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Research Article

Assessment of Genetic Parameters for Vitamin A, Vitamin C, and TSS Content Results in Melon Line Crosses at Five Maturity Stages

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Melon breeding is directed at improving the quality of the fruit needed to meet consumers' demands. The assessment of hybrid melon candidates on important characteristics (vitamin A, vitamin C, and TSS) at five maturity stages is needed to get hybrid melon varieties with good fruit quality and determine the right harvest time. This study aimed to evaluate the genetic parameters of vitamin A, vitamin C, and TSS contents of D-612 × PK-669 and PK-361 × PK-165 crossings at five stages of maturity. The study used a randomized complete block design (RCBD) with eight genotypes as treatment and three replications, so there were 24 experimental units. The eight melon genotypes were G_1 = D-612 × PK-669, G_2 = PK-669 × D-612, G_3 = D-612, G_4 = PK-669, G_5 = PK-361 × PK-165, G_6 = PK-165 × PK-361, G_7 = PK-361, and G_8 = PK-165. The content of vitamin A, vitamin C, and TSS was observed at five maturity stages, namely, at 55 DAP, 60 DAP, 65 DAP, 70 DAP, and 75 DAP. The right harvest time for the eight genotypes tested was maturity stage 4 (70 DAP) because it had the highest vitamin A, vitamin C, and TSS contents compared to other maturity stages. The inheritance of vitamin A and C content was not affected by the maternal effect, while TSS was influenced by the maternal effect. The vitamin A, vitamin C, and TSS content characteristics had higher phenotypic diversity coefficients than genetic diversity coefficients, while heritability values in the broad sense for the three melon genotypic characteristics ranged from 0.613 to 0.968. Crosses of PK-165 × PK-361 can be used to assemble hybrid melon varieties that have high vitamin A, vitamin C, and TSS contents because they have positive values for heterosis and heterobeltiosis for the three characteristics.

1. Introduction

Melon (*Cucumis melo* L) is a popular fruit commodity worldwide due to its sweet taste and diverse flesh color [1]. Additionally, cantaloupe melon has 54% and 49% vitamins A and C, respectively, which are extremely useful to the body's health [2]. Each year, the World Health Organization (WHO) estimates that over 7 million people worldwide become blind [3]. The main cause of blindness is vitamin A deficiency [4]. Vitamin C is used by the human body as an antioxidant and increases immunity [5, 6]. Vitamin C deficiency can cause several diseases and trigger disease complications [7, 8]. Melon's fruit has a moderate glycemic index of 56, making it appropriate for people with diabetes to consume [9].

Human awareness of health causes the level of consumption of melons to increase every year. The high level of consumption is countered by an increase in global melon output (cantaloupe type), which was 10.004.133 tons in 2017, 10.144.991 tons in 2018, and 10.317.850 tons in 2019 [10]. WHO recommends that the consumption of fruit and vegetables per day is at least 400 g/person per day or 150 kg/

person per year. According to projections, the world's population of 8,457 billion in 2050 will consume 862 grams of fruit and vegetables per person per day, requiring 2660,825 million tons of fruit and vegetables. [11]. Fruit and vegetable output in 2020 is 1732.960 million tons [12]; therefore, an additional 927.865 million tons of fruit and vegetable production is required to meet projected fruit and vegetable needs in 2050. For this reason, it is necessary to increase the production of fruit that has a high nutritional content, one of which is cantaloupe melon.

A plant breeding program, especially hybridization, can be used to increase the production of high-nutrient melons. The melon plant breeding program aims to develop melon varieties with high yields, good fruit quality, and resistance to plant pests and diseases [13]. Previously conducted research identified two-hybrid melon with high sugar content and high production through diallel crossings, namely D-612 PK-669 and PK-361 PK-165 [14]. Furthermore, the content of vitamin A, vitamin C, and sugar of the two-hybrid melon candidates was determined to develop a hybrid melon type with superior fruit quality. Fruit quality character testing is carried out at several stages of maturity because it is thought that fruit quality is affected by the stage of maturity [15]. Testing the quality of the fruit at several maturity stages will make it easier to determine the right harvest time [16, 17].

Information on several genetic parameters in melon plants is needed to determine the appropriate breeding method for obtaining melon varieties with good fruit quality. The presence or absence of a maternal effect on reciprocal crosses is determined to assure the best possible combination of parents to produce a variety with the desired characteristic [18, 19]. The heritability value gives an overview of the genetic influence on plant appearance [20, 21], whereas the information of the correlation between characteristics makes it easier to choose the desired plant character [22, 23]. Furthermore, the heterosis value is used to determine the best combination of crosses in the assembly of hybrid varieties [24, 25]. This study aimed to evaluate the genetic parameters of vitamin A, vitamin C, and TSS content of D-612 × PK-669 and PK-361 × PK-165 crossings at five stages of maturity.

2. Materials and Methods

2.1. Planting Materials and Experimental Design. The planting material for this study consisted of eight genotypes of melons: four genotypes were derived from crosses (F_1 and F_1 reciprocal) and four genotypes were derived from parents. The eight melon genotypes were G_1 = D-612 × PK-669, G_2 = PK-669 × D-612, G_3 = D-612, G_4 = PK-669, G_5 = PK-361 × PK-165, G_6 = PK-165 × PK-361, G_7 = PK-361, and G_8 = PK-165. Crosses of D-612 × PK-669 (F_1 and F_1 reciprocal) and PK-361 × PK-165 (F_1 and F_1 reciprocal) were conducted between April and July 2021.

Vitamin A, vitamin C, and total soluble solid (TSS) content tests on eight melon plant genotypes were conducted during the rainy season of September–November 2021. The research was conducted at the Experimental Garden, Faculty of Agriculture, Trunojoyo University, Madura, Indonesia. The research location was at a latitude of 7°07 S, a longitude of 112°44E, and an altitude of 5 m asl, with a mean annual rainfall of 269 mm, a temperature of 28–32°C, Grumosol soil type, and a pH of 6.9.

The research used a randomized complete block design (RCBD) with eight genotypes as treatment and three replications, so there were 24 experimental units. Each experimental unit consisted of 30 plants. Ten-day-old melon plants were transferred to beds with dimensions of 10.0 m × 1.2 m × 0.7 m (length × width × height) with a spacing of 60 cm × 60 cm. Basal fertilization was carried out during soil preparation at the rate of 150 kg·NPK·ha^{-1} (2 : 2 : 1), and organic manure was applied at the rate of 10 tons ha^{-1}. Starting 14 days after planting (DAP), 2 g of NPK fertilizer was applied at weekly intervals at a rate of 2 g per plant. After the plants had entered the generative phase, NPK fertilization was applied at weekly intervals at a dosage of 3 g per plant. Plant pests and diseases are controlled according to plant conditions. Each plant kept one melon fruit on segment number eight.

The plant characteristics observed were leaf area, fruit length, fruit diameter, flesh thickness, fruit weight, vitamin A, vitamin C, and TSS contents. Vitamin A, vitamin C, and TSS were observed at five stages of maturity, namely at 55 DAP, 60 DAP, 65 DAP, 70 DAP, and 75 DAP. At each stage of maturity, the concentration of vitamin A, vitamin C, and TSS was measured in 3 melons fruit per genotype per replication, so there were 15 plant samples per genotype per replication.

2.2. Determination of the Content of Vitamin A, Vitamin C, and TSS. The total carotenoids in melon fruit are used to calculate the vitamin A content [26]. 5 mg of melon flesh was placed in an Erlenmeyer flask (13 × 100 ml), and 5 ml of petroleum ether-acetone (1 : 1 v/v) was extracted three times. The supernatant obtained from the extraction was divided into two phases: the air-acetone phase and the petroleum ether-carotenoid phase. Then, in a 10-ml volumetric flask, anhydrous Na_2SO_4 was added and diluted with petroleum ether. After shaking, the sample was placed in a 1-cm cuvette, and the absorbance was measured at λ = 450 nm.

Vitamin C contents were determined using the iodine titration method [27]. Melon fruit weighing 200–300 grams was crushed in a Waring blender until a slurry was obtained. A centrifuge was used to separate the filtrate. 10 ml of the filtrate with a volume pipette was taken and added to a 125-ml Erlenmeyer flask. Then, 2 ml of 1% starch solution (soluble starch) and 20 ml of distilled water were added and titrated with 0.01 N standard iodine.

TSS measurement is done by taking a sample of the fruit flesh, and then it is mashed and squeezed to get the liquid. The resulting fruit liquid is then placed over the lens on the refractometer. The lens on the refractometer was cleaned using distilled water and calibrated until the value read on the refractometer screen showed 0. The TSS value is measured in ^{0}Brix units.

2.3. Data Analysis. Quantitative character data were analyzed using the F test. If there is a significant effect, the DMRT test ($p < 0.05$) is performed using SPSS software version 22.0. The data from the crosses were analyzed using the mean difference test (t-test) at $p < 0.05$ to determine the maternal effect on the character of the melon plant by comparing the population mean values of F_1 and F_1 reciprocal (F_{1R}). The estimates of environmental, genetic, and phenotypic variance were calculated based on the expected value of the mean square of each character [28]. The phenotypic diversity coefficients (PDC) and genetic diversity coefficients (GDC) were calculated based on the study by Singh and Chaudary [29]. The estimation of heritability in the broad sense (h^2_{bs}) was carried out based on the study by Allard [30]. Pearson correlation coefficient analysis is done based on [31].

GDC and PDC are calculated using the following formulas:

$$\begin{aligned} \text{GDC} &= \frac{\sigma_g^2}{\sqrt{x}} \times 100, \\ \text{PDC} &= \frac{\sigma_p^2}{\sqrt{x}} \times 100, \end{aligned} \tag{1}$$

where $\overline{x}$ is the mean of the genotype or phenotype and σ_g^2 and $\sigma^2{}_p$ are the phenotypic and genotypic variance, respectively.

Heritability in the broad sense is calculated using the following formula:

$$h_{bs}^2 = \frac{\sigma_g^2}{\sigma_p^2}. \tag{2}$$

Mid-parent heterosis (MPH) and better parent (BHP) are calculated using the following formulas:

$$\begin{aligned} \text{MPH} &= \frac{F_1 - MP}{MP} \times 100, \\ \text{BPH} &= \frac{F_1 - HP}{HP} \times 100. \end{aligned} \tag{3}$$

Pearson correlation coefficient analysis is calculated using the following formula:

$$r = \frac{n\sum XY - \left(\sum X\right)\left(\sum Y\right)}{\sqrt{\left(n\sum x^2 - \left(\sum x\right)^2\right)\left(n\sum y^2 - \left(\sum y\right)^2\right)}}. \tag{4}$$

where n is the number of data pairs x and y, $\sum x$ is the total number of variable x, $\sum y$ is the total number of variable y, $\sum x^2$ is the square of the total number of variable x, $\sum y^2$ is the square of the total number of variable y, and $\sum xy$ is the total multiplication of variable x and variable y.

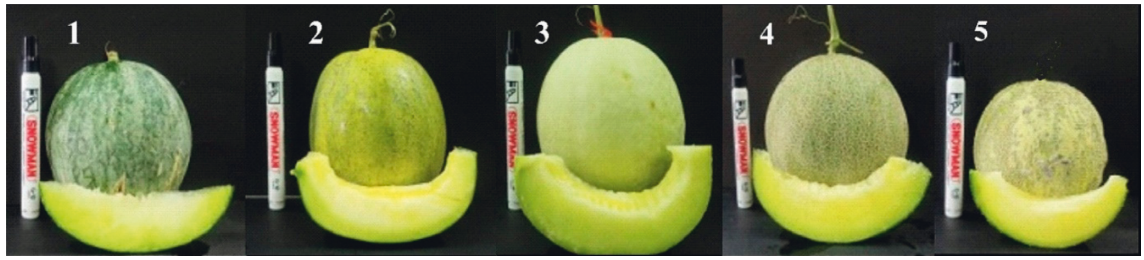
3. Results and Discussion

3.1. Content of Vitamin A, Vitamin C, and TSS at Five Maturity Stages. Melon fruit is distinguished by climacteric (*reticulatus* and *cantaloupe type*) and non-climacteric (*inodorus type*) characteristics [32, 33]. This study used melon with climacteric character. Climacteric melon can produce the hormone ethylene which plays a role in fruit ripening so that the fruit undergoes further ripening after being harvested [34]. The hormone ethylene in climacteric melon causes this type of melon to be harvested when the fruit is not yet ripe. However, climacteric fruit harvested early causes fruit to be underripe [33], while fruit harvested late causes fruit to be too ripe when consumed [35]. The determination of the right harvest time is needed to maintain the quality of melons. The appearance of melon fruit from a crossing of D-612 × PK-669 and PK-361 × PK-165 at five stages of maturity can be seen in Figure 1. At maturity stage 1 (55 DAP), the fruit surface has no small net , the fruit surface has hairs , and the fruit surface is sticky. At maturity stage 2 (60 DAP), the fruit surface has a small net, the fruit stalk has not been detached, and the fruit surface has hairs. Nets of medium intensity were present at maturity stage 3 (65 DAP), and the fruit surface had not been split. At maturity stage 4 (70 DAP), there are many nets with lots of intensity, and the fruit stalks have not been separated. At maturity stage 5 (75 DAP), there were nets with lots of intensity, even distribution of nets on the entire surface of the fruit, and loose fruit stalks.

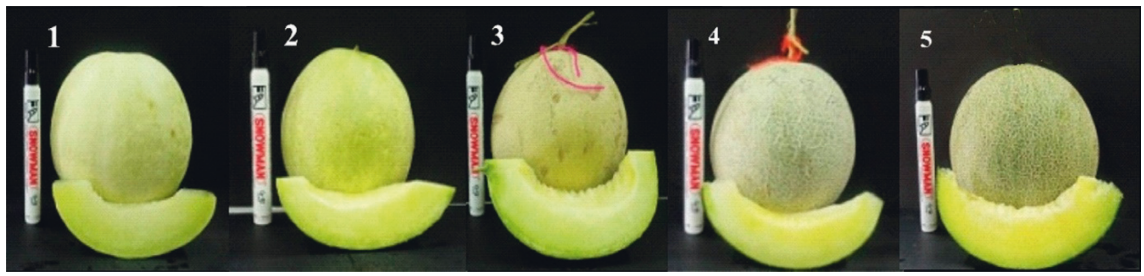
The content of vitamin A increased from maturity stage 1 (55 DAP) to maturity stage 4 (70 DAP) in eight melon genotypes studied but then decreased at maturity stage 5 (75 DAP) (Table 1). At maturity stage 4, the G_6 genotype (crossing PK-361 × PK-165) had the highest vitamin A content (4.922 IU), while the G_1 genotype (crossing D-612 × PK-669) had the lowest vitamin A content (1.377 IU). The content of vitamin A increased from maturity stage 1 to maturity stage 4 in the crosses D-612 × PK-669 (F_1 and F_{1R}) and PK-165 × PK-361 (F_1 and F_{1R}) but decreased at maturity stage 5 (Figure 2(a)). In agreement with the results of this study, [36] reported that the content of vitamin A and vitamin C in muskmelon has consistently increased until the mature stage and decreased in the ripe stage.

The content of vitamin C increased from maturity stage 1 (55 DAP) to maturity stage 4 (70 DAP) in eight melon genotypes studied but then decreased at maturity stage 5 (75 DAP) (Table 2). At maturity stage 4, the G_2 genotype (PK-669 × D-612) had the highest vitamin C content (131.217 mg/100 g), while the G_8 genotype (PK-165) had the lowest vitamin C content (73.229 mg/100 g). The content of vitamin C increased from maturity stage 1 to maturity stage 4 in the crosses D-612 × PK-669 (F_1 and F_{1R}) and PK-165 × PK-361 (F_1 and F_{1R}) but decreased at maturity stage 5 (Figure 2(b)).

TSS analysis at five maturity stages on eight melon genotypes studied revealed an increase in TSS from maturity stage 1 to maturity stage 5 (Table 3). At maturity stage 5, the G_6 genotype (crossing PK-361 × PK-165) had the greatest TSS of 13,777 ^{O}Brix, while the G_5 genotype (crossing PK-165 × PK-361) had the lowest TSS of 8,901 ^{0}Brix. TSS increased from maturity stage 1 to maturity stage 5 in the crosses D-612 × PK-669 (F_1 and F_{1R}) and PK-165 × PK-361 (F_1 and F_{1R}) (Figure 2(c)). In agreement with the result of this study, [37] reported that TSS content continued to increase in melon cantaloupe (*Cucumis melo* L. var.



(a)



(b)

Figure 1: Morphological characteristics of melons at five stages of maturity: (a) crossing of D-612 × PK-669, (b) crossing of PK-165 × PK-361, 1 = 55 DAP; 2 = 60 DAP; 3 = 65 DAP; 4 = 70 DAP; 5 = 75 DAP.

Table 1: The content of vitamin A (IU) for eight melon genotypes at five stages of maturity.

Maturity stage	Genotypes							
	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8
1	1.241^{ab}	0.933b	2.526^{a}	1.314^{ab}	0.431^{b}	0.411^{b}	0.621^{b}	0.507^{b}
2	1.304^{b}	1.211^{b}	3.222^{a}	1.477^{b}	1.285^{b}	3.462^{a}	1.544^{b}	1.672^{b}
3	1.322^{c}	1.425^{bc}	3.351^{ab}	1.572^{bc}	1.471^{bc}	4.872^{a}	2.423^{bc}	1.982^{bc}
4	1.377^{c}	1.491^{c}	3.414^{ab}	1.612^{c}	1.476^{c}	4.922^{a}	2.532^{bc}	2.162^{bc}
5	0.923^{d}	1.007^{d}	3.120^{b}	1.127^{d}	0.913^{d}	4.613^{a}	2.111^{c}	$1.670c^{d}$

1, 55 DAP; 2, 60 DAP; 3, 65 DAP; 4, 70 DAP; 5, 75 DAP; numbers in one row followed by the same letter show no significant difference based on the DMRT test ($p < 0.05$).

reticulatus Naudin) from 38 days after anthesis to overripe. Furthermore, [38] reported that there was an increase in TSS content in 3 cultivars of cantaloupe melon from the unripe stage to the overripe stage.

The study results on the content of vitamin A, vitamin C, and TSS showed differences in the content of the three compounds at five stages of maturity. The difference in vitamin A, vitamin C, and TSS contents at the five stages of maturity is caused by the biosynthetic process in melon plants [39]. In the fruit ripening process, there will be physical and chemical changes such as water, protein, fat, organic acids, vitamins, minerals, and carbohydrates content [40]. Young fruit has high water content, so the enzymes converting simple sugars (sucrose, fructose, and D-galactose) into vitamin C are still relatively small [41]. At maturity stages 1 to 4, there is an increase in vitamin C content because the fruit is in the process of development, where the synthesis of vitamin C also increases due to the L-gluconolactone oxidase enzyme in the fruit. At maturity stage 5, the vitamin C content decreased because the maximum increase point was exceeded. The decrease in vitamin C content is due to the activity of ascorbic acid oxidase [42]. Ascorbic acid oxidase participates in the reorganization of vitamin C by oxidizing ascorbate to dehydroascorbic acid [43].

The content of TSS in fruit can be used to determine the level of fruit maturity. TSS shows the content of soluble substances in solution. The components contained in the fruit consist of water-soluble components, such as glucose, fructose, and sucrose, and water-soluble protein (pectin) [44]. The content of TSS at maturity stages 1 to 5 continues to increase because many carbohydrate compounds are still available to be converted into saccharides by the enzymes such as phosphorylase, glucoamylase, and amylase, causing high TSS content in melons [45]. In addition, the TSS content is affected by the respiration rate, which continues to increase so that sucrose, glucose, and fructose are formed, making the fruit sweeter [46]. Fruit at early ripening (unripe) has a low TSS content because the carbohydrate content has not turned into saccharides but still forms starch (polysaccharides) [47]. In fully ripe melon fruit, carbohydrates have been converted into saccharides so that the TSS content is higher than fruit harvested at early ripening.

Reciprocal crossing aims to determine whether or not there is a maternal effect on the inheritance pattern of vitamin A, vitamin C, and TSS contents. The maternal effect

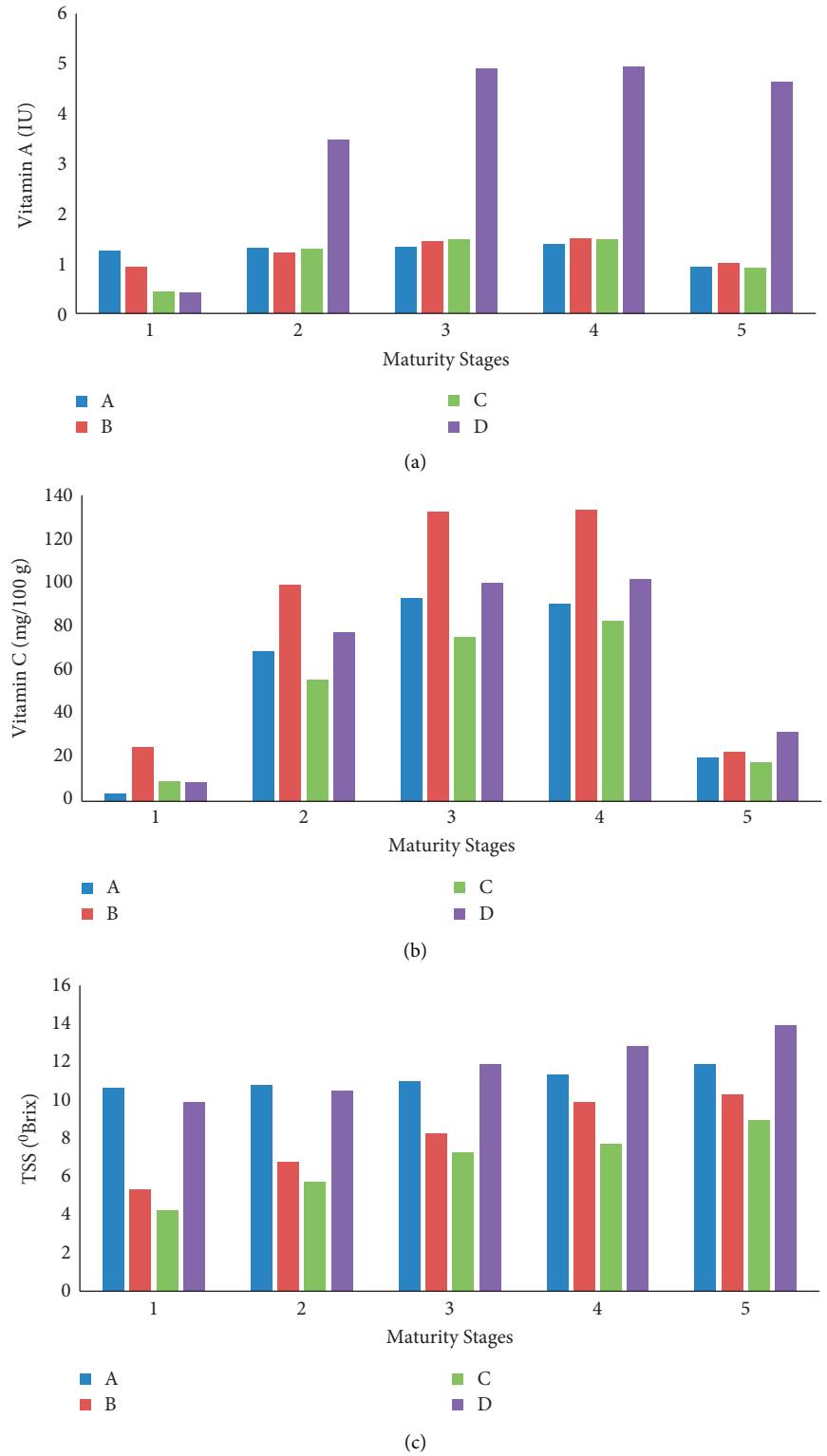


Figure 2: (a) The content of vitamin A at five stages of maturity; (b) the content of vitamin C at five stages of maturity; (c) TSS at five stages of maturity. Note: A, crossing of D-612 × PK-669 (F_1); B, crossing of PK-669 × D-162 (F_{1R}); C, crossing of PK-165 × PK-361 (F_1); D, crossing of PK-361 × PK-165 (F_{1R}).

on a character indicates that the character is controlled by genes inherited cytoplasmically from outside the nucleus. The t-test on the population mean values of F_1 and F_{1R} on the content of vitamins A and C in crosses of D-612 × PK-669 and PK-165 × PK-361 revealed no significant differences (Table 4). These results indicate no maternal effect in the

Table 2: The content of vitamin C (mg/100 g) for eight melon genotypes at five stages of maturity.

Maturity stage	Genotypes							
	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8
1	3,462^{c}	24,441^{a}	23,552^{a}	25,363^{a}	23,553^{a}	8,634^{b}	9,873^{b}	8,212^{b}
2	67,537^{b}	97,442^{a}	72,321^{b}	69,962^{b}	72,324^{b}	76,214^{b}	67,431^{b}	54,982^{c}
3	91,571^{bc}	130,716^{a}	78,442^{bcd}	84,251^{bcd}	78,861^{bcd}	98,367^{b}	73,265^{cd}	68,209^{d}
4	89,211^{bcd}	131,217^{a}	79,437^{cd}	94,214^{bc}	79,444^{cd}	100,212^{b}	78,428^{d}	73,229^{d}
5	19,812^{c}	22,163^{c}	22,547^{c}	42,677^{a}	22,551^{c}	31,107^{b}	19,224^{c}	23,214^{c}

1, 55 DAP; 2, 60 DAP; 3, 65 DAP; 4, 70 DAP; 5, 75 DAP; numbers in one row followed by the same letter show no significant difference based on the DMRT test ($p < 0.05$).

Table 3: Total soluble solids (TSS) (^{0}Brix) for eight melon genotypes at five stages of maturity.

Maturity stage	Genotypes							
	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8
1	5.291^{d}	10.542^{a}	8.253^{b}	8.119^{bc}	4.117^{d}	9.806^{a}	8.249^{b}	7.357^{c}
2	6.708^{ab}	10.691^{a}	8.872^{ab}	8.431^{ab}	5.67^{b}	10.434^{a}	9.233^{ab}	7.987^{ab}
3	8.214^{cd}	10.878^{ab}	9.412^{bc}	8.924^{cd}	7.211^{d}	11.807^{a}	9.431^{bc}	8.753^{cd}
4	9.802^{abc}	11.236^{ab}	10.441^{abc}	9.424^{bc}	7.651^{c}	12.742^{a}	9.761^{abc}	8.943^{bc}
5	10.220^{bc}	11.763^{b}	11.207^{bcd}	9.777^{cd}	8.901^{e}	13.777^{a}	11.282^{bc}	9.571^{de}

1, 55 DAP; 2, 60 DAP; 3, 65 DAP; 4, 70 DAP; 5, 75 DAP; numbers in one row followed by the same letter show no significant difference based on the DMRT test ($p < 0.05$).

Table 4: F_1 and F_{1R} t-tests on the crossing of D-612 × PK-669 and PK-165 × PK-361.

Character	Mean values					
	D-612 × PK-669			PK-165 × PK-361		
	F_1	F_{1R}	t-value	F_1	F_{1R}	t-value
Vitamin A	1.233	1.213	0.146^{ns}	1.315	3.656	0.722^{ns}
Vitamin C	54.319	81.196	0.884^{ns}	55.347	62.901	0.333^{ns}
TSS	8.047	11.022	2.975*	6.701	11.713	4.536*

* a significant at $p < 0.05$, ns indicates a non-significant at $p < 0.05$.

Table 5: Estimation value of variance component and heritability in the broad sense of quantitative characteristics of melon genotypes tested at five stages of maturity for characteristics of vitamin A, vitamin C, and TSS contents.

Maturity stages	Characteristics	σ_e^2	σ_g^2	σ_p^2	GDC	PDC	h^2_{bs}
1	Vitamin A	0.193	2.571	2.764	20.770	21.535	0.930
	Vitamin C	2.696	57.096	58.023	47.553	47.938	0.968
	TSS	0.226	4.506	4.732	27.497	28.177	0.952
2	Vitamin A	0.447	0.709	1.156	44.317	58.985	0.613
	Vitamin C	2.057	4.171	6.228	2.826	3.453	0.670
	TSS	1.927	5.841	7.768	28.433	32.790	0.752
3	Vitamin A	0.781	3.585	4.366	82.322	90.848	0.821
	Vitamin C	2.176	8.082	10.258	3.232	3.641	0.788
	TSS	0.954	6.901	7.855	28.156	30.039	0.879
4	Vitamin A	0.673	4.955	5.628	82.322	90.848	0.880
	Vitamin C	1.987	5.755	7.742	3.232	3.641	0.743
	TSS	1.657	4.213	5.870	20.526	24.228	0.718
5	Vitamin A	0.140	1.762	1.902	300.090	348.071	0.926
	Vitamin C	4.448	60.235	64.683	30,543	31,651	0,931
	TSS	1.077	2.229	3.306	13.811	16.821	0.674

σ_e^2, environment variance; σ_g^2, genetic variance; σ_p^2, phenotypic variance; GDC, genotypic diversity coefficient; PDC, phenotypic diversity coefficient; h^2_{bs}, heritability in the broad sense.

inheritance of vitamin A and C content in melon plants. For this reason, the use of male or female parents in one of the lines in the cross did not affect the inheritance of vitamin A and C content because female and male parents gave the same genetic contribution to offspring. In the TSS character, there is a significant difference between the population mean

Table 6: Pearson correlation coefficient between characteristics on the melon genotype tested.

	LA	FL	FD	FT	FW	Vit A	Vit C	TSS
LA	1							
FL	−0.310	1						
FD	0.143	0.256	1					
FT	0.654	0.037	0.513	1				
FW	0.031	0.395	0.943**	0.587	1			
Vit A	−0.034	0.633	−0.384	−0.023	−0.196	1		
Vit C	−0.342	0.158	0.642	0.180	0.702	−0.346	1	
TSS	−0.350	0.763*	0.093	−0.253	0.072	0.520	0.118	1

*indicates a significant correlation at $p < 0.05$; LA, leaf area; FL, fruit length; FD, fruit diameter; FT, flesh thickness; FW, fruit weight; Vit A, vitamin A content; Vit C, vitamin C content; TSS, total soluble solid. ** indicates a significant correlation at p<0.01.

values of F_1 and F_{1R} in the two crosses (D-612 × PK-669 dan PK-165 × PK-361). These results indicate a maternal effect on the inheritance of TSS character, so the use of female or male parents will affect the inheritance of TSS character. PK-669 and PK-361 lines are very suitable lines for female parents in both cross combinations because they produce offspring with high TSS characteristics.

3.2. Genetic Parameter Analysis. The characteristics of vitamin A, vitamin C, and TSS contents observed at five stages of maturity had a phenotypic diversity coefficient (PDC) greater than the genotypic diversity coefficient (GDC) (Table 5). In agreement with the result of this study, [48] reported that eight Thai commercial melon varieties tested had PDC values higher than GDC in all tested characteristics. The PDC value greater than GDC indicates that the character is heavily affected by environmental factors rather than genetic factors, while the PDC value that is almost the same as the GDC value indicates that the appearance of the characteristics is not much affected by the environment [49–51] [52], so the selection can be made based on the appearance of these characteristics [53, 54]. Table 6 shows that the three characteristics observed in the five stages of maturity have PDC values almost the same as GDC.

Heritability is the ratio of genetic variance to phenotypic variance for a given character [55]. Heritability value illustrates whether a character is affected by genetic factors or environmental factors (non-genetic) [56]. Heritability values in the broad sense of the three melon genotype characteristics tested at five stages of maturity ranged from 0.613 to 0.968. The study results showed that the heritability value in the broad sense for the three characteristics at the five stages of maturity had a value >0.6 [57]. A high heritability value indicates that genetic factors are greater in determining phenotypic variation than environmental factors [58–60]. The selection of characteristics with high heritability values has a high chance of genetic advancement because genetic factors control these characteristics so that they will be passed on to their offspring [61]. The selection of characteristics with high heritability values can be done in early generations [62–64].

3.3. Correlation between Quantitative Characteristics. Plant breeding programs often use an indirect selection approach to improve the desired characteristics by selecting characteristics that correlate with the character to be improved. The correlation between characteristics will facilitate selection because an increase in a character will be followed by a decrease or increase in the characteristics [65]. The closeness of the relationship between the characteristics studied is estimated by using the correlation coefficient. In this study, the content of vitamin A, vitamin C, and TSS was the main component of melon which is the focus of research. The content of vitamins A and C was not significantly correlated in all tested characteristics, while TSS had a significant positive correlation with fruit length (Table 6). Selection will be more effective if there is a correlation between the characteristics to be selected [66], where an increase in a character will be followed by an increase or decrease in another character. The results showed that the content of vitamins A and C was not significantly correlated with all observed characteristics, while TSS was significantly correlated with fruit length. Breeding strategies to assemble melon varieties with high TSS content can be done by selecting melon lines with long melons because there is a significant positive correlation between the TSS content character and the fruit length character.

3.4. Heterosis Studies. Heterosis provides information on increasing and decreasing the heterosis value of the mid-parent (MPH/heterosis) and the best parent (BPH/heterobeltiosis) in F_1 plants. The value of heterosis and heterobeltiosis is affected by the action of the overdominant gene in both parents which is passed on to the offspring for quantitative characteristics [67, 68]. High heterosis and heterobeltiosis indicate that the F_1 genotype has a value that exceeds the average of the two parents and the best parent [69, 70]. High heterosis is thought to be because both parents have distant genetic backgrounds or distant kinship relationships.

In the character of vitamin A content, the highest mean value was found in the G_6 genotype (PK-165 × PK-361), which was 3,656 IU (Table 7). The PK-165 × PK-361 cross had the highest positive heterosis and heterobeltiosis values compared to other crosses of 112.21% and 98.37%, respectively. The G_2 genotype (D-612 × PK-669), with an average value of 81,196 mg/100 g, produced the highest average amount of vitamin C content. The crossing of D-612 × PK-669 had the highest values of positive heterosis and heterobeltiosis compared to other crosses of 36.97% and 28.29%, respectively. In the TSS character, the highest mean value for the G_6 genotype (PK-165 × PK-361) cross was 11,711 ^{0}Brix. The PK-165 × PK-361 cross had the highest positive heterosis and heterobeltiosis values compared to other crosses of 29.41% and 22.15%, respectively.

Numbers in one row followed by the same letter show no significant difference based on the DMRT test ($p < 0.05$)

The estimation of heterosis value is needed to determine potential parents used to assemble hybrid melon varieties [71]. This research's melon variety assembly program is

Table 7: Estimates of heterosis over the mid-parent (MP) and better parent (BP) for vitamin A, vitamin C, and total soluble solids in melon.

Genotypes	Total soluble solids			Vitamin A			Vitamin C		
	Mean values	MP (%)	HP (%)	Mean values	MP (%)	HP (%)	Mean values	MP (%)	HP (%)
G_1 (PK-669 × D-612)	11.021^{b}	18,71	14,38	1.233^{e}	−46,05	−60,70	54.319^{bc}	−8,37	−14,18
G_2 (D-612 × PK-669)	8.052^{f}	−13,34	−16,50	1.213^{e}	−46,93	−61,34	81.196^{a}	36,97	28,29
G_3 (PK-669)	8.931^{d}			3.126^{b}			55.259^{bc}		
G_4 (D-612)	9.641^{c}			1.420^{d}			63.293^{b}		
G_5 (PK-361 × PK-165)	6.734^{g}	−25,67	−29,84	1.115^{e}	−34,88	-39,13	55.346^{bc}	10.30	13.98
G_6 (PK-165 × PK-361)	11.711^{a}	29,41	22,15	3.656^{a}	112,21	98,37	62.906^{b}	2,78	32,13
G_7 (PK-361)	9.591^{c}			1.846^{c}			49.644^{c}		
G_8 (PK-165)	8.514^{e}			1.599^{d}			45.569^{c}		

directed at assembling hybrid varieties with high vitamin A, vitamin C, and TSS characteristics. The results showed that the cross of PK-165 × PK-361 had positive heterosis and heterobeltiosis values for the character of vitamin A, vitamin C, and TSS contents; thus, the cross of PK-165 × PK-361 could be used to assemble a hybrid melon variety containing high vitamin A, vitamin C, and TSS.

4. Conclusions

The content of vitamins A and C increased at maturity stages 1 to 4 for all melon genotypes tested and decreased in vitamin A and C content at maturity stage 5. The TSS content increased at maturity stage 1 to maturity stage 5 for all tested genotypes. The right harvest time for the eight genotypes tested was maturity stage 4 (70 DAP) because it had the highest vitamin A, vitamin C, and TSS contents compared to other maturity stages. The inheritance of vitamin A and C content was not affected by the maternal effect, while TSS was influenced by the maternal effect. The vitamin A, vitamin C, and TSS content characteristics had higher phenotypic diversity coefficients than genetic diversity coefficients. Heritability values in the broad sense for the three melon genotypic characteristics ranged from 0.613 to 0.968. Crosses of PK-165 × PK-361 can be used to assemble hybrid melon varieties that have high vitamin A, vitamin C, and TSS contents because they have positive values for heterosis and heterobeltiosis for the three characteristics.

Data Availability

All the data that support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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