each sample extract was put into a 125 mL Erlenmeyer, and 2 mL of 1% amylum solution was added. The sample was titrated with 0.002 mol/L iodine solution, and the end point of titration was indicated by the trace of color change from dark blue-black to starch-iodine complex. The titration was repeated with the remaining samples until all samples were exhausted and the corresponding results were obtained.

The quantitative character were evaluated using analysis of variances (ANOVA). If there was a fundamental difference, continued with HSD at 5%. Cluster analysis of qualitative characteristics was performed through the Gower dissimilarity and clustering method using average linkage. The software used PKBT STAT 3.1 (https://pbstat.com), PBSTAT-CL 2.1.2 (https://apps.pbstat.co), and Microsoft Excel.

RESULTS AND DISCUSSION

Table 1 summarizes the coefficient of variation and the mean square of the generative characters of the F5 generation. It is worth noting that genotypefactor play a pivotal role in determining weight per fruit, coloration, fruit length, fruit diameter, fruit weight per plant, number of fruits per plant, and vitamin C contents. The results in Table 1 demonstrate that the diversity coefficient in the F5 generation spans from 3.41-19.53%. This coefficient of diversity is a critical metric that provides insights into the diversity within the population. A lower coefficient of diversity indicates a higher level of selection accuracy. The results suggest the experiment was exposed to a homogenous environment with a relatively high observation accuracy. The diversity coefficient falls within the medium to low category, implying that the data's accuracy level is reasonably high, leading to a plausible conclusion (Delgado et al. 2019). Based on these findings, the subsequent test employed is the 5% HSD test, as detailed in Table 2-4.

The mean values of fruit weight per plant, number of fruits per plant, fruit length, fruit diameter, and fruit weight were presented in Table 2. The Bishop Crown genotype was the heaviest, with fruit weight per plant at 94.24 g, and the lightest was the Lemon Drop at 37.73 g. Genotype 4k-6p had the highest median number of fruits per plant at 30.95 but was not significantly different from 7m-2q and 7m-4q. Furthermore, genotype 7m-8m had the lowest median at 11.46 fruits. An exciting finding was the cross between *C. baccatum*, which produced the highest number of fruits per plant at 317 fruits (Moulin et al. 2015), highlighting the potential for hybridization in fruit production. The observations of Medeiros et al. (2018) showed that fruit weight per plant reached 8.69 tons ha^{-1}, with *C. baccatum* producing an average of 237.45 fruits. Our research findings have shown that the fruit weight per plant

and the number of fruits per plant are both characteristics that reflect the observed productivity potential of *C. baccatum* chili plants. Similarly, the character of fruit length is related to the diameter and thickness of the fruit flesh, which will determine the weight of the fruit and the weight of chili production.

Table 1. Recapitulation of coefficient of variation and mean square values on generative characters of 12 genotypes of chili *Capsicum baccatum* F5 generation

Character	Mean square			CV (%)
	Replication	Genotype	Error	
Weight per fruit (g)	3.11	21.20**	2.86	19.53
L*	12.76	197.77**	8.32	9.41
a*	3.58	281.93**	9.02	15.24
b*	15.68	246.38**	31.73	15.08
Chroma	19.03	237.53**	38.42	14.32
Hue (º)	0.07	555.55**	4.51	3.41
Fruit length (cm)	0.01	2.60**	0.06	5.57
Fruit diameter (mm)	0.58	135.00**	2.10	5.29
Fruit weight per plant (g)	32.37	710.65**	16.97	6.38
Number of fruits per plant (fruits)	7.84	91.89**	6.34	12.58
Soluble solids (%)	1.70	6.11**	0.81	7.96
Vitamin C (mg/g)	3.62	9.59**	1.38	8.25

Note: CV: coefficient of variance; *: significant at level of 5%; **: significant at level of 1%; ns: not significant

Table 2. Mean values of fruit weight per plant, number of fruits per plant, fruit hardness, fruit length, fruit diameter, and weight per fruit in 12 genotypes of *Capsicum baccatum*

Genotype	Fruit weight per plant (g)	Number of fruits per plant (fruits)	Fruit length (cm)	Fruit diameter (mm)	Weight per fruit (g)
4K-6P	57.94 ^{def}	30.95 ^{a}	4.63 ^{c}	34.15 ^{b}	7.50 ^{bc}
7M-2Q	69.45 ^{cd}	24.21 ^{abc}	4.42 ^{c}	24.35 ^{cd}	8.04 ^{bc}
4K-7K	74.97 ^{bc}	21.52 ^{bc}	4.31 ^{c}	32.03 ^{b}	8.73 ^{b}
2M-2M	52.53 ^{f}	17.22 ^{cde}	2.65 ^{e}	25.73 ^{cd}	8.31 ^{bc}
7M-3Q	84.33 ^{ab}	19.06 ^{cd}	5.44 ^{ab}	25.10 ^{cd}	7.72 ^{bc}
7M-3M	56.08 ^{ef}	19.85 ^{bc}	4.56 ^{c}	21.48 ^{d}	9.68 ^{b}
7M-8M	71.71 ^{c}	11.46 ^{e}	4.28 ^{c}	26.34 ^{c}	8.33 ^{bc}
7M-4Q	53.08 ^{ef}	26.78 ^{ab}	3.28 ^{de}	25.46 ^{cd}	7.44 ^{bc}
7M-1M	58.43 ^{def}	19.40 ^{bcd}	6.08 ^{a}	24.40 ^{cd}	11.15 ^{ab}
2M-2Q	64.95 ^{cde}	19.75 ^{bc}	4.33 ^{c}	32.69 ^{b}	8.67 ^{b}
Bishop Crown	94.24 ^{a}	11.90 ^{de}	3.42 ^{d}	41.43 ^{a}	14.89 ^{a}
Lemon Drop	37.73 ^{g}	18.17 ^{cde}	4.93 ^{bc}	15.70 ^{e}	3.43 ^{c}
CV %	6.38%	12.58%	5.57%	5.29%	19.53%

Note: Numbers followed by the same letter in each column of variables are not significantly different at BNJ α 0.05

Table 3. Mean values of coloring, chroma, and hue performance in 12 genotypes of chili *Capsicum baccatum*

Genotype	L*	a*	b*	Chroma	Hue
4K-6P	39.17 ^{ab}	7.03 ^{f}	37.37 ^{bcd}	38.09 ^{bc}	80.23 ^{a}
7M-2Q	38.11 ^{ab}	12.48 ^{ef}	48.41 ^{ab}	50.00 ^{ab}	75.60 ^{a}
4K-7K	41.93 ^{a}	5.62 ^{f}	38.72 ^{bcd}	39.13 ^{bc}	81.79 ^{a}
2M-2M	23.68 ^{cde}	21.89 ^{bcd}	22.90 ^{d}	31.69 ^{bc}	46.54 ^{c}
7M-3Q	22.84 ^{cde}	27.93 ^{abc}	31.23 ^{cd}	41.92 ^{bc}	48.12 ^{c}
7M-3M	30.96 ^{bc}	20.09 ^{cde}	36.22 ^{bcd}	41.43 ^{bc}	60.95 ^{b}
7M-8M	22.24 ^{de}	31.49 ^{a}	38.19 ^{bcd}	49.50 ^{ab}	50.49 ^{c}
7M-4Q	38.27 ^{ab}	14.20 ^{def}	27.41 ^{cd}	30.87 ^{c}	62.60 ^{b}
7M-1M	23.55 ^{cde}	30.06 ^{ab}	33.66 ^{bcd}	45.17 ^{bc}	47.80 ^{c}
2M-2Q	30.58 ^{bcd}	28.66 ^{abc}	57.45 ^{a}	64.20 ^{a}	63.49 ^{b}
Bishop Crown	19.06 ^{e}	28.27 ^{abc}	35.82 ^{bcd}	45.64 ^{abc}	51.65 ^{c}
Lemon Drop	37.45 ^{ab}	8.74 ^{f}	40.82 ^{abc}	41.75 ^{bc}	77.88 ^{a}
CV %	9.41%	15.24%	15.08%	14.32%	3.41%

Note: Numbers followed by the same letter in each column of variables are not significantly different at BNJ α 0.05

The fruit length of F5 generation was longest in the 7m-1m genotype at 6.08 cm and shortest in the 2m-2m at 2.65 cm. *C. baccatum* crosses produced a range of fruit lengths of approximately 2.94-13.56 cm (Moulin et al. 2015). As shown in Table 1, the Bishop Crown genotype had the highest value for fruit diameter at 41.43 mm, while Lemon Drop had 15.70 mm. Tanaka et al. (2017) reported that fruit morphology in *C. baccatum* from 36 genotypes ranged from the narrowest diameter of 7.8 cm (Arivivi) to the widest at 53.8 cm (Bishop crown). Other reports stated that the average diameter of Bishop crown fruit was approximately 3.92 cm (Sayekti et al. 2021). These findings provide a solid foundation for understanding chili plant productivity (Nisa and Ambarwati 2022). The middleweight value per fruit was the largest in the F5 generation, as observed in the Bishop Crown at 14.89 g, but not significantly different from the 7m-1m genotype. Meanwhile, the middle value of the most minor performance was the Lemon Drop genotype at 3.43 g for weight per fruit. Mavi et al. (2021) reported that a cross between *C. baccatum* with Lemon drop parents and Bishop crown elders had the heaviest fruit weight of 19.06 g and the lightest, 4.69 g. *C. baccatum* was also found to have a weight range of 4.5-38.8 g from 8 varieties (Patel et al. 2016).

The quality of chili fruit is generally determined by several characteristics, capable of affecting visual presentation, flavor, chemical composition, and nutritional value. Among these characteristics, fruit color is the most important because the pigments that provide color are related to nutrition, health, and taste (Wang et al. 2023). The CIELAB color scale is commonly used to express color, which consists of the coordinates L*, a*, and b*. Specifically, the L* value indicates brightness, a* represents reddish or greenish, and b* denotes yellowish or bluish (Cömert et al. 2020), with the hue angle starting from a* axis. The hue value is zero when +a* (red), 90 is defined as +b* (yellow), 180º is -a* (green), and 270º is -b* blue (Moura et al. 2014). Table 3 shows the coloring, chroma, and hue characteristics observed in this study. The median value of the performance on fruit coloring is divided into three parts. First, genotype 4k-7k had the highest L* value at 41.93, showing a high brightness level, which suggests freshness. Second, the median value of a* was highest in genotype 7m-8m at +31.49, with a positive value of fruit in the red color category. Third, the median value of b* was highest in the 2m-2q genotype at +57.45 fruit, falling into the yellow color category.

Color differences between two samples in the same or separate situation are usually assessed by calculating the hue (h) and chroma (c) angles (Moura et al. 2014). The calculation result for chroma intensity was the lowest in the 7m-4q genotype at 30.87 and the highest in the 2m-2q at 64.20. Higher chroma value correlated with brighter fruit color, while low value showed faded color (Swandari et al. 2017). The hue angle (h) is considered a qualitative attribute of color related to the expression of reddish, yellowish, and other colors. It determines the color difference concerning the gray with the same brightness level (Cömert et al. 2020). The hue angle obtained from the calculation of L*, a*, and b* values can be used to describe the color of the fruit surface. The calculation results for the hue angle (h) values in Table 2 varied from 46.54° to 80.23°, which fall into the red and yellow categories. This classification is based on the hue value axis, with 0° indicating red while ≤90° shows yellow color. Higher chroma values indicate lighter fruit colors, while low values indicate faded colors (Swandari et al. 2017). An increase in chroma makes the color more intense, and a decrease in chroma makes the color duller (Manivannan et al. 2021).

The use of the Munsell and the CIELAB scale in measurements reveals intriguing differences in spatial dimensions. The Munsell scale, for instance, categorizes colors into pale yellow, intense yellow, bright yellow, intense orange, pale orange, peach, and red, as depicted in Figure 1. Notably, the pale yellow is unique to genotypes 4k-6p, while intense yellow is observed in genotypes 4k-7k and 7m-4q. The bright yellow category is found in the Lemon Drop genotype, pale orange in genotype 7m-1m, and intense orange in 7m-2q and 7m-3q. The peach color in 2m-2q falls into the orange category, while the red category is found in genotypes 2m-2m, 7m-3m, 7m-8m, and Bishop Crown. This demonstrates the fascinating role of genotypes and crossbreeding in color variations. Regarding ripe fruit color intensity, all genotypes fall into the medium category except for Lemon Drop, which is in the light category, as shown in Figure 1. Mavi et al. (2021) further add to this intrigue by stating that the cross between Lemon Drop and Bishop Crown produced saplings with ripe fruit colors of white, yellow, dark yellow, light orange, orange, dark orange, red, and dark red. Similarly, Cardoso et al. (2018) observed that crossing *C. baccatum* produced lemon yellow, orange, yellow, pale orange, orange, red, and dark red.

Soluble solids, a key indicator used to measure Brix in fruit, refer to all the components in a fruit that can dissolve in water. This includes sugar and other soluble components, the concentration measured by light refraction. The brix measurement is further divided into soluble solids (SS) and insoluble solids (ISS) (Rathnayaka et al. 2021). In the F5 generation of *C. baccatum* chili plants, we observed the characteristic of soluble solids. The mean values of soluble solids, Scoville organoleptic, and vitamin C are presented in Table 4. Genotype 7m-3q had the highest soluble solids of 13.49% but was not significantly different from genotypes 7m-2q, 2m-2m, 7m-8m, 7m-1m, 2m-2m, and Lemon Drop. The 2m-2m genotype showed the lowest dissolved solids performance at 8.77%. Research conducted by Oliveira et al. (2015) showed that the results of the cross between *C. baccatum* produced a range of soluble solids of 6.40-12.67% from about 45 genotypes. The results showed varying results between genotypes, indicating the species' diversity. An increase in soluble solids in liquid indicates that the refractive index also increases, but sugar is not always responsible for the soluble solid components (Rathnayaka et al. 2021).

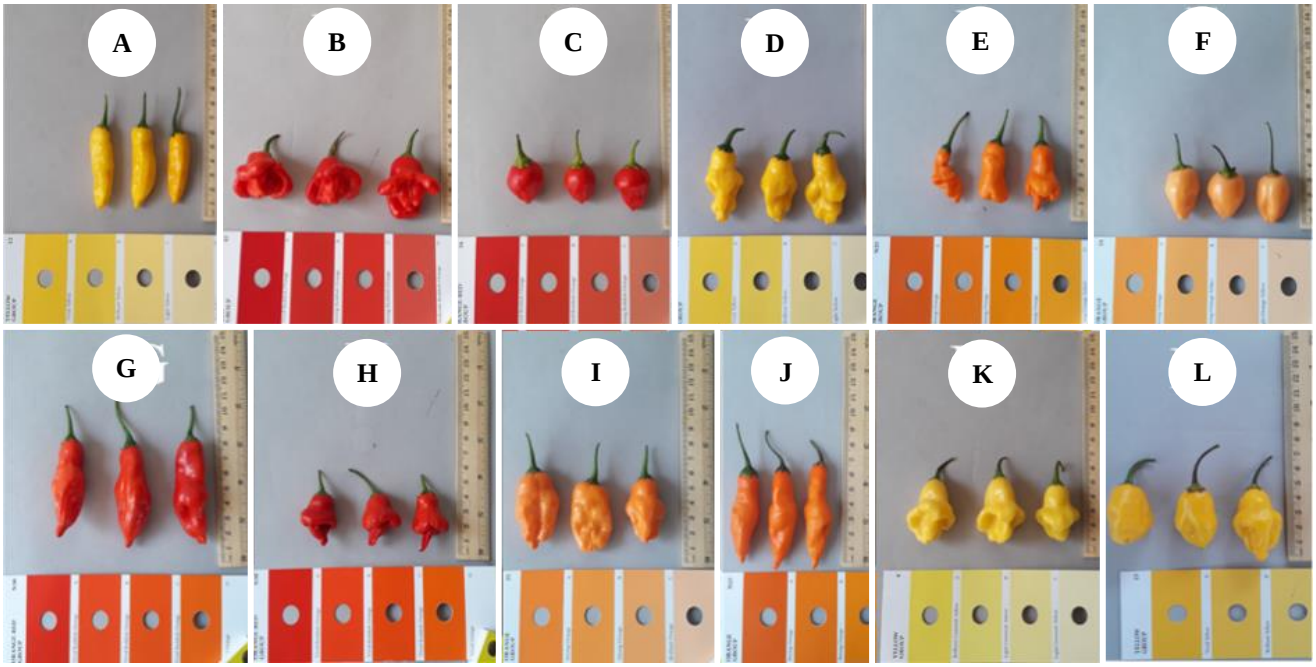

Figure 1. Ripe fruit color of chili *Capsicum baccatum*: A. Lemon drop; B. Bishop Crown; C. F5 LD x BS 2m-2m; D. F5 LD x BS 4k-7k; E. F5 LD x BS 7m-3q; F. F5 LD x BS 2m-2q; G. F5 LD x BS 7m-8m; H. F5 LD x BS 7m-3m; I. F5 LD x BS 7m-1m; J. F5 LD x BS 7m-2q; K. F5 LD X BS 4k-6p; L. F5 LD x BS 7m-4q

Table 4. Mean values of soluble solids and Scoville organoleptic performance in 12 genotypes of *Capsicum baccatum*

Genotype	Soluble solids (%)	Vitamin C (mg/g)
4K-6P	10.32 ^{bcd}	16.25 ^{ab}
7M-2Q	11.38 ^{abcd}	16.43 ^{ab}
4K-7K	9.34 ^{cd}	13.75 ^{bc}
2M-2M	8.77 ^{d}	12.33 ^{c}
7M-3Q	11.73 ^{abc}	13.23 ^{bc}
7M-3M	13.49 ^{a}	13.04 ^{bc}
7M-8M	12.33 ^{ab}	12.55 ^{c}
7M-4Q	10.65 ^{bcd}	17.74 ^{a}
7M-1M	12.98 ^{ab}	12.20 ^{c}
2M-2Q	11.96 ^{abc}	14.31 ^{abc}
Bishop Crown	10.52 ^{bcd}	14.26 ^{abc}
Lemon Drop	12.21 ^{ab}	15.09 ^{abc}
CV %	7.96%	8.25%

Note: The numbers followed by the same letter in each column of variables are not significantly different at BNJ α 0.05

In Table 4, the iodimetric titration method revealed that genotype 7m-4q had the highest mean vitamin C content at 17.74 mg/20 g, although this result was not significantly different from several other genotypes. Notably, the observations indicated that yellow-colored fruit, specifically genotype 7m-4q, exhibited the highest levels of vitamin C. Conversely, genotype 7m-1m showed the lowest vitamin C content at 12.20 mg/20 g in bright orange fruit. The vitamin C analysis in *C. baccatum* from 123 genotypes demonstrated a wide range, from 2.54 to 50.44 mg/g (Perla et al. 2016), highlighting the variation in vitamin C content among these genotypes. Moreover, the vitamin C content in *Capsicum baccatum* from 6 genotypes ranged from 34.6 to 110.8 mg/100 g (Gomes et al. 2019). Additionally, the vitamin C extraction of Bishop Crown with 85% ethanol yielded results ranging from 150.16 mg/100 g to 170.44 mg/100 g (Silva et al. 2020). Vitamin C content in some chili genotypes varies between 43-247 mg/100 g (Olatunji and Afolayan 2018). The testing of vitamin C levels in large chilies, curly chilies, and cayenne peppers revealed that curly chilies have the highest levels compared to other chilies. Variations in the shapes of chili peppers may contribute to the differences in their vitamin C levels between varieties (Kirana et al. 2023). Additionally, the vitamin C content can be affected by factors such as fruit shapes, species, cultivars/varieties, growing environment, fruit maturity, post-harvest handling, and fruit storage conditions (Bosland and Votava 2012). Green peppers contain 1.3 times higher vitamin C than yellow, red, and orange peppers, highlighting the significant influence of color on vitamin C content (Mendoza et al. 2015). Based on the variety, a single 100 g serving of unripe green bell pepper (roughly equivalent to one jalapeno or half of a large bell pepper) can provide more than the recommended daily intake of vitamin C, which is 90 mg/day for men and 75 mg/day for women (Padmanabhan et al. 2016; Xavier and Pérez-Gálvez 2016).

Estimating heritability value (h^2bs) plays a pivotal role in our research. This value, the ratio between the value of genotype variance to the observed phenotype, is not just a number. It is a precise and accurate estimator that quantifies the genetic influence on plant phenotypes (Jogi et al. 2017). Heritability is the ratio of genetic to total variance, usually expressed as a percentage (%), serving as an essential parameter in plant breeding. In the *C.*

baccatum, most characteristics have high values, as shown in Table 5. Classification of heritability value categories ranges from low to high, with values greater than 50% considered high. Values between 20% and 50% are in medium category, while values less than 20% represent low category (Syukur et al. 2015).

Several quantitative characteristics showed a high heritability category, indicating slightly or not influenced by the environment. The influence of environmental and genetic factors must be tested to determine the heritability value of characteristics. Based on the classification, characters that fall into the high category are weight per fruit, coloring (L*, a*, b*), chroma, hue, fruit length, fruit diameter, fruit weight per plant, number of fruits per plant, soluble solids, and vitamin C analysis. The cause of the high heritability value of these characters is influenced more by genetic factors than environmental factors (Belay et al. 2020). A high heritability value indicates an elevated genetic influence of the plant, leading to sustained productivity with minimal environmental impact. Moreover, an environment with uniform conditions for all plants can increase heritability values (Austi et al. 2014).

Regarding the number of locules, 12 genotypes are divided into two categories, as shown in Figure 2. Category Two is represented by 7m-8m, 7m-2q, and 4k-6p, while other genotypes fall into Category Three. The depth of the furrow in a locule is divided into two categories: deep and very deep. Based on the deep category, there are 7m-3q, 7m-3m, 7m-1m, and Lemon Drop, while other genotypes fall into the very deep category.

The shape of the cross-section was divided into two categories, square and round, as shown in Figure 2. The square category was observed in genotypes 4k-6p, 4k-7k, 2m-2m, 7m-3q, 7m-3m, 7m-4q, Bishop Crown, and Lemon Drop. Meanwhile, the round category in the cross-section shape character was observed in genotypes 7m-2q, 7m-8m, 7m-1m, and 2m-2q. Based on the results, fruit surface texture observed for all genotypes was smooth. However, Cardoso et al. (2018) stated that the texture of the fruit surface was smooth, half wrinkled, wrinkled, and smooth with elongation. Several categories of fruit tip shape characteristics were also found, including round, pointed, bent inward, and very pointed. The pointed category was found 7m-2q, 7m-3q, 7m-3m, 7m-4q, and Bishop Crown, while 4k-6p, 4k-7k, and 2m-2q genotypes were round. Genotypes 2m-2m and 7m-1m were inwardly curved, while 7m-8m and Lemon Drop showed very pointed.

Figure 2 shows several observed characteristics, including the shape of the longitudinal cut, ripe fruit color, and ripe fruit color intensity. Based on the observations, there were various categories of longitudinal cut shape, namely, trapezoidal in genotypes 7m-3q, 7m-8m, 7m-4q, and Bishop Crown. Narrowly triangular was found in 7m-2q, 7m-3m, and Lemon Drop, while oblate was observed in 4k-6p and 4k-7k. Cordate was found in 2m-2m. and 2m-2q, the square was only observed in 7m-1m genotype, and moderately triangular was identified in 7m-3m genotype. The two subspecies of *C. baccatum* have the following fruit shapes: 68.7% triangular, 13.4% heart-shaped, 11.9% round, 3% horn-shaped, 1.5% box-shaped, and 1.5% bell-shaped (Kanal et al. 2021).

The experiment in Figure 3 uses the Gower method for dissimilarity values to group data with certain variables. The results of the dendrogram analysis using PBStat based on the observed qualitative characteristics showed that the 12 genotypes had similarity coefficients ranging from 0.0-0.5, which were divided into four main groups, as shown in Figure 3. Group 1 consisted of genotypes 4k-6p, 7m-4q, 4k-7k, 2m-2m and 2m-2q. Group 2 consisted of 7m-3q, 7m-3m, bishop crown, and lemon drop; Group 3 contained 7m-1m genotype, while Group 4 consisted of 7m-2q and 7m-8m. This study classifies *C. baccatum* chili plants into four groups based on the number of loci, depth of grooves on the loci, cross-sectional shape, and longitudinal section of the fruit, which is of significant importance. The research conducted by Leite et al. (2016) revealed that the dissimilarity among 30 genotypes of *C. baccatum* ranged from 0.13 to 0.91, with an average dissimilarity of 0.58. This range falls within the high diversity category. With a need for more information on the quantitative and qualitative characteristics of *C. baccatum* chili plants in Indonesia, this study provides a crucial starting point. This newfound understanding could lead to broader cultivation of this type of chili in Indonesia, thereby diversifying sources of chili production. The potential of this opportunity is substantial, given the crucial and central role chilies play in the lives of Indonesian people.

Table 5. The estimated heritability of quantitative characteristics of F5 generation of *Capsicum baccatum*

Character	σ^2_e	σ^2_g	σ^2_p	Hbs (%)	Criterion
Weight per fruit (g)	2.86	16.83	19.45	85.47	High
L*	8.32	173.1	181.44	95.43	High
a*	9.02	250.38	258.65	96.52	High
b*	31.73	196.93	226.04	86.12	High
Chroma	38.42	182.67	217.92	82.62	High
Hue (°)	4.51	505.54	509.68	99.12	High
Fruit length (cm)	0.06	2.33	2.39	97.49	High
Fruit diameter (mm)	2.10	121.93	123.85	98.31	High
Fruit weight per plant (g)	16.97	636.40	651.97	97.40	High
Number of fruits per plant (fruit)	6.34	78.49	84.30	92.53	High
Soluble solids (%)	0.81	4.86	5.61	85.72	High
Vitamin C (mg/g)	1.38	7.53	8.80	8.52	High

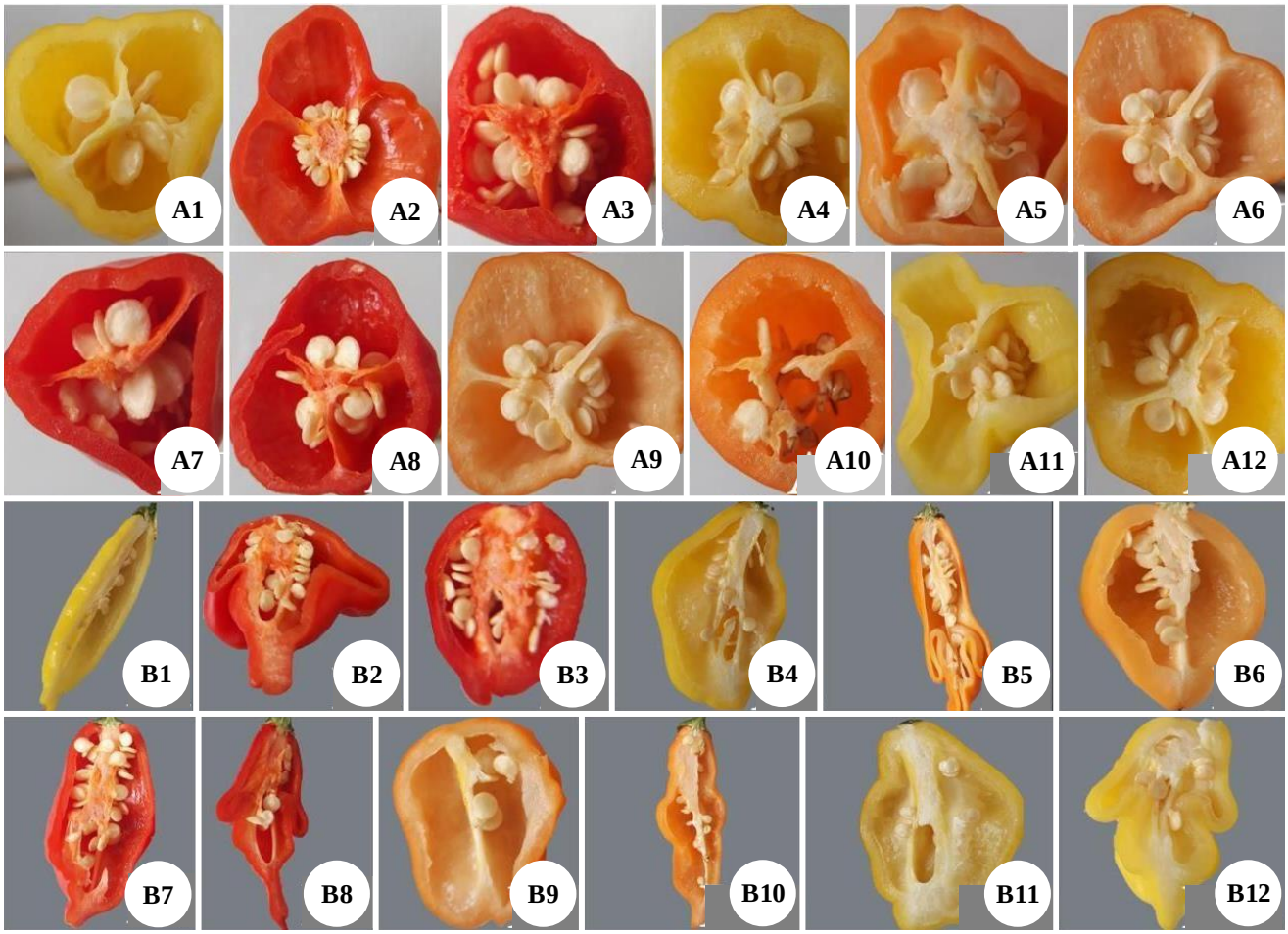

Figure 2. A: Number of locules, depth of locule furrow and shape of cross-section of mature fruit of chili C. baccatum: A1. Lemon drop; A2. Bishop Crown; A3. F5 LD x BS 2m-2m; A4. F5 LD x BS 4k-7k; A5. F5 LD x BS 7m-3q; A6. F5 LD x BS 2m-2q; A7. F5 LD x BS 7m-8m; A8. F5 LD x BS 7m-3m; A9. F5 LD x BS 7m-1m; A10. F5 LD x BS 7m-2q; A11. F5 LD x BS 4k-6p; A12. F5 LD x BS 7m-4q. B: Longitudinal section of ripe fruit of chili C. baccatum: B1. Lemon drop; B2. Bishop Crown; B3. F5 LD x BS 2m-2m; B4. F5 LD x BS 4k-7k; B5. F5 LD x BS 7m-3q; B6. F5 LD x BS 2m-2q; B7. F5 LD x BS 7m-8m; B8. F5 LD x BS 7m-3m; B9. F5 LD x BS 7m-1m; B10. F5 LD x BS 7m-2q; B11. F5 LD x BS 4k-6p; B12. F5 LD x BS 7m-4q

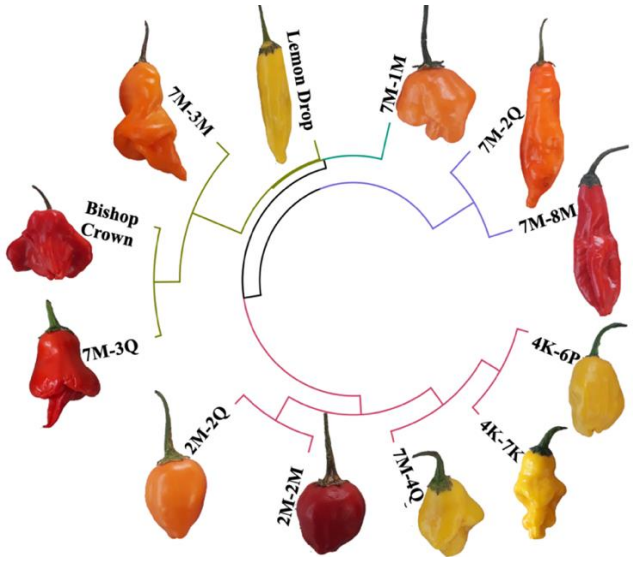

Figure 3. Dendrogram of qualitative characteristics of the F5 generation of *Capsicum baccatum*

In conclusion, this study presents general information on the quantitative and qualitative characteristics of *C. baccatum* chili plants. The results of quantitative observations showed that the bishop crown genotype had the highest fruit weight, fruit diameter, and weight per fruit. The results of observations of fruit weight characters per plant of 12 genotypes ranged from 37.73 to 94.24 g. Fruit diameter characters ranged from 15.70 to 41.43 mm. Weight per fruit from the observations made ranged from 3.43-14.89 g. The character of the number of fruits per plant can produce about 11.46-30.95 fruits, where genotype 4k-6p has the highest number of fruits per plant. The fruit length of *C. baccatum* plants from the 12 genotypes observed ranged from 2.65-6.08 cm, while genotype 7m-1m had the most extended fruit length. Brightness or L* values ranged from 19.06 to 41.93, a* values ranged from 5.62 to 31.49, and b* values ranged from 22.90 to 57.45. The chroma value ranged from 30.87 to 64.20, and the hue value ranged from 46.54 to 80.23. The analysis results of vitamin C content in chili *C. baccatum* were 12.20-17.74 mg/20 g while genotype 7m-4q had high vitamin C content. The test

results of soluble solids in *C. baccatum* were 8.77%-13.49%, and genotype 7m-3q had the highest soluble solids. From the observations, each genotype has the best characteristics, so each has its characteristics. Yield characters and yield quality of the observed F5 population of *C. baccatum* showed high productivity. The heritability values for all quantitative traits are high. When observing qualitative traits, we looked at the number of locules, depth of locule groove, shape of transverse cut, texture of fruit surface, shape of fruit tip, shape of longitudinal cut, color of ripe fruit, and intensity of ripe fruit color. The dendrogram analysis based on these traits showed that the twelve *C. baccatum* chili peppers have similarity coefficients ranging from 0.0 to 0.5. The similarity analysis grouped the twelve genotypes of *C. baccatum* into four main groups, which has important implications for further research and breeding strategies.

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