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Evaluation of proximate analysis and yield production of watermelon in Lampung, Indonesia

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Abstract. *Wahyudi A, Sari MF, Rajamin I, Arsri M. 2023. Evaluation of proximate analysis and yield production of watermelon in Lampung, Indonesia. Biodiversitas 24: 6017-6022.* The breeding of watermelon plants is carried out to produce new superior varieties. This study aimed to test the moisture, fat, carbohydrate, ash, and vitamin contents, and the yield potential of a hybrid watermelon line (F1). The materials used were 6 hybrid watermelon and 2 commercial lines as control varieties. A randomized block design was adopted in this study and was analyzed by LSD test, dendrogram, and proximate analysis. The result showed that the 6 hybrid watermelon lines had high yield potential. Furthermore, the moisture content of the fruit of the WM 2110-1204 lines (92.24%) was higher than other lines. Proximate data analysis showed that the WM 2110-0616 line had a higher ash content (0.16%), and the carbohydrate content of the fruit of the WM 2110-0806 line (3.64%) was also higher. The vitamin C-vitamin content of the fruit of the WM 2110-0308 line (0.36 $mg.g^{-1}$) was higher, while the 4 watermelon lines, namely WM 2110-0308, WM 2110-204, WM 2110-0806, and WM 2110-1606 had advantages in terms of skin color and striation, fruit sweetness level and weight. In a dendrogram analysis, qualitative characters were divided into two clusters, with clusters I and II containing 8 and 1 lines, respectively.

Keywords: Hybrid, plant breeding, variety

Abbreviations: WM: Watermelon, LSD: Least Significant Difference, CV: Coefficient of Variance

INTRODUCTION

Watermelon, also known as *Citrullus lanatus*, is widely cultivated in Indonesia and is in great demand due to its high nutritional content. Seed Technology Study Program, Politeknik Negeri Lampung (Polinela), has carried out several investigations on watermelon varieties since 2014. Consequently, 6 hybrid watermelons were produced: WM 2110-0104, WM 2110-0308, WM 2110-1606, WM 2110-0806, WM 2110-1110, and WM 2110-1204. One of the methods used to improve the quality and productivity of watermelons is high-yielding varieties through plant breeding programs. Hybrid varieties (F1) have the advantage of having more uniform plant structure, producing optimal growth, high productivity, and being disease-resistant. Addressing these problems necessitates the use of superior varieties. The breeding of watermelon plants was aimed to yield hybrid varieties that can be developed quickly, resulting in high yields to meet consumer demand. Watermelon plants are widely cultivated by the community, specifically in the lowlands. This cultivation benefits farmers and entrepreneurs, significantly improving Indonesia's economic system, specifically in the agricultural sector.

Watermelon is suitable for planting in the lowlands to 600 meters above sea level (Kyriacou et al. 2018). One of the main goals of the breeding program is to develop varieties that perform similarly across sites, years, and environmental conditions for wider adaptability and longevity. Therefore, before the release of new varieties, they are evaluated in trials to assess the genetic and environment (G×E) interaction (Griffey et al. 2020). Watermelon fruit can be grouped both by weight and size, with 6 different weight categories, namely mini (1.5 to 4.0 kg), icebox (4.0 to 5.5 kg), small (5.5 to 8.0 kg), medium (8.0 to 11 kg), large (11.0 to 14 kg) and giant (>14 kg). Commercially, fruits are grouped by counts that fit into 24″ containers, such as 36 (7.7 to 10 kg per fruit), 45 (6.4 to 7.7 kg per fruit), and 60 counts (4.5 to 6.4 kg per fruit) (Bertucci et al. 2018). Mini-sized watermelons are packaged in cartons of 4 to 6 pieces per carton. Since the early 2000s, consumer preferences have shifted away from large and giant fruits, and they presently prefer mini to medium watermelons (Gusmini and Wehner 2007; Sandlin et al. 2012). Fruit weight can be shifted in years by high selection intensity, but due to few effective factors governing weight, the trait can be fixed in several generations of selection. Therefore, it is easier to introgress certain traits into individuals with the fruit weight of interest through pedigree breeding or back-crossing. While yield and its components are important to producers, fruit quality traits, such as sweetness, shape, skin pattern, flesh color, and nutritional factors, are important to retailers and consumers.

For consumers, one of the most important characteristics of a watermelon is fruit sweetness, which is determined by the total soluble solids or sugar content, as measured by degrees Brix. According to U.S. Standards for Grades of

Watermelon, a value 8-10° Brix in the center of the flesh fruit is sufficiently ripe and considered to be of good quality (USDA 2020), while >10° Brix is considered excellent quality (Correa et al. 2020). The soluble sugar content is made up of three sugars, namely fructose, glucose, and sucrose. According to (Kader 2008; Kyriacou et al. 2016), a ripe watermelon has higher levels of fructose or sucrose, which differ between varieties. Broad heritability for °Brix, fructose, glucose, and sucrose was previously calculated using a recombinant inbred line mapping population (Klondike Black Seeded × New Hampshire Midget), which yielded low heritabilities of 0.30, 0.41, 0.51, and 0.70, respectively (Fall et al. 2019). Unfortunately, °Brix can vary by year and location; still, Dia et al. (2016b) identified genotypes that showed stability in experiments with 40 sample sizes in 3 years at 8 sites in the United States. Most commercial watermelon varieties produce fruit that is 8-10° Brix, meeting the minimum requirements of USDA standards, with most having over 10° Brix. This study aimed to test the yield potential and moisture, fat, carbohydrate, ash, and vitamin contents of hybrid watermelon lines (F1) produced by a study analyst team at Politeknik Negeri Lampung.

MATERIALS AND METHODS

Materials

This study was conducted at a Teaching Factory, namely Seed Teaching Farm (STEFA), Politeknik Negeri Lampung, Indonesia. It includes 6 tested varieties: WM 2110-0104, WM 2110-0308, WM 2110-1606, WM 2110-0806, WM 2110-1110, and WM and 2110-1204, as well as 2 control commercial varieties, such as Bonita F1 and Red Dragon.

Proximate analysis

Proximate analysis was conducted using the Official Analytical Chemists (AOAC) methods (Mamman et al. 2022), and atomic absorption spectrometry was used to determine the mineral contents. The moisture, fat, ash, carbohydrate, and C-vitamin contents were determined following the association of the Official Analytical Chemists (AOAC 2010) method. The analysis was carried out in triplicates; the results obtained were the average values. The proximate analysis began with about 100 g of the powder was weighed in a hot-air oven at 105°C to constant weight, and the weight difference was recorded as the moisture content. Afterward, 3 g of the powder was placed in a pre-weighed porcelain crucible and ignited in an ashing furnace at 600°C. The ash content was determined immediately after obtaining white ash, maintaining a constant weight. As reported by Saidu et al. (2021), the Micro-Kjeldahl method was used to determine the nitrogen content.

Experimental design and statistical analysis

The experiment was conducted using a randomized block design, with a single factor of 6 test and 2 control varieties, with three replications. All quantitative data were statistically analyzed by determining the statistically significant differences ($p<0.05$) using Analysis of Variance (ANOVA). This is followed by the Least Significant Difference (LSD) tests using statistical software SPSS Statistics, Chicago. Each experimental unit consisted of two plots of beds, measuring 50 cm x 200 cm, and each bed contained 20 planting holes, with 1 per hole. The observation and recording of characterization data were carried out using observation sheets, which were made to recap and document the images of each characteristic. The observed variables refer to the International Union for the Protection of New Varieties of Plants (UPOV 2009).

Dendrogram analysis

Cluster analysis is a statistical tool that offers a variety of options, allowing the analysis to be uniquely tailored to the data and objectives. In samples that appear superficially homogeneous, hierarchical cluster analysis is suggested as a practical method of identifying meaningful clusters. Hierarchical cluster analysis in this study was carried out using SPSS statistical software following a tutorial guide by Yim and Ramdeen (2015).

RESULTS AND DISCUSSION

Proximate analysis

Another study focused on increasing shelf-life (Al-Sayed and Ahmed 2013) and the nutritional/quality of the fruit juice (proximate) contents (Fila et al. 2013), the rind (peels), which could encourage their consumption or further use (Gladvin et al. 2017). Proximate analysis was performed using standard AOAC methods, and atomic absorption spectrometry was used to determine the mineral contents. The results for the proximate composition of the watermelon fruits are shown in Figure 1. The moisture content of the WM 2110-1204 genotype (92.24%) exceeded others, while the WM 2110-0616 genotype exhibited a higher ash content (0.16%). Furthermore, the carbohydrate content showed that the WM 2110-0806 genotype (3.64%) was higher than other genotypes.

The C-vitamin content of watermelon fruit showed that the WM 2110-0308 genotype (0.36 $mg.g^{-1}$) was higher, as shown in Figure 1. Melon is a nutrient-rich fruit, with every 100 grams of fresh fruit meat containing 92.1% water, 0.5% protein, 0.3% fat, 6.2% carbohydrate, 0.5% fiber, and 350 IU vitamin A. A previous study investigated the rind of watermelon composition of the vitamin (Gladvin et al. 2017) showed the presence of vitamins A -52.13, B1-1.23, B2-2.71, B3-4.25, B6-5.34, and C-8.46 in mg/100 g. Furthermore, solanum lipocalin TILs and CHL protein can increase the yield of plants and environmental stresses (Wahyudi et al. 2018; Wahyudi et al. 2020).

Figure 1 shows the proximate fruit compositions of watermelon. Climatic and agronomic practices influence vary widely in mineral content as represented by the ash value. The protein and carbohydrate contents contributed 25% of the total variation in proximate components, having the highest correlations with the 2 and 3 CDFs (Henshaw 2008). These components are important in determining watermelon's nutritional quality and processing quality.

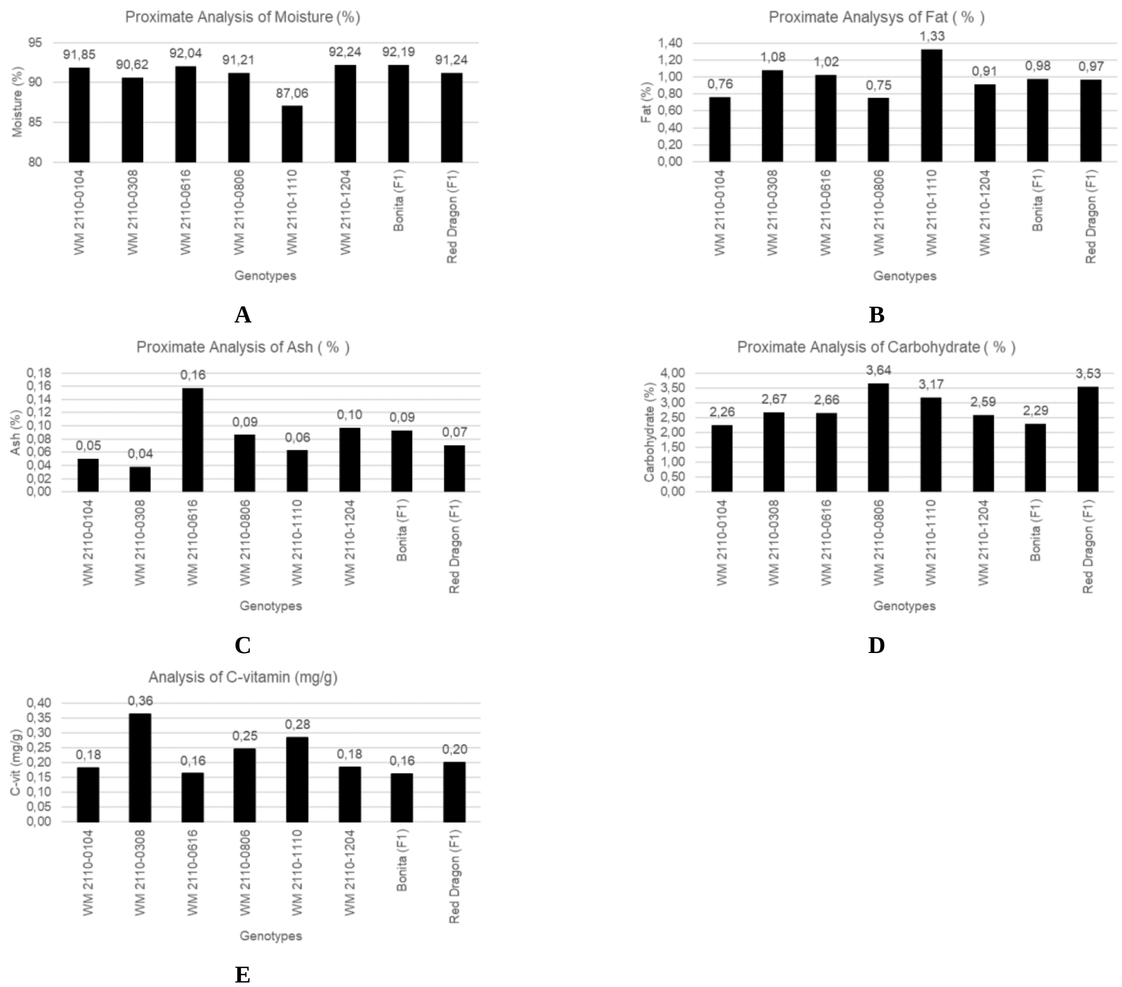

Figure 1. Proximate analysis data on fruits. A. Moisture content, B. Fat content, C. Ash content, D. Carbohydrate content, E. C-vitamin content. Proximate analysis was performed using standard AOAC methods, and atomic absorption spectrometry was used to determine mineral contents

The quantitative character

A previous study of the cowpea field evaluation of advanced breeding materials across multiple environments is one way of identifying high-performing genotypes (Wahyudi and Syukur 2021). Previous studies in watermelon identified 4 genotype stability-performance combinations: high stability-high, high stability-low yield, low stability-high, and low stability-low yields (Dia et al. 2016a). In the tropics, the low yield of watermelon [(*Citrullus lanatus* var. lanatus (Thunb.)] is partially due to the use of low-yielding watermelon cultivars. Using high-yielding cultivars adaptable in the tropics can increase watermelon productivity (Mrema et al. 2022). In this study, the recapitulation of the F-test showed that stem length, petiole length, fruit weight, fruit skin thickness, sugar content, fruit length, fruit diameter, and number of seeds were significantly different with the coefficient of variance between 2.27% to 12.01%. Furthermore, leaf length and width parameters were not significantly different, with coefficients of variance of 7.10% and 10.07%, as shown in Table 1. As shown in Table 2, the leaf data indicated that WM 2110-0806 has 256.96 cm and is the longest compared with other genotypes. WM 2110-0104 and WM 2110-0308 were the longest petiole length.

The observation data of fruit weight (Table 3) showed that 4 genotypes, namely WM 2110-0308, WM 2110-1606, WM 2110-1110, and WM 2110-1204, were >3 kg in fruit weight and significantly different compared with control varieties (Bonita F1 and Reda Dragon). WM 2110-0308 and WM 2110-1606 significantly differed in fruit skin thickness and number of seeds compared to control varieties. This result showed that the hybrid watermelon produced by Politeknik Negeri Lampung has the potential for new superior varieties. Watermelon fruit can be grouped both by weight and size, with 6 different categories, namely mini (1.5 to 4.0 kg), refrigerator (4.0 to 5.5 kg), small (5.0 to 8.0 kg), medium (8.0 to 11 kg), large (11.0 to 14 kg) and giant (>14 kg). Commercially, fruits are grouped by counts that fit into 24" containers, such as 36 (7.7 to 10 kg per fruit), 45 counts (6.4 to 7.7 kg per fruit), and 60 counts (4 .5 to 6.4 kg per fruit) (Bertucci et al. 2018). Mini-size watermelons are packaged in cartons of 4 to 6 pieces per carton. Consumers prefer mini to medium watermelons and have shifted away from large and giant fruits since the early 2000s (Gusmini and Wehner 2007; Sandlin et al. 2012).

The qualitative character

The watermelon plants' qualitative parameters consisted of leaf and fruit shape, skin color, striated type, and flesh color. Table 4 shows the qualitative characteristics and the type of leaf curve; generally, the watermelon has a medium and strong type of curve, and the shape is oval and oblong. The color of the fruit skin is green, light green, and dark green. The striated types of the fruit tested were plain, thin, and thick, and the color of the watermelon flesh was red and yellow, as shown in Table 4 and Figure 2. In addition, the 2 lines had the moderate type of leaf grooves from several of the tested watermelon hybrid lines, and the strongest type belonged to the WM 2110-0104, WM 2110-0308, WM 2110-1606, WM 2110-0806, WM 2110-1110, and WM 2110-1204. The shape of the watermelon, which is generally round, oval, and oblong type, is very important in attracting attention to market demand.

Table 1. Recapitulation of F-test and coefficient of variance

Parameter	F-test	Coefficient of variance (%)
Stem length (cm)	4.28 **	7.61
Leaf length (cm)	1.16 ns	7.10
Leaf width (cm)	2.20 ns	10.07
Petiole length (cm)	4.30 **	10.29
Fruit weight (kg)	71.38 **	2.27
Fruit skin thickness (cm)	3.49 *	6.96
Sugar content (°brix)	5.17 **	3.40
Fruit length (cm)	12.53 **	2.41
Fruit diameter (cm)	12.52 **	2.80
Number of seeds	15.77 **	12.01

Note: **: Very significant different, *: Significant different: ns: Non significant different

Table 2. Recapitulation of F-test and coefficient of variance

Genotype	Stem length (cm)		Leaf length (cm)		Leaf width (cm)		Petiole length (cm)	
WM 2110 - 0104	190.81	a	23.00	ab	18.00	abc	16.00	b
WM 2110 - 0308	205.68	ab	23.83	b	19.83	bc	15.33	b
WM 2110 - 1606	233.89	bcd	23.01	ab	19.00	abc	13.00	ab
WM 2110 - 0806	256.96	d	20.83	a	17.50	abc	14.17	ab
WM 2110 - 1110	237.07	cd	23.84	b	17.83	abc	14.17	ab
WM 2110 - 1204	227.54	bcd	23.20	ab	16.67	abc	11.20	a
BONITA F1	224.70	bcd	24.00	b	20.67	c	13.22	ab
RED DRAGON	214.44	abc	22.67	ab	16.00	a	11.67	a

Note: The numbers followed by the same letter in the same column are not significantly different according to the 5% LSD test

Table 3. The observation data of fruits and seeds

Genotype	Fruit weight (kg)		Fruit length (cm)		Fruit diameter (cm)		Fruit skin thickness (cm)		Sugar content (˚brix)		Number of seeds	
WM 2110 - 0104	2.80	b	28.58	d	14.40	b	1.36	bcd	8.92	ab	231.22	c
WM 2110 - 0308	3.45	f	26.60	bc	15.53	d	1.49	d	9.29	bc	295.89	d
WM 2110 - 1606	3.17	d	28.09	d	14.39	b	1.50	d	9.42	bcd	237.11	c
WM 2110 - 0806	2.77	ab	24.50	a	14.29	ab	1.41	cd	9.51	cd	271.11	cd
WM 2110 - 1110	3.31	e	26.57	bc	15.17	cd	1.43	cd	9.34	bc	267.78	cd
WM 2110 - 1204	3.56	f	26.20	bc	16.32	e	1.04	a	9.56	cd	235.11	c
BONITA F1	2.65	a	26.94	c	13.70	a	1.20	ab	8.60	a	178.67	b
RED DRAGON	2.93	c	25.50	ab	14.50	bc	1.30	bc	9.93	d	98.67	a

Note: The numbers followed by the same letter in the same column are not significantly different according to the 5% LSD test

Table 4. The observation data of qualitative character

Variable	Distribution of qualitative character traits		Genotype
Leaf angled type	Currently	Medium (2 genotypes)	A7, A8
	Strong	Strong (6 genotypes)	A1, A2, A3, A4, A5, A6
Fruit shape	Ovals	Oval (0 genotypes)	
	Oval	Oval (8 genotypes)	A1, A2, A3, A4, A5, A6, A7, A8
Fruit skin color	Light green	Bright green (3 genotypes)	A2, A6, A8
	Green	Green (1 genotype)	A3
	Dark green	Dark green (4 genotypes)	A1, A4, A5, A7
Striped type	Plain	Plain (0 genotypes)	
	Thin	Thin (7 genotypes)	A1, A2, A4, A5, A6, A7, A8
	Thick	Thick (1 genotypes)	A3
Fruit flesh color	Red	Red (7 genotypes)	A1, A2, A3, A4, A5, A7, A8
	Yellow	Yellow (1 genotype)	A6

Note: A1: WM 2110-0104, A2: WM 2110-0308, A3: WM 2110-1606, A4: WM 2110-0806, A5: WM 2110-1110, A6: WM 2110-1204, A7: Bonita F1, A8: Red Dragon

Table 5. The results data of qualitative observations of fruit shape, skin color, fruit striations, and fruit flesh color

Hybrid field code (reciprocal)	Fruit shape	Fruit skin color	Fruit striations	Fruit flesh color
WM 2110-0104	Oval	RHS 135A (Dark Green)	Weak	RHS 42A (Red)
WM 2110-0308	Oval	RHS 140B (Light Green)	Weak	RHS 43A (Red)
WM 2110-1606	Oval	RHS 135A (Dark Green)	Medium	RHS 51A (Red)
WM 2110-0806	Oval	RHS 140B (Light Green)	Strong	RHS 52B (Red)
WM 2110-1110	Oval	RHS 136B (Dark Green)	Weak	RHS 53C (Red)
WM 2110-1204	Oval	RHS 134A (Green)	Strong	RHS 7A (Yellow)
Bonita F1	Oval	RHS 136A (Dark Green)	Weak	RHS 50B (Red)
Red Dragon	Oval	RHS 136B (Green)	Medium	RHS 50B (Red)

Note: WM: Watermelon, observed of color using RHS color chart

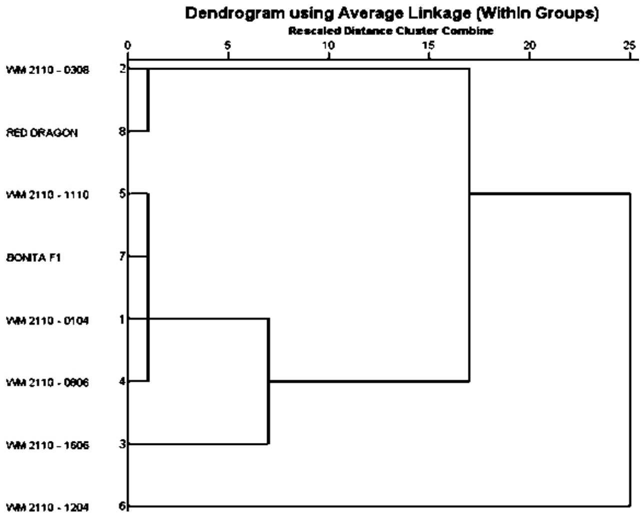

Figure 2. Dendrograms from a hierarchical cluster analysis with average linkage using SPSS statistical software

The dendrogram data analysis in Figure 2 showed that cluster I consisted of 8 hybrid watermelon lines with the qualitative characteristics of leaf and fruit shape, skin color, striated type, and flesh color. The lines within the initial cluster exhibiting the same phenotypic characters, namely leaf shape, fruit shape, skin color, striated type, and flesh color, are WM 2110-0104, WM 2110-0308, WM 2110-1606, WM 2110-0806, WM 2110-1110, WM 2110-1204, Bonita F1 and Red Dragon. Cluster II containing one watermelon, namely WM 2110-1204, has a yellow flesh color. The watermelon variety assembly program aims to create superior varieties with early maturity, high production, thick skin, and high total soluble solids in the fruit. Superior watermelon varieties are expected to have a harvest age of less than 80 days, fruit weights ranging from 4-5 kg, skin thickness of 1.1-1.4 cm (Makful et al. 2019), and total soluble solids of more than or equal to 8 °Brix (United Nation Economic Commission for Europe 2017). Fruit length and diameter are supporting weight characteristics, and there is a positive correlation between the two characteristics (Bhagyalekshmi et al. 2020). According to (Daryono et al. 2019), *Cucumis melo* L. 'Melonia' is a new Indonesian melon cultivar produced by segregation of the Meloni cultivar. It has a yellowish-skin color, orange-colored flesh fruit, and a sweet taste (Daryono et al. 2019).

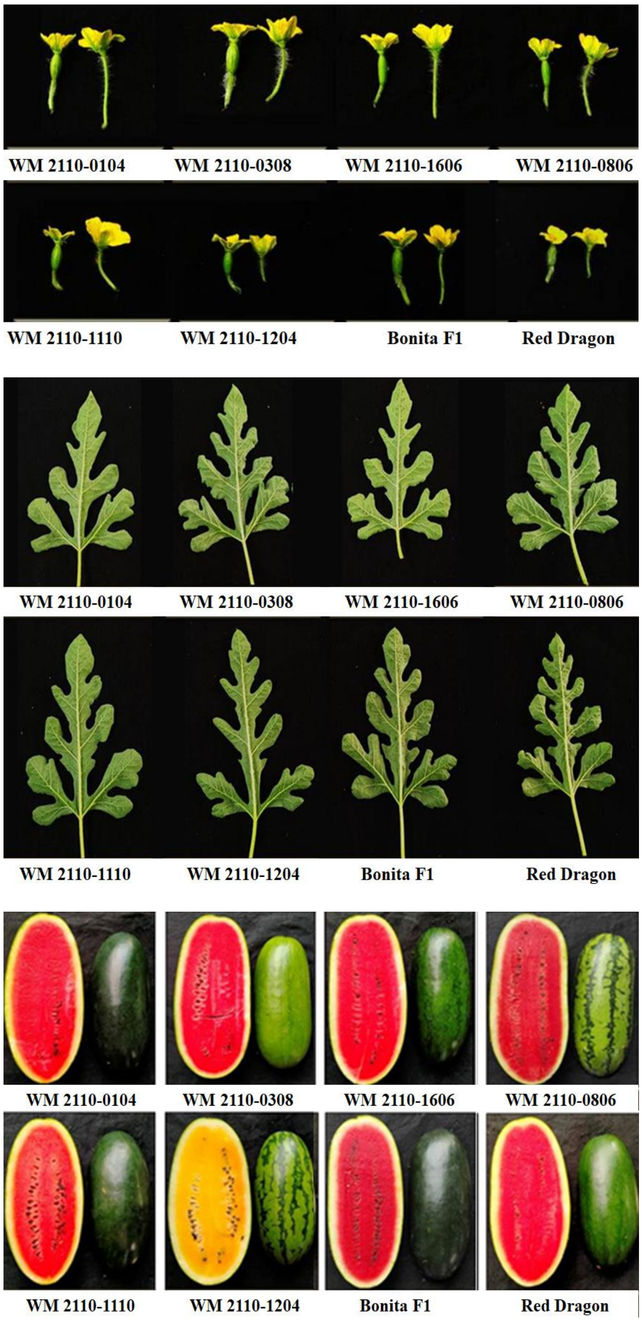

Figure 3. The morphology of flowers, leaves, and fruits of watermelon

The observational data in Table 5 and Figure 3 showed that the shape of the variety tested is oval to oblong, classifying the watermelon as oval type. WM 2110-0104, WM 2110-0806, WM 2110-1110, and WM Bonita F1 have dark green skin and weak-medium striated fruit with red flesh. WM 2110-0308 has light green or bright green skin with weak or thin fruit striations and red flesh. WM 2110-1606, WM 2110-1204, and WM Red Dragon have green fruit skin color with strong or thick fruit striations and red flesh. Furthermore, the skin color of watermelons is light green with stripes, plain light green, and dark green. The watermelon exhibits different skin coloration, each bearing specific characteristics. Watermelons with a striated light green color are common, and those with dark green skin are characterized by their robust and resilient texture and their resistance to breakage and storage. In contrast, watermelons with plain light green skin color are thought to be due to the merging of two recessive characters during skin color formation. This study does not indicate which strain is preferable by consumers or has the highest yield to mass production. This indication is important for reference in the next study.

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