JUATIKA
JURNAL AGRONOMI TANAMAN TROPIKA
VOL. 6 NO. 2 May 2024

DOI :https://doi.org/10.36378/juatika.v6i2.3579
eissn 2656-1727
pissn 2684-785X
Hal : 208 – 223

# Characterization And Genetic Relationship of Several Tomato (*Solanum lycopersicum* L.) Genotypes from Various Regions

Yunandra*, Fikri Rahmadian, Elza Zuhry, Irfandri, Rahmad Saputra, Niskan Walid Masruri, Yohana Aprilita Br Hutabarat, Natalia Yosephine Simanjuntak, Eka Destiani

Universitas riau,
Jl. Bina widya KM. 12,5, Simpang baru, Kec. Tampan, Pekanbaru, Riau 28293. Indonesia
*E-mail: yunandra@lecturer.unri.ac.id

## ABSTRACT

The research aims to obtain information about the morphological characters and genetic relationships of several tomato genotypes from various regions. The study was conducted from May to October 2023 at the Experimental Garden and Plant Breeding Laboratory, Faculty of Agriculture, University of Riau. The research used a randomized block design (RBD) consisting of eight genotypes and four repeats, and 32 experimental units were obtained. The observations were made to observe some qualitative characters. Qualitative data were analyzed using principal component analysis and cluster analysis to see genetic relationships. The results showed that the Magelang genotype (T27) had a high average plant fruit weight of 619.74 g, the Pane tongah (T24) had an average thick fruit flesh of 6.05 mm, the Silimakuta (T22) had an average large fruit size of 63.28 g. In contrast, the Purba (T25) had an average number of large planting fruits of 15.41 pieces. Grouping eight tomato genotypes based on clustering of MC1 and MC2 and cutting the dendrogram at a 90% similarity rate resulted in six groups. Group One consists of three genotypes, specifically Silimakuta (T22), Alahan Panjang (T26), and Magelang (T27). Group Two has Raya (T23), Group Three has Purba (T25), Group Four has Pane tongah (T24), group five has Servo F1 and group six has Ratna. The closest kinship based on the smallest euclidiean distance value is the Silimakuta (T22) and Alahan panjang (T26), with a value of 19.44. The genotypes with the farthest similarity are Raya (T23) and Purba (T25) because they have a 46.24 genetic distance.

**Keywords**: *Characterization, cluster analysis, genotype, tomato*

## 1. INTRODUCTION

Tomato (Solanum lycopersicum L.) is a highly sought-after horticultural plant for its fruits. Most Indonesians incorporate tomatoes as an essential ingredient in various traditional dishes. Additionally, tomatoes serve as a primary raw material in the food processing industry, notably in the production and marketing of tomato sauce. While tomatoes typically thrive in highlands, there is a growing demand for increased output in low-lying areas like Riau. However, tomato plants cultivated in lowlands struggle to achieve high and consistent yields due to the subpar quality and suboptimal growth of the varieties commonly used by farmers in these areas (Maskar et al., 2005).

The tomato productivity in Riau in 2019 was 1.87 tons per hectare, which increased to 2.13 tons per hectare in 2020. further rose to 3.42 tons per hectare in 2021. and continued to increase to 4.48 tons per hectare in 2022 (Badan Pusat Statistik, 2022). The tomato productivity in Riau has been growing annually and can continue to rise if tomato genotypes that thrive well in lowlands are continuously developed through plant breeding programs.

A plant breeding program is the initial step to support effective and efficient selection methods. This program includes exploring, characterizing, and analyzing the diversity and relationships among several tomato genotypes. Exploration involves collecting various tomato genotypes from different regions. The exploration process serves to enhance genetic diversity in the characterization process. High genetic diversity assists plant breeders in obtaining the right cross combinations with a mix of favorable traits, thus increasing the chances of success in developing superior varieties (Saputra et al., 2014). Characterization can be interpreted as recording or describing a plant based on inheritable traits, easily observable characteristics, and expression in all environments. Characterization aims to identify morphological and genetic diversity in each tested tomato genotype, thereby revealing the relationships and genetic distances within each genotype.

Research on the characterization and relationships of several tomato genotypes has been carried out by several researchers (Ramadhan et al., 2016), who conducted a study on the morphology characterization and relationships of 28 tomato genotypes. The research results indicate that the Costoluto Fiorentino genotype has a taller average plant height than other genotypes and can produce 35.2 fruits. Qualitative traits observed in the 28 tomato genotypes include fruit shape, fruit color, and leaf type. Genotypes Yellow Pear, Garden Pearl, and Red Pear have fruit shapes resembling a pear. The dendrogram results reveal the presence of 2 clusters at a similarity level of 0.763. In contrast to previous studies, this research utilized local genotypes explored from various regions.

Analyzing diversity and genetic relationships is crucial for obtaining insights into the biological closeness among genotypes. This information is vital for a more targeted and precise development of superior varieties (Senior et al., 1998). Hence, an experiment titled "Characterization and Genetic Relationships Among Several Tomato Genotypes (Solanum lycopersicum L.) from Various Regions" was conducted to acquire information regarding the morphological characteristics and genetic relationships of several tomato genotypes from different regions.

## 2. MATERIAL AND METHOD

This study was conducted at the Experimental Garden Unit, Faculty of Agriculture, University of Riau, Bina Widya Campus KM 12.5. Simpang Baru Village, Bina Widya District, Pekanbaru City. The research took place for six months, from May 2023 until October 2023. at coordinate point 0.48169406. 67257363. 101.3794512851082.

The materials used were six local tomato genotypes from various regions: Silimakuta, Raya, Pane tongah, Purba, Alahan panjang, Magelang, and two additional genotypes, Ratna and Servo F1. Black soil, husk charcoal, manure, black and silver plastic mulch (MPHP), bamboo pieces, NPK Mutiara fertilizer (16-16-16), foliar fertilizer, fruit fertilizer, zipper plastic, dolomite lime $CaMg(CO_3)_2$. fungicide made from mankozeb 80%, insecticide made from carbofuran 3%, and lamda sihalotrin 106 g.l-1 and tiamethoxam 141 g.l-1. The tools used in this study were seedling trays, paddles, mulch punchers, hand sprayers, knapsack sprayers, raffia ropes, rulers, digital scales, digital callipers, stationery, and cameras.

This study used a randomized block design (CRD) with a single factor, specifically 8 tomato genotypes with four replications, so there were 32 experimental units. Each experimental unit consisted of 20 plants; 10 were taken randomly as sample plants.

The research included seeding, land preparation, essential fertilization, planting, maintenance, harvesting, and observations on each experimental genotype. Data from the field were qualitative data that were first transformed into quantitative data following the IPGRI (1996) characterization keywords and then analyzed using Principal Component Analysis and Cluster Analysis to observe the relationship between several tomato genotypes to obtain the clustering pattern and diversity between genotypes in the form of dendrograms

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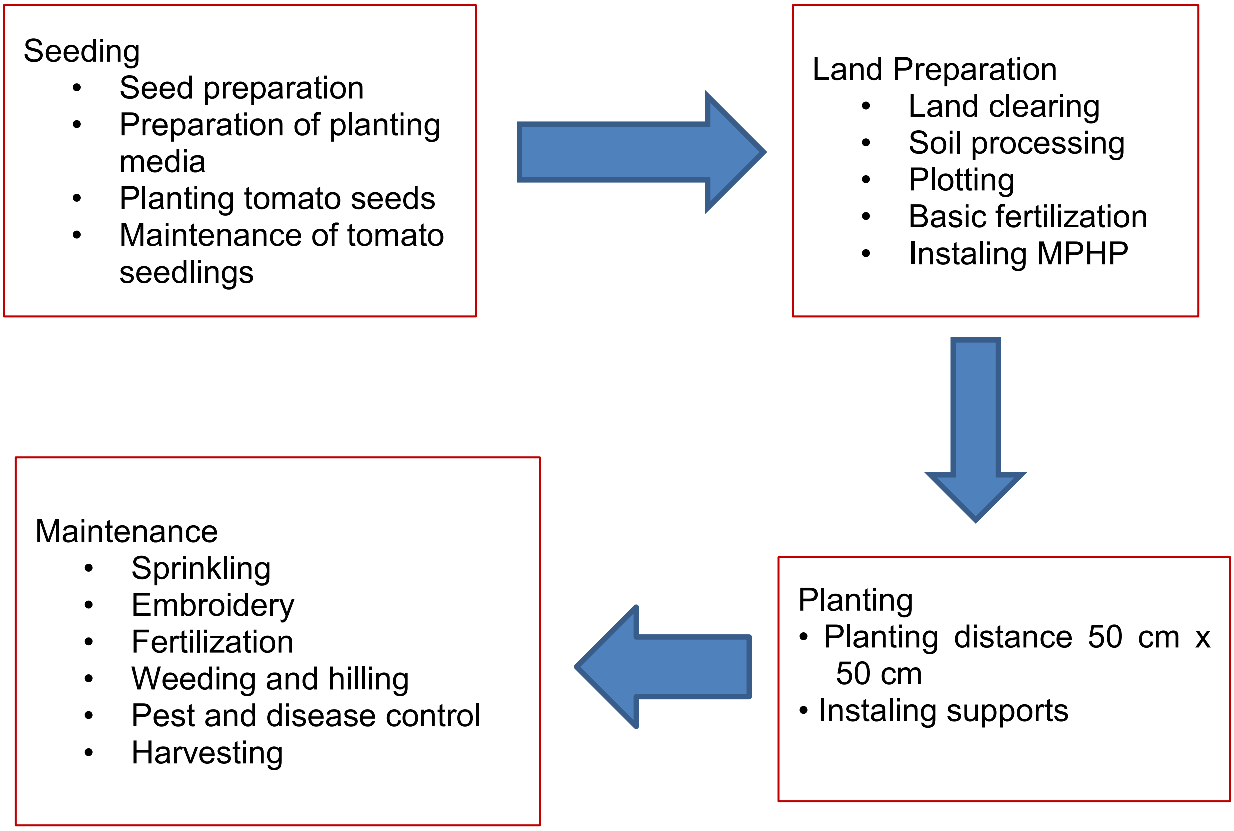


**Figure 1.** Flow chart of research implementation

## 3. RESULT AND DISCUSSION

### A. Qualitative Character

Table 1. Qualitative character classification of anthocyanin staining of hypocotyls, growth type of tomato plants and anthocyanin staining of the top three internodes

| Genotype | Classification of anthocyanin staining in hypocotyl | Types of growing tomato plants | Anthocyanin staining of the top three segments |
|---|---|---|---|
| T22 | Yes | *Indeterminate* | Weak |
| T23 | Yes | *Determinate* | Medium |
| T24 | Yes | *Determinate* | Strong |
| T25 | Yes | *Indeterminate* | Weak |
| T26 | Yes | *Determinate* | Medium |
| T27 | Yes | *Indeterminate* | Medium |
| Ratna | Yes | *Determinate* | Strong |
| Servo F1 | Yes | *Determinate* | Medium |

Based on Table 1. the observation of anthocyanin coloring classification characters on hypocotyls found no diversity because, in all seedlings of tomato genotypes observed, there is coloring on the hypocotyls. The color of the hypocotyls of tomato genotypes is purple and green, whereas the purple hypocotyl color appears dominantly compared to green (Rahmadani et al., 2021).

The genotypes Raya (T23), Pane tongah (T24), Alahan panjang (T26), Ratna and Servo F1 have determinate plant growth types, while the genotypes Silimakuta (T22), Purba (T25) and Magelang (T27) have indeterminate plant growth types. The characteristics of this growth type need to be considered in lowland areas with many factors that interfere with the growth of tomato plants, specifically hot temperatures, drought, and pest and disease attacks (Daryanto et al., 2020). Indeterminate tomato plants are more susceptible to high temperatures than determinate tomato accessions (Ganeva et al., 2018).

Silimakuta (T22) and Purba (T25) genotypes have weak anthocyanin coloration on the top three internodes. The genotypes Raya (T23), Alahan panjang (T26), Magelang (T27) and Servo F1 have moderate coloration, and the genotypes Pane tongah (T24) and Ratna have intense coloration.

Table 2. Qualitative characters of the location of tomato plant leaves, division of tomato plant leaflets and the location of leaflets against the main leaf bones in tomato plants

| Genotype | Location of Tomato plant leaves | Leaf blade division of tomato plants | Location of leaflets against the main leaf blade in tomato plants |
|---|---|---|---|
| T22 | Horizontal | Double pinnate | Horizontal |
| T23 | Horizontal | Double pinnate | Leaves up |
| T24 | Semi erect | Double pinnate | Leaves up |
| T25 | Semi erect | Double pinnate | Horizontal |
| T26 | Horizontal | Double pinnate | Leaves up |
| T27 | Horizontal | Double pinnate | Leaves up |
| Ratna | Semi erect | pinnate | Horizontal |
| Servo F1 | Semi erect | Double pinnate | Horizontal |

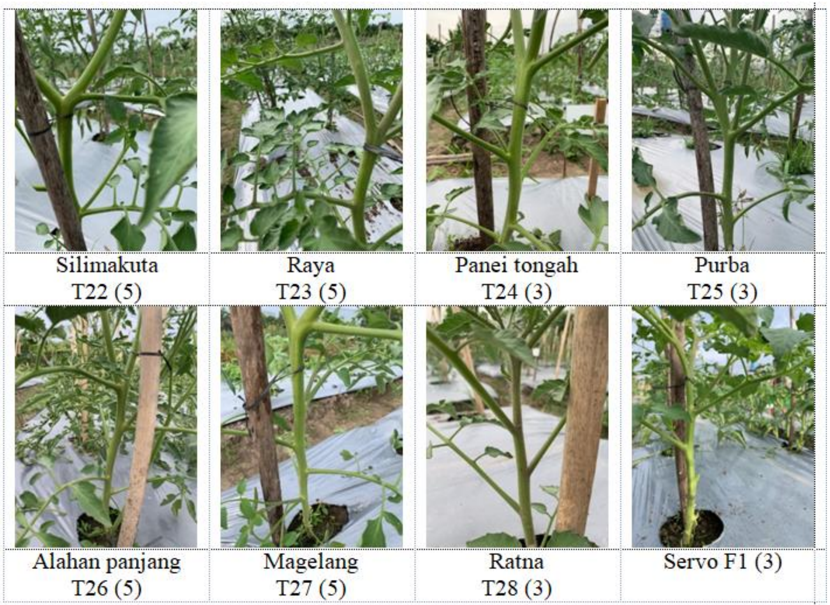


**Figure 2**. Location of tomato plant leaves

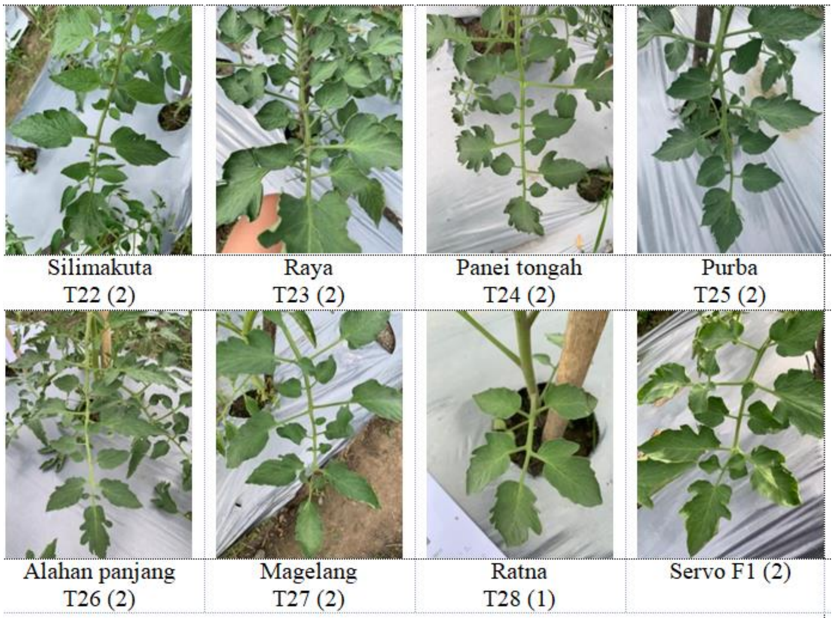


**Figure 3**. Division of tomato plant leaves

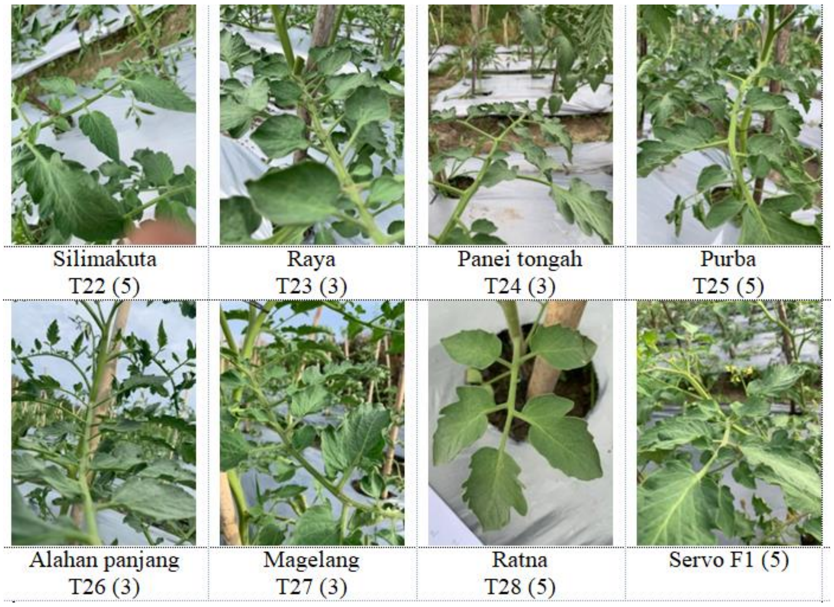


**Figure 4.** Location of leaflets against the main leaf blade in tomato plants

Based on Table 2. Attributes observations of the tomato plants' leaf position were observed in two positions, precisely horizontal, which was identified in the Silimakuta (T22), Raya (T23), Alahan Panjang (T26) and Magelang (T27) genotypes, while the leaf position was semi-erect in the Pane Tongah genotype. (T24), Purba (T25), Ratna and Servo F1.

There are two types of leaf division characters in tomato plants, specifically double pinnate leaf division in the genotypes Silimakuta (T22), Raya (T23), Pane Tongah (T24), Purba (T25), Alahan Panjang (T26), Magelang (T27) and Servo. F1. while the pinnate leaf type is found in the Ratna genotype.

The horizontal position of the leaflets on the central leaf vein is found in the Silimakuta (T22), Purba (T25), Ratna and ServoF1 genotypes. In contrast, those with upward leaflets are found in the Raya (T23), Pane tongah (T24), and Alahan Panjang genotypes. (T26) and Magelang (T27).

Table 3. Qualitative characteristics of tomato plant leaf types, the intensity of the green color of tomato plant leaves and the type of tomato plant fruit bunches

| Genotype | Types of tomato plant leaves | the green color intensity of tomato plant leaves | Types of fruit bunches of tomato plants |
|---|---|---|---|
| T22 | *Pimpinellifolium* | Medium | Mostly multiparous |
| T23 | *Potato leaf type* | Bright | Partly *uniparous* Partly *multiparous* |
| T24 | *Pimpinellifolium* | Medium | Mostly multiparous |
| T25 | *Standard* | Medium | Mostly multiparous |
| T26 | *Peruvianum* | Dark | Mostly multiparous |
| T27 | *Peruvianum* | Dark | Mostly multiparous |
| Ratna | *Peruvianum* | Dark | Mostly multiparous |
| Servo F1 | *Potato leaf type* | Medium | Mostly multiparous |

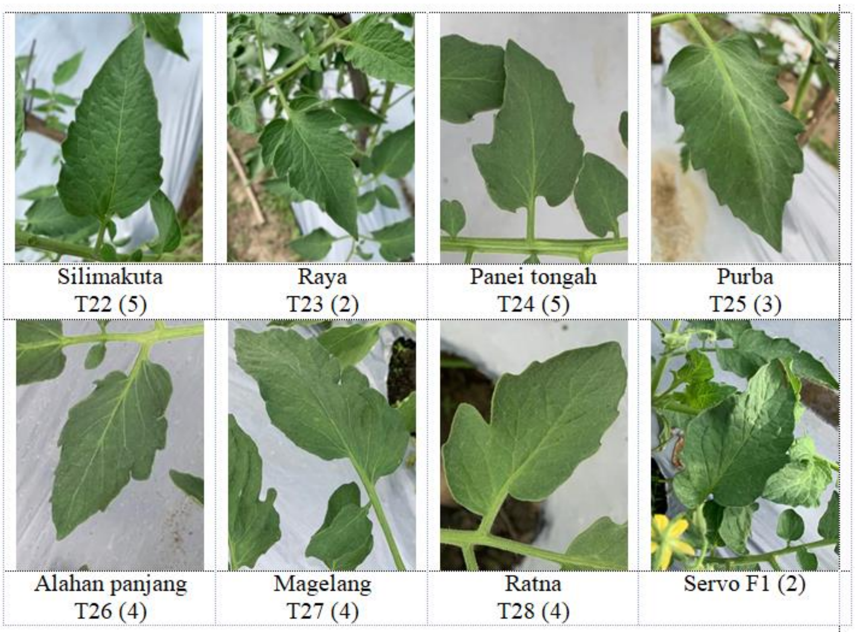


**Figure 5.** Types of tomato plant leaves

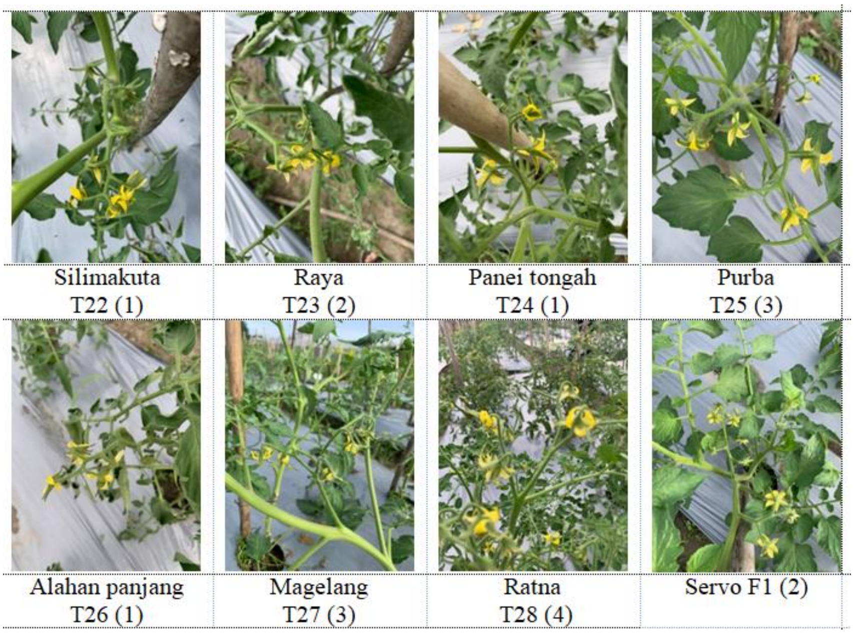


**Figure 6**. Types of fruit bunches of tomato plants

According to Table 3. tomato plants exhibit four different leaf type characters: pimpinellifolium in the Silimakuta (T22) and Pane tongah (T24) genotypes, potato leaf type in the Raya (T23) and Servo F1 genotypes, standard in the Purba genotype (T25), and peruvianum in genotypes Alahan Panjang (T26), Magelang (T27), and Ratna. The green color intensity of tomato plant leaves can be categorized into three levels: dark in the Alahan Panjang (T26), Magelang (T27), and Ratna genotypes, medium intensity in the Silimakuta (T22), Pane Tongah (T24), Purba (T25), and Servo F1 genotypes, and light intensity in the Raya genotype (T23). When observing the fruit bunch types in tomato plants, two types are identified: multiparous in the genotypes Silimakuta (T22), Pane tongah (T24), Purba (T25), Alahan Panjang (T26), Magelang (T27), Ratna, and Servo F1. while the Raya genotype (T23) exhibits both uniparous and partly multiparous types. Simple genes determine qualitative characters and are minimally influenced by the environment, thus remaining stable across different growing conditions (Reddy et al., 2017).

Table 4. Qualitative characteristics of the hairs on the pistils of tomato plants, the color of tomato plant flowers and the abscission layer on tomato fruit stalks

| Genotype | Hairs on the pistil of a tomato plant | Tomato plant flower color | Abscission layer on the stem of a tomato fruit |
|---|---|---|---|
| T22 | Yes | Yellow | Yes |
| T23 | Yes | Yellow | Yes |
| T24 | Yes | Yellow | Yes |
| T25 | Yes | Orange | Yes |
| T26 | Yes | Orange | Yes |
| T27 | Yes | Yellow | Yes |
| Ratna | Yes | Yellow | Yes |
| Servo F1 | Yes | Yellow | Yes |

Based on the data presented in Table 4. it can be observed that there is a lack of diversity in the presence of hairs on the pistils of tomato plants, as all genotypes examined exhibited this characteristic.

The flower color traits of tomato plants were found to be either yellow in genotypes Silimakuta (T22), Raya (T23), Pane Tongah (T24), Magelang (T27), Ratna, and Servo F1. or orange in genotypes Purba (T25) and Alahan long (T26). Shabira et al. (2019) noted that the development of color traits in reproductive structures is influenced by metabolic processes that rely on energy derived from food reserves.

Furthermore, there was a uniformity in the presence of the abscission layer on the tomato fruit stalk across all genotypes examined, indicating a lack of variation in this particular characteristic.

Table 5.Qualitative characteristics of tomato plant pedicel length, tomato fruit size and tomato fruit shape

| Genotype | Length of tomato plant pedicel | Size of tomatoes | Tomato fruit shape |
|---|---|---|---|
| T22 | Long | Medium | *Obovate* |
| T23 | Intermediate | Small | *Obovate* |
| T24 | Intermediate | Small | *Elliptic* |
| T25 | Intermediate | Medium | *Elliptic* |
| T26 | Long | Medium | *Obovate* |
| T27 | Long | Small | *Obovate* |
| Ratna | Short | Small | *Circular* |
| Servo F1 | Short | Small | *Elliptic* |

Based on Table 5. observations of the pedicel length of tomato plants have three dimensions, notably the length in the Silimakuta (T22), Alahan Panjang (T26) and Magelang (T27) genotypes, while in the Raya (T23), Pane Tongah (T24) and Purba (T25) genotypes. And short in the Ratna and Servo F1 genotypes. The characteristics of tomato fruit size that were observed had two sizes, specifically medium in the Silimakuta (T22), Purba (T25) and Alahan Panjang (T26) genotypes, and small in the Raya (T23), Pane Tongah (T24), Magelang (T27) genotypes. , Ratna and Servo F1. There are three shapes of tomato fruit shapes observed, specifically obovate in the Silimakuta (T22), Raya (T23), Alahan Panjang (T26) and Magelang (T27) genotypes, elliptic in the Pane Tongah (T24), Purba (T25), Servo genotypes—F1. as well as circular in the Ratna genotype.

Table 6.Qualitative characteristics of the shape of the tomato fruit in cross-section, the number of fruit cavities and the depression of the tomato fruit at the end of the fruit stalk

| Genotype | Shape the tomatoes in cross-section | Number of fruit cavities | Depression of tomato fruit at the end of the fruit stalk |
|---|---|---|---|
| T22 | Not round | Two and three | Weak |
| T23 | Round | Two and three | Weak |
| T24 | Round | Two and three | None or very weak |
| T25 | Not round | Three and four | None or very weak |
| T26 | Not round | Two and three | Weak |
| T27 | Round | Two and three | None or very weak |
| Ratna | Not round | More than four | Weak |
| Servo F1 | Round | Two and three | Weak |

According to Table 6. the cross-sectional observations of tomato fruit reveal the presence of two distinct shapes. The Raya (T23), Pane Tongah (T24), Magelang (T27), and Servo F1 genotypes exhibit a round shape, whereas the Silimakuta (T22) and Purba (T25) genotypes display non-round shapes. The Alahan Panjang (T26) and Ratna genotypes also exhibit non-round shapes. Furthermore, the Silimakuta (T22), Raya (T23), Pane Tongah (T24), Alahan Panjang (T26), Magelang (T27), and Servo F1 genotypes possess two or three fruit cavities, while the Purba (T25) genotype has three or four fruit cavities. On the other hand, the Ratna genotype showcases more than four fruit cavities. In terms of the depression character at the tip of the fruit stalk, two types were observed. The Pane Tongah (T24), Purba (T25), and Magelang (T27) genotypes exhibit either no depression or a feeble one. Conversely, the Silimakuta (T22), Raya (T23), Alahan Panjang (T26), Ratna, and Servo F1 genotypes display a weak depression.

Table 7. Qualitative characteristics of the shape of the tip of the tomato fruit, the shoulder of the tomato fruit in immature tomatoes and the width of the shoulder in green tomatoes

| Genotype | Shape the tip of the tomato | The tomato shoulders on tomatoes are not yet ripe | Shoulder width of green tomatoes |
|---|---|---|---|
| T22 | Flat tapered | Yes | Medium |
| T23 | Flat tapered | Yes | Small |
| T24 | Flat | Yes | None or very small |
| T25 | Flat | Yes | Small |
| T26 | Flat tapered | Yes | Medium |
| T27 | Flat tapered | Yes | Big |
| Ratna | Flat | Yes | None or very small |
| Servo F1 | Curved slightly flat | Yes | Medium |

Based on Table 7. observations of the shape of the tip of the tomato fruit have three shapes, specifically flat, tapered in the Silimakuta (T22), Raya (T23), Alahan Panjang (T26) and Magelang (T27) genotypes, flat shape in the Pane tongah (T24), Purba (T27) genotypes. T25) and Ratna, as well as a slightly flat curved shape in the Servo F1 genotype. The character of the fruit's shape and the fruit's tip can be used as characterizing characters in tomato plants because they are stable (Reddy et al., 2017).

The immature tomatoes from different genotypes displayed consistent characteristics in terms of shoulder size. For instance, Pane Tongah (T24) and Ratna genotypes exhibited either no shoulder area or a very small one on green tomatoes. On the other hand, Raya (T23) and Purba (T25) genotypes had a minor shoulder area, while Silimakuta (T22), Alahan Panjang (T26), and Servo F1 showed a medium-sized shoulder area. Lastly, the Magelang genotype (T27) displayed a large shoulder area.

Table 8. Qualitative characteristics of the intensity of the green color of the fruit on the shoulder of the tomato fruit and the intensity of the green color of the tomato fruit before it is ripe

| Genotype | The intensity of the green color of the fruit on the shoulder of the tomato | green color intensity of tomatoes before they are ripe | The color of ripe tomatoes | Color of tomato flesh |
|---|---|---|---|---|
| T22 | Medium | None | Orange | Orange |
| T23 | Weak | None | Red | Pink |
| T24 | None | None | Orange | Pink |
| T25 | Medium | None | Orange | Pink |
| T26 | Medium | None | Pink | Pink |
| T27 | Weak | None | Orange | Yellow |
| Ratna | None | Yes | Orange | Orange |
| Servo F1 | Weak | Yes | Orange | Yellow |

According to Table 8. tomatoes exhibit varying levels of green color intensity on their shoulders across different genotypes. Specifically, the Pane Tongah (T24) and Ratna genotypes show no green color intensity, while the Raya (T23), Magelang (T27), and Servo F1 genotypes display weak intensity. On the other hand, the Raya (T23), Magelang (T27), and Servo F1 genotypes exhibit low intensity, while the Silimakuta (T22), Purba (T25), and Alahan Panjang (T26) genotypes demonstrate moderate intensity. Interestingly, the Silimakuta (T22), Raya (T23), Pane Tongah (T24), Purba (T25), Alahan Panjang (T26), and Magelang (T27) genotypes lack green color intensity before ripening. In contrast, the Ratna and Servo F1 genotypes display green color intensity in tomatoes even before they are fully ripe.

The observation of color characteristics of ripe tomatoes reveals three colors, specifically orange in the genotypes Silimakuta (T22), Pane tongah (T24), Purba (T25), Magelang (T27), Ratna, and Servo F1. light pink in the genotype Alahan panjang (T26), and red in the genotype Raya (T23). The color characteristics of tomato flesh observed also exhibit three colors, specifically orange in the genotypes Silimakuta (T22) and Ratna, light pink in the genotype Raya (T23), Pane tongah (T24), Purba (T25), and Alahan Panjang (T26), and yellow in the genotypes Magelang (T27) and Servo F1.

## B. Principal Component Analysis

Principal component analysis (PCA) is a statistical technique commonly employed to determine a genotype's distinguishing features by quantifying each character variable's contribution (Afuape et al., 2011). Subsequently, the diversity of genotypes is visualized through a biplot diagram test (Maxisella et al., 2008). The primary objective of employing PCA is to categorize each observed genotype into distinct principal components, which possess reduced dimensions and are mutually independent, achieved by condensing a substantial number of observed characters (Saputra et al., 2014). By reducing the number of characters, PCA facilitates grouping genotypes into a smaller set of variables, and the outcomes of PCA serve as the foundation for subsequent analyses, such as cluster analysis.

Table 9. Value of the proportion of diversity of each factor

| Principal Component | Feature root value | | |
|---|---|---|---|
| | Total | % diversity | % Cumulative |
| KU 1 | 7.07 | 33.64 | 33.64 |
| KU 2 | 3.73 | 17.76 | 51.41 |
| KU 3 | 2.83 | 13.49 | 64.90 |
| KU 4 | 2.60 | 12.37 | 77.27 |
| KU 5 | 2.17 | 10.35 | 87.62 |
| KU 6 | 1.53 | 7.30 | 94.92 |
| KU 7 | 1.07 | 5.08 | 100.00 |

Note: Results from the principal component analysis method

According to Table 9. there are seven primary components with a characteristic root value exceeding 1. The cumulative percentage value has also surpassed 50% in the second primary component. Consequently, these two main components can effectively represent and account for the diversity of 51.406%. The characteristic root value plays a significant role in influencing each factor when calculating the diversity of each analyzed variable (Santoso, 2004). It is important to note that a characteristic root value greater than 1 is considered valid data for determining the number of principal components formed. Consequently, values below one can be disregarded (Bhartaya et al., 2011). This result is because a characteristic root value exceeding 1 serves as a determinant in principal component analysis and subsequently undergoes cluster analysis for further examination.

Table 1. The constituent characters of each principal component are based on the two-component feature vector values

| Character | Component | |
|---|---|---|
| | 1 | 2 |
| Types of growing tomato plants | **0.51** | **0.56** |
| Anthocyanin staining of the top three segments | -0.65 | -0.37 |
| Location of tomato plant leaves | **0.84** | -0.30 |
| Division of tomato plant leaves | **0.66** | -0.34 |
| The location of the leaflets is towards the central leaf vein | -0.40 | **0.61** |
| Types of tomato plant leaves | 0.21 | 0.35 |
| the green color intensity of tomato plant leaves | -0.06 | 0.46 |
| Types of fruit bunches of tomato plants | -0.19 | 0.45 |
| Tomato plant flower color | 0.39 | **0.51** |
| Tomato plant pedicel length | **0.94** | 0.06 |
| Size of tomatoes | **0.64** | **0.61** |
| Tomato fruit shape | **0.78** | -0.27 |
| Tomato fruit shape in cross-section | -0.33 | -0.73 |
| Number of fruit cavities | -0.60 | **0.64** |
| Depression of tomato fruit at the end of the fruit stalk | -0.06 | -0.24 |
| Shape the tip of the tomato | **0.81** | -0.07 |
| Shoulder width of green tomatoes | **0.61** | -0.10 |
| green color intensity of the fruit on the shoulder of the tomato | **0.78** | 0.34 |
| The intensity of the green color of tomatoes before they are ripe | -0.84 | 0.03 |
| The color of ripe tomatoes | 0.35 | -0.59 |
| Color of tomato flesh | 0.24 | 0.06 |

Note: A value > 0.5 is included in the character of the main component

Various characteristics shape the diversity observed in the first and second main components, as outlined in Table 10. Specifically, attributes with a vector value exceeding 0.5 are considered influential. In the first principal component, factors such as the growth pattern of the tomato plant, the positioning of the leaves, the segmentation of leaf blades, the length of the pedicel, the size and shape of the fruit, as well as the characteristics of the fruit tip, shoulder width, and green color intensity all contribute to diversity. On the other hand, the second principal component is influenced by factors including the growth pattern of the tomato plant, leaflet positioning concerning central veins, flower color, fruit size, and the number of fruit cavities.

Principal components one and two are then analyzed in biplot form to see the distribution pattern. The distribution patterns of the eight tomato genotypes tested and the groups formed from main component one and main component two are presented in Figure 1.

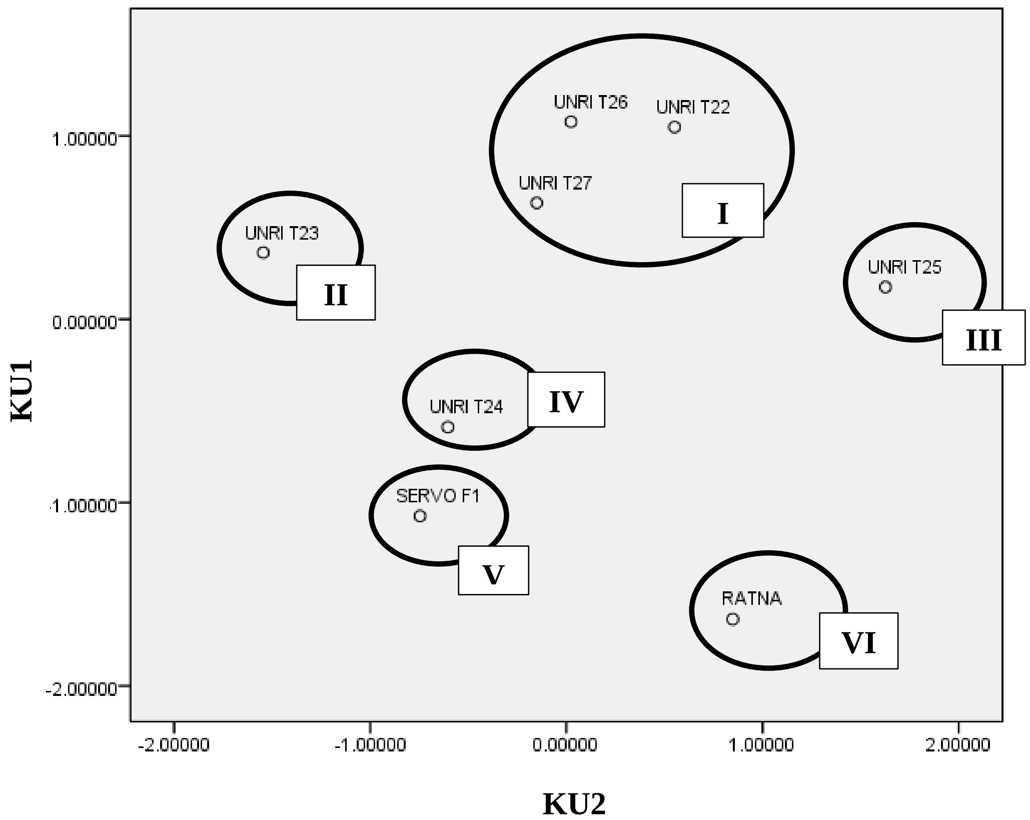


**Figure 7.** Biplot grouping eight tomato genotypes based on principal component 1 and principal component 2.

The grouping results of principal components one and two of the eight tomato genotypes tested with a diversity proportion value of 51.41% obtained six groups of tomato genotypes. In group one, there are three genotypes, notably Silimakuta (T22), Alahan panjang (T26) and Magelang (T27); group two consists of one genotype, notably Raya (T23). In group three, there is the Purba genotype (T25); in group four, there is Pane tongah (T24); in group five, there is Servo F1. In contrast, in group six, there is the Ratna genotype.

## C. Cluster Analysis

Cluster analysis is an extension of principal component analysis, represented as a dendrogram. Its objective is to categorize or cluster observational data into multiple groups or clusters, utilizing dissimilarity measures (Yunianti et al., 2007). Genotypes within the same cluster exhibit limited genetic diversity, whereas genotypes in distinct clusters display extensive genetic diversity (Deviona et al., 2023). The dendrogram in Figure 2 illustrates the outcomes of cluster analysis conducted on eight tomato genotypes.

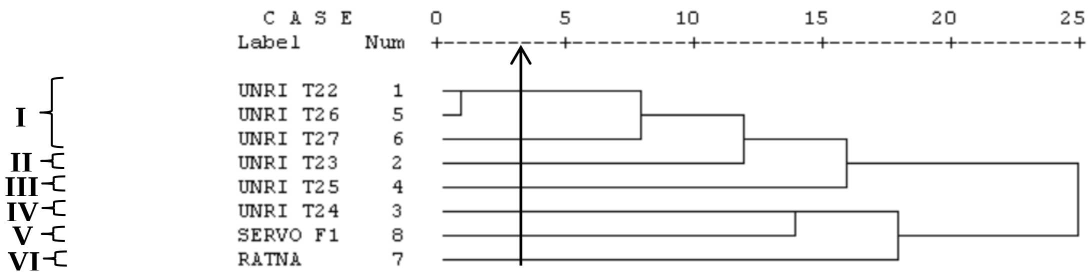


**Figure 8.** Dendrogram of grouping 16 tomato genotypes based on cluster analysis

Based on Figure 2. grouping eight tomato genotypes by cutting the dendrogram at the 90% similarity level resulted in 6 groups. Group one consists of the Silimakuta (T22), Alahan panjang (T26), and Magelang (T27) genotypes, group two contain the Raya genotype (T23), group three contains the Purba genotype (T25), group four contains the Pane tongah genotype (T24), group five contains the Servo F1 genotype, while in group six there is the Ratna genotype.

The results of the dendrogram grouping in Figure 1 are the same as those of the primary component grouping in Figure 2. Grouping in cluster analysis can determine the level of similarity between genotypes by looking at the resulting genetic distance. The similarity between objects can be measured using distance measures such as genetic distance; the closer or smaller the genetic distance between genotypes indicates the more similar the genotypes are (Mattjik and Sumertajaya., 2011).

Table 11. Genetic distance of genotypes used in the study

| Genotype | Genetic distance | | | |
|---|---|---|---|---|
| | Silimakuta (T22) | Raya (T23) | Pane tongah (T24) | Purba (T25) |
| Silimakuta (T22) | 000 | 36.180 | 44.635 | 29.833 |
| Raya (T23) | 36.180 | 000 | 33.553 | 46.239 |
| Pane tongah (T24) | 44.635 | 33.553 | 000 | 39.787 |
| Purba (T25) | 29.833 | 46.239 | 39.787 | 000 |
| Alahan panjang (T26) | 19.438 | 27.627 | 40.061 | 34.557 |
| Magelang (T27) | 24.902 | 36.628 | 37.349 | 40.611 |
| Ratna | 63.931 | 58.810 | 38.575 | 49.542 |
| Servo F1 | 50.482 | 42.173 | 35.161 | 46.755 |

| Genotype | Genetic distance | | | |
|---|---|---|---|---|
| | Alahan Panjang (T26) | Magelang (T27) | Ratna | Servo F1 |
| Silimakuta (T22) | 19.438 | 24.902 | 63.931 | 50.482 |
| Raya (T23) | 27.627 | 36.628 | 58.810 | 42.173 |
| Pane tongah (T24) | 40.061 | 37.349 | 38.575 | 35.161 |
| Purba (T25) | 34.557 | 40.611 | 49.542 | 46.755 |
| Alahan panjang (T26) | 000 | 30.968 | 63.485 | 57.245 |
| Magelang (T27) | 30.968 | 000 | 58.616 | 47.521 |
| Ratna | 63.485 | 58.616 | 000 | 41.333 |
| Servo F1 | 57.245 | 47.521 | 41.333 | 000 |

The genetic dissimilarity among tomato genotypes revealed by cluster analysis is presented in Table 11. This genetic distance metric is utilized to assess the degree of similarity between the genotypes under investigation. Notably, Silimakuta (T22) and Alahan Panjang (T26) exhibit the highest similarity, as indicated by the smallest Euclidean distance value of 19.44. placing them in the same group. Conversely, the genotypes Raya (T23) and Purba (T25) display the most remarkable dissimilarity, with an Euclidean distance of 46.24. resulting in their classification into distinct groups.

## 4. CONCLUSION

From the research that has been carried out, several things can be concluded, specifically as follows:

1. The Magelang genotype (T27) has a high average fruit weight at 619.74 g, the Pane tongah genotype (T24) has an average thick fruit flesh of 6.05 mm, the Silimakuta genotype (T22) an average average fruit size was large, specifically 63.28 g. In contrast, the Purba genotype (T25) had an average number of large fruit per crop, 15.41.
2. Grouping eight tomato genotypes based on KU1 and KU2 clustering and cutting the dendrogram at a 90% similarity level produces six groups. Group one consists of three genotypes, specifically Silimakuta (T22), Alahan Panjang (T26), and Magelang (T27). The other group consists of one genotype, precisely group two has the Raya genotype (T23), group three has the Purba genotype (T25), group four has the Pane tongah (T24) genotype, group five has the Servo F1 genotype, and group six has the Ratna genotype.
3. The closest relationship based on the smallest genetic distance value is the Silimakuta (T22) and Alahan Panjang (T26) genotypes with a value of 19.44. and the genotypes with the furthest similarity are Raya (T23) and Purba (T25) because they have a genetic distance of 46. 24.

## ACKNOWLEDGMENT

The authors would like to thank the Institute for Research and Community Service of Riau University for funding this research through a research grant from DIPA UNRI in 2023.

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