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# IDENTIFICATION OF KEY TRAITS INFLUENCING TOMATO GENOTYPE PERFORMANCE USING PRINCIPAL COMPONENT ANALYSIS

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***Abstract*** *This study examines tomato genotype variability concerning morphological and biochemical fruit attributes. The Ayub Agriculture Research Institute in Faisalabad, Pakistan has a genetic collection of tomato plants that includes experimental material. Fruit size, locule count, index of fruit form, fruit color, dry matter content, total sugar contents, total acidity, lycopene, and vitamin C content were all examined about genotypes. The key markers of variability (CV and σ) and the minimum, maximum, and mean values were computed. Using principal component analysis, the variability source structure was determined. Four main components that account for 93.74% of the overall variability were chosen for analysis. The definition of the first primary component includes vitamin C, locule number, and fruit form index. Dry matter content and overall acidity decide the second component, whereas lycopene, fruit mass, and fruit color determine the third. The most significant portion of the fourth component was made up of total sugars.*

**Keywords:** *Fruit quality; variability; physiological traits; PCA; tomatoes*

## Introduction

Tomato (*Lycopersicon esculentum* Mill., 2n = 2x = 24) is one of the most important vegetables of the Solanaceae family spread worldwide. It is flexible and can be used in many cooking and coating materials and in new salad forms. It can be processed into purees, tomato paste, ketchup, sauces, and soups. In 2013-2014, the harvest area was 4.73 million hectares, with 163,964 million tons of global production (FAOSTAT 2019). Total tomato production in Pakistan is 570,600 tons, and the cultivated area is 60,700 hectares. Pakistan's average yield per hectare is 9.4 tons, and Khyber Pakhtunkhwa is 9.9 tons, well below the world average of 36 tons per hectare (MNFSR 2014-15). In addition to the limited benefits, genetic diversity and lack of health information can complicate the selection of suitable parents for different services. Therefore, hybrids (F1s) or recombinants (selected in F1 or lineage) often do not show all varieties of genetic interest due to a limited genetic base, and parental selection is not required. This problem can only be overcome if the breeder has detailed information about the population's genetics. Tomato fruit is widely used in the human diet as fresh, ripe fruit and in different forms (Takač et al., 2007). The benefits of tomatoes for human nutrition are related to antioxidants, lycopene, and beta-carotene. Carotenoids are essential in human nutrition and immunity (Ye et al., 2000; Fatima et al., 2023). One hundred grams of edible tomatoes contains 94.1g of water, 1.0g of protein, 0.3g of fat, 0.4g of carbohydrates, 0.6g of lipids, 0.20mg of Vitamin A & Vitamin B, Vitamin C 23mg, Vitamin E 0.27mg, Biotin 0.004 mg, malic acid 150 mg, citric acid 390 mg, copper oxalate 305 mg, sodium 3 mg, potassium 268 mg, copper 10 mg, manganese 0.19 mg, phosphorus 27 mg, sulfur 11 mg, and chlorine 51 mg (Chatfield et al., 1998). In many countries, its juice is used as a substitute for orange juice for children who consume pasteurized milk. 100 g of tomatoes provide 20% and 40% of the recommended daily intake for vitamins A and C, respectively (Grierson and Kader, 1986a). Global consumption of tomatoes requires the use of high-yielding varieties and hybrids. Pursuing maximum yield and higher fruit firmness results in reduced fruit quality. Thanks to the latest medical research on the human health benefits of tomatoes, breeding strategies are aimed at increasing yields and diseases and improving the fruit's quality. Considering many cultivars' very narrow genetic range, the importance of different starting materials in breeding programs is striking. The many old varieties (aged tomatoes), wild species, and the great diversity of local people represent the importance of

seeds needed (Aliya et al., 2016; Ahsan et al., 2013; Allard, 1960; Ali et al., 2014ab; Ali et al., 2016). Authors Takač et al. (2005) emphasized the importance of this breed due to its adaptability and good fruit quality. The Institute of Field and Vegetable Crops in Novi Sad, Serbia, is dedicated to storing, inspecting, and monitoring harvested tomatoes.

Considering the background, this study was conducted with the following objectives.

1. To separate parents for pure line breeding and hybrid breeding.
2. To determine which lines would combine the best for the desired plant features.
3. To research the genetic diversity of some fruit quality criteria within that sample.

**Material and Methods:**

The experimental material consists of ten tomato genotypes (Roma, Rio Grande, Sahil, FM-9, Topsin M., Beef tomato, Cherry tomato, Moneymaker, Benlate, and 1359). A randomized complete block design is used to experiment with three replications, two rows in each, at the Ayub Agriculture Research Institute, Faisalabad, Pakistan, during the season of 2021-22. The rows-to-row distance was 1.4m, and the plants-to-plant distance was kept at 0.5m. Data were recorded for the following traits: fruit size, dry matter (total dry matter), total sugar content, total acidity, lycopene, vitamin C, locule number, and fruit index. Determine the dry matter content by drying the sample at 105°C until it is consistent. Estimate TA volume (titratable acidity) using NaOH standard solution titration. The LuffSchool method was used to calculate the sugar content. Clinical trials were conducted at the Ayub Agricultural Research Institute in Faisalabad, Pakistan. The amount of vitamin C was determined using an HPLC system (Agilent 1100, USA) equipped with a C-8 column and a DAD detector. Spectrophotometric analysis was used to determine the lycopene concentration after column chromatography separation. A mixture of Al2O3 and MgO (1:1) is activated at 400°C to form a stable phase. A mixture of hexane and methanol (9:1) was used as the mobile phase. Fundamental analysis was used to determine the origin and composition of the variation and the role of the found items in the total variation. Statistix 8.1 (StatSoft Inc. Corporation, Tulsa, USA) and MS Excel 2019 were used to analyze the data.

**Results**

In this study, as the main indicators of variation for the genotype, minimum, maximum, and average values, as well as coefficient of variation and standard difference, were calculated in Table 1.

**Table 1: Minimum, maximum, and average values for measured traits with their coefficient of variance and standard deviation.**

| GENOTYPE | FS | DM | TSC | TA | LCP | VIT. C | LN | FI |
|---|---|---|---|---|---|---|---|---|
| **G1** | 201.7 | 6.9 | 94.3 | 6.9 | 1540.9 | 842.2 | 3.4 | 0.9 |
| **G2** | 47.7 | 5.6 | 53.9 | 6.2 | 786.5 | 939.8 | 2.4 | 0.7 |
| **G3** | 66.1 | 5.5 | 81.4 | 6.4 | 1487.1 | 728.5 | 2.9 | 1.3 |
| **G4** | 56 | 6.4 | 50 | 4.6 | 990.9 | 847 | 2.3 | 1.2 |
| **G5** | 120.1 | 5.9 | 72.2 | 7.9 | 932.1 | 1022.1 | 10.8 | 0.8 |
| **G6** | 90.8 | 5.2 | 75 | 7.8 | 923.5 | 659.4 | 2.7 | 0.6 |
| **G7** | 171 | 5.9 | 72.8 | 9.2 | 340 | 799.9 | 4.4 | 0.8 |
| **G8** | 152.2 | 6.8 | 73.7 | 4.7 | 917 | 863.7 | 4.9 | 0.5 |
| **G9** | 96.6 | 6.2 | 60.5 | 4 | 1139.9 | 953.1 | 6.3 | 0.8 |
| **G10** | 126.2 | 6.1 | 51.7 | 6.7 | 1184 | 942.1 | 3.4 | 0.9 |
| **MEAN** | 112.84 | 6.05 | 68.65 | 6.44 | 1024.19 | 859.78 | 4.35 | 0.85 |
| ***MIN*** | 47.7 | 5.2 | 50 | 4 | 340 | 659.4 | 2.3 | 0.5 |
| ***MAX*** | 201.7 | 6.9 | 81.4 | 7.9 | 1540.9 | 1022.1 | 10.8 | 1.3 |
| ***CV %*** | 45.25 | 9.06 | 20.59 | 25.51 | 33.76 | 12.84 | 59.52 | 28.95 |
| **Σ** | 51.52 | 0.49 | 14.51 | 1.52 | 351.25 | 121.19 | 2.71 | 0.23 |

G1: Roma, G2: Rio Grande, G3: Sahil, G4: FM-9, G5: Topsin M., G6: Beef tomato, G7: Cherry tomato, G8: Moneymaker, G9: Benlate, G10: 1359; FS: fruit size, DM: dry matter (total dry matter), TSC: total sugar content, TS: total acidity, LCP: lycopene, VIT. C: vitamin C, LN: locule number, FI: fruit index.

Table 2 shows the contribution of the first four items, expressed as a percentage, to the total variance and the key features for defining the component. The first element accounts for around 33.05% of the overall variation. Vitamin C, the number of locules, and the index of fruit form were the three most critical characteristics in the first principal component.

***Vitamin C:*** It is known that vitamin C (ascorbic acid) plays an essential role in biochemical processes, neurotransmission, and immunity (Martinez, 1998). The high content of vitamin C in tomatoes determines

its high biological value. However, the ascorbic acid content is not constant and varies greatly depending on the environment. Among the research data, the vitamin C content varies between 659.4 and 1022.1 mg/100 g dm with a CV of
12.84%. The genotype with the highest vitamin C content is Topsin M, and the lowest is the variety beef tomato.

***Locule number:*** It affects the shape and size of the fruit. Among the genotypes analyzed, the locules ranged from 2.3 to 10.8 with a CV of 59.52%. Among the samples, the FM-9 variety with the smallest fruit had the lowest locules, while the Topsin M. variety with the flattest fruit had the highest.

***Fruit shape*** is usually calculated as the ratio of fruit length to width and is called the "fruit shape index" (Gonzalo & Van der Knaap, 2008). Medium-sized round fruits are suitable for manual harvesting, and thin fruits are suitable for mechanical harvesting. The fruit index ranges from 0.5 to 1.3, with a CV of 28.95%. Moneymaker has the lowest fruit and the flattest, ribbed fruit. Although consumers have different needs, most want round tomatoes of the same size.

The second component accounts for approximately 23.57% of the total variance. This component is defined by dry matter content and total acidity.

***Dry matter content*** is an important component of fruit quality for the canning industry and fresh consumption. The dry matter of tomatoes contains water-soluble dry matter (about 88%), mainly derived from sugars, acids, proteins, and water-soluble pectic substances (pectic acid). Water-insoluble components include cellulose, hemicellulose, pectic acid, and protopectin (Tepić et al., 2006). Tomatoes with a high dry content are very popular when processed because they can improve the quality of the finished product (De Pascale et al., 2001). The determined dry values vary between 5.2% and 6.9%, with a CV of 9.06%. The Roma and Moneymaker variety has the highest dry matter content, and the beef tomato variety has the lowest. Most of the genotypes screened had a dry matter content of 6.0%.

***Acid content:*** The acid concentration is crucial for fruit flavour and the quality of processed tomatoes. Citric, malic, and oxalic acids are the most prevalent acids in tomato fruit. The kind of tomato, its level of maturity, and the growing environment all affect how much organic acid is present in tomato fruits. Benlate had the lowest amount of acids (4 g/100 g dm), whereas cultivar Topsin M. had the greatest amount of acids (7.9 g/100 g dm).

In the examined material, the CV for this quality metric was 25.51%.

The third major component contributes 21.56% of the overall variance. Lycopene, fruit bulk, and fruit colour were the characteristics of this component that were most significant.

***Lycopene:*** Tomatoes are an important source of lycopene. Carotenoid lycopene is a natural antioxidant that is important in preventing many diseases. The inability of human cells to produce lycopene makes the tomato an important food source and, therefore important for reproduction. Lycopene-rich varieties are important for commercial and fresh consumption as consumers demand nutritious foods. The genotypes identified differed in lycopene content from 340 to 1,540.9 mg/100 g dm with a CV of 33.76%. The Roma tomato variety has the highest lycopene content, while the Cherry tomato variety has the lowest lycopene content.

***Fruit mass*** depends on many factors: variety, environment, plant type, etc. According to quality, the fruits are divided into several groups: large (120-250 gr), medium (80-120 gr), small (60-80 gr) cocktail (30-50 gr), and cherry type (10-30 gr) (Đurovka and others, 2006). Fruit size ranges from 47.7 to 201.7 grams with 42.25% CV. It should not be forgotten that this quality determines the purpose of breeding; genetic material diversity in good fruit is very important for breeding. The Roma variety had the best fruit quality and dry matter content among all the genotypes analyzed. The Rio Grande population has the lowest fruit yield.

The fourth main source explains 15.47% of the total variation; the most important is total sugar. Total sugar content and acidity are the most important factors for fruit flavor (Rodica et al., 2008). Total sugar is between 50 and 81.4 g/100 g dm with 20.59% CV. The highest sugar content is in the Sahil variety, and the lowest sugar content is in the
FM-9 variety.

**Table 2: Rotated components of nine tomato traits**

| Variable | Main components | | | |
|---|---|---|---|---|
| | **PCA 1** | **PCA2** | **PCA 3** | **PCA4** |
| **DRY MATTER** | 0.032372 | -0.8777774 | 0.58686 | -0.375758 |
| **TOTAL SUGARS** | 0.100687 | 0.47578 | -0.178682 | -0.98576 |
| **LYCOPENE** | 0.447678 | 38868 | 0.54576 | -0.70888 |
| **VITAMIN C** | -0.6437987 | -0.6868 | -0.348688 | 0.276667 |

| | | | | |
|---|---|---|---|---|
| **TOTAL ACIDITY** | -0.525431 | 0.775754 | -0.175877 | -0.87686 |
| **FRUIT SIZE** | -0.5600569 | -0.367547 | 0.6878972 | -0.397575 |
| **LOCULE NUMBER** | -0.947281 | -0.1868879 | -0.2646571 | -0.15757 |
| **FRUIT INDEX** | 0.8347653 | 0.76877 | 0.58678979 | 0.094214 |
| **EIGENVALUE** | 2.963475 | 2.54768 | 1.808764 | 1.38686 |
| **% VARIANCE** | 33.05175 | 23.57658 | 21.564655 | 15.475687 |
| **CUMULATIVE %** | 32.9347 | 56.6475 | 78.254 | 93.7456 |

**Conclusions**

Differences in morphological and biochemical characteristics were examined for all genotypes included in the analysis. The biggest differences occurred in locule number (CV 59.52%), fruit size (CV 45.25%), and lycopene content (CV 33.36%). Market-oriented varieties should be produced using different fruits according to the genotypes with dry matter and lycopene content and the harvesting method. Genotypes with sugar/acid balance, dry matter, lycopene content, and vitamin C are suitable for breeding new varieties. High dry matter, lycopene, total sugar, and vitamin C contents were detected in most genotypes. Since consumers want good tomatoes with good taste (like traditional tomatoes) and resistance to diseases, genotypes screened during production and cultivation should be used to improve fruit quality.

**Declaration**

**Conflict of interest**

The researchers affirm that there were no financial or commercial ties that might be seen as a potential conflict of interest throughout the research's execution.

**Data Availability statement**

All data generated or analyzed during the study have been included in the manuscript.

**Ethics approval and consent to participate**

These aspects are not applicable in this research.

**Consent for publication**

Not applicable

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