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Research Article

Determination Of Some Engineering, Pomological And Chemical Parameters Of The Wild Tomato (*Solanum peruvianum* and *Solanum huaylasense*) Genotypes To Be Used In Breeding Programs

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Abstract

In this study, pomological, chemical and strength parameters of three different wild tomato genotypes were determined and their potential use in further breeding programs was investigated. Experiments were conducted with Solanum peruvianum (LA2744, LA0462) and S. huaylasense (LA1982) in randomized blocks design with three replicates. Statistical analyses revealed that genotypes had significant effects on pomological and chemical properties. For strength parameters, genotypes did not have significant effects on firmness and poison ratio, but had significant effects on the other strength parameters at 1% level. It was concluded based on present findings that LA1982 was prominent for pomological properties, chemical and strength parameters and thus was considered as a significant gen source for further breeding programs.

Keywords: Force, hardness, mechanical parameter, quality, breeding

INTRODUCTION

Tomato is the most important vegetable and it is consumed as either fresh vegetable or processed tomato worldwide. According to the Food and Agriculture Organization (FAO), world annual tomato production is currently around 182 million tons from about 4.8 million hectares. China, EU, India, US and Turkey are the leading tomato producers of the world (Kabas, 2019). Besides its economic importance, nutritional values has made tomato as the leading agricultural crop worldwide. Tomato fruits are quite rich in natural antioxidants (Mohammed and Alsuhaibani, 2018). Through domestication, modern tomato varieties have been developed with all shapes, colors, sizes, increased yield performance, disease tolerance and extended shelf life. However, all these domestication efforts, little attention has been paid to qualitative traits such as taste, flavor and nutritional attributes (Dorais et al., 2008). Since the breeding programs have mostly focused on yield, disease resistance and firmness, fruit quality attributes, taste and flavor were ignored in recent years (Ballester et al., 2016; Calafiore et al., 2019). Wild genotypes are generally are native of South America and distributed from Ecuador to northern Chile. Two endemic species of the Galápagos Islands have been used in breeding programs to develop new varieties resistant to biotic and abiotic stresses (Fentik, 2017). These characteristics of agricultural products should meticulously be determined before the design of new machines to be used in various agricultural practices or before the modification of already available machines and to minimize the losses from sowing to end-use. Several researches were conducted on physical properties of seeds, vegetables and fruits such as in tomato (Reddy and Srinivas, 2017), carrot (Jahanbakhshi et al., 2018), tawain (Tulagha and Raji, 2018), green pea (Ganjloo et al., 2018), orange (Dhineshkumar and Siddharth, 2015) and onions (Yalcin and Kavuncuoglu, 2014), and nutritional properties of walnut (Mirzabe et al., 2014), garlic (Rafe and Nadjafi, 2014), hackberry (Ikinci et al., 2018), pomological properties of avocado (Bayram and Tepe, 2019), and mechanical properties of pomegranate (Jithender et al., 2017). However, there were not any studies about the determination of selection criteria for a rootstock to be used in breeding programs. Wild genotypes have powerful genetic resources, diversity, nutritional and organoleptic quality (Calafiore et al., 2019). Especially fruit quality (both nutritional and organoleptic quality) including flavor, antioxidant activity and Brix degree has become a major target in tomato breeding studies (Rahman, 2016). In this study, pomological, chemical and mechanical strength parameters of different wild tomato genotypes (Solanum peruvianum and S. huaylasense) will be determined and the best genotypes with superior strength parameters will be identified.

MATERIALS and METHODS

Solanum peruvianum (LA2744, LA0462) and *S. huaylasense* (LA1982) were grown in the greenhouse in Antalya. Tomato seeds were grown in sterile peat and vermiculite mixture as a growing medium (Figure 1). Four weeks after sowing, plants were transplanted into greenhouse. Experiments were conducted in randomized blocks design with three replications with 20 plants in each replication.

LA2744 LA0462 LA1982

Figure 1. Wild tomato (*Solanum peruvianum* and *Solanum huaylasense)* genotypes

For three genotypes, 20 fruits were collected from each replicate to evaluate soluble solids content (SSC), titratable acidity (TA) and lycopene content. The soluble solids content was measured as °Bx (brix) in the homogenized juice from ripe fruit by a refractometer. Titratable acidity was determined by diluting 5 ml of the tomato serum to 30 ml and titrating to a pH of 8.1 with 0.1 N NaOH and results were expressed in percent citric acid. Approximately 0.5 g samples were weighed from each puree into two falcon tubes that contained 5 ml of 0.05% (w/v) butylated hydroxytoluene (BHT) in acetone, 5 ml of 95% USP grade ethanol, and 10 ml of hexane. Purees were stirred on a magnetic stirring plate during sampling. Samples were extracted on an orbital shaker at 180 rpm for 15 min on ice. After shaking, 3 ml of deionized water were added to each vial and the samples were shaken for an additional 5 min on ice. The vials were then left at room temperature for 5 min to allow for phase separation. The absorbance of the upper hexane layer was measured in a 1 cm path length quartz cuvette at 503 nm blanked with hexane. The lycopene content of each sample was then estimated using the absorbance at 503 nm and the sample weight (Mirdehghanand Valero, 2017). To determine the linear dimensions and mass of wild tomato genotypes, 45 fruits were harvested from each replicate and then randomly selected for the study. Dimensions (length, widthand thickness) of wild tomato genotypes were measured by using a digital caliper (±0.01 mm). The geometric mean diameter, Dg (mm), sphericity, ϕ (%) and surface area, S (mm^2) of the samples were determined by using the following equations (Mohsenin, 1980; Kurt andArioglu, 2018) and fruit mass M (g) was measured with a precise scale (±0.001 g).

$$Dg = (LWT)^{1/3} \quad (1)$$

$$\phi = (D_g/L)x100 \quad (2)$$

$$S = \pi Dg^2 \quad (3)$$

To determine some strength properties of wild tomato genotypes in compressive tests, a texture analysis device was used with a force measurement range of 0–100 N (Figure 2). Force-deformation curves were recorded by its software during compression test and saved in the format of Excel file on attached computerfor all samples. The measurement accuracy was ±0.001 N in force and 0.001 mm in deformation. A curve-ended cylindrical probe (5 mm in diameter) was used to compress the fruit at 7 mm/min loading rate during the tests (ASAE, 1994).

Figure 2. Texture analyses device

Some strength parameters such as force, energy and deformation at rupture were determined by using these force-deformation curves. For each genotype, 45 samples were randomly selected and tested. The energy absorbed was determined directly from the chart by measuring the area under the force-deformation curves (Figure 3).

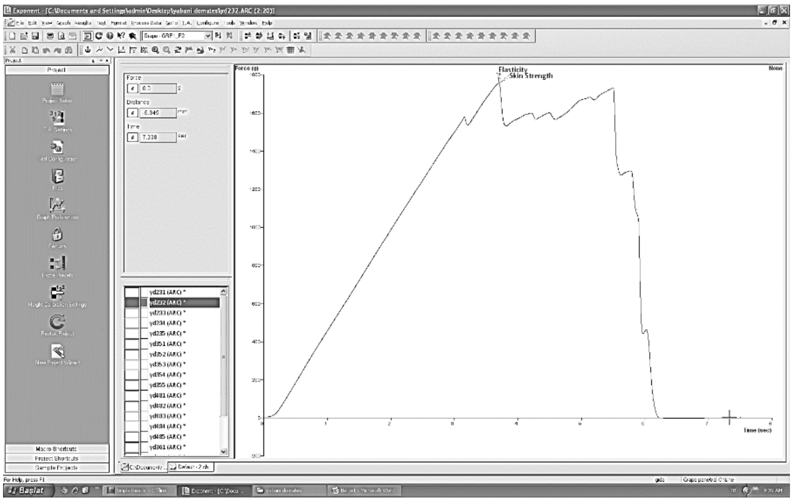

Figure 3. Force-deformation curve for wild tomatoes examples

Hardness (H – N mm^{-1}) and Poisson ratio (λ) were calculated by using the following equations (Mohsenin, 1980).

$$H=\frac{F_{max}}{D} \quad (4)$$

where:

F_{max}- maximum force in curve (N);

D - deformation at maximum force (mm)

$$\lambda = {(\Delta d|d_0)}/{(\Delta l|l_0)} \quad (5)$$

where:

d_0 - original diameter of tomato (mm);

d - diameter of tomato after compression (mm), $\Delta d = (d-d_0)$;

l_0 - original length of tomato (mm);

l_0 - length of tomato after compression (mm) $\Delta l = (l_0-l)$ (mm).

The strain (ε) and stresses σ (Nmm^{-2}) were obtained from the following expressions (Sitkei, 1986)

$$\varepsilon={\Delta L}/{L_0} \quad (6)$$

$$\sigma={F}/{A} \quad (7)$$

where:

ΔL - the compression between plates (mm);

L_0 - initial length of the tomato sample (mm);

F - force(N);

A - initial cross-section of the tomato sample (mm^2).

The modulus of elasticity *E (*Nmm^{-2}*)* of the sample was calculated by using Boussinesq techniques as follows (Mohsenin, 1980).

$$E=F(1-\nu^2)/2aD \quad (8)$$

where:

E - the modulus of elasticity in compression (N mm^{-2});

F - compressive force (N);

N - poisson ratio;

D - deformation (mm);

a - the diameter of the cylindrical probe (5 mm).

RESULTS

Total acidity, brix and lycopene content of the samples are provided in Table 1. Present findings revealed that there were significant differences in acidity, brix and lycopene content of the samples. Total acidity values of the wild tomato genotypes varied between 1.01 – 1.41 g $100ml^{-1}$ with the greatest value from LA0462 genotype. Besides sensory characteristics, acidity also plays a significant role in microbiological resistance of the fruits. Brix values of the genotypes varied between 4.17 – 6.47% with the lowest value in LA0462 genotype. Lycopene content of the genotypes varied between 0.57 – 0.75 mg kg^{-1}. The greatest value was observed in LA1982 genotype (0.75 mg kg^{-1}) and the differences in lycopene content of LA2744 and LA0462 genotypes were not found to be significant (Table 1).

Table 1. Acidity, brix and lycopene content of the genotypes

Genotype	LA1982	LA2744	LA0462	Sig. Level
Acidity % (g 100 mL^{-1})	1.014c	1.269b	1.419a	**
Brix (%)	6.47a	5.20b	4.17c	**
Lycopene (mg kg^{-1})	0.75a	0.57b	0.59b	**

*: 0,05, **: 0,01, ns: not-significant

Some pomological properties of three different wild tomato genotypes investigated in this study are provided in Table 2.

Table 2. Pomological properties of three different wild tomato genotypes

	LA1982	LA2744	LA0462	Sig. Level
Length (mm)	25.55a	17.73c	19.41b	**
Width (mm)	22.55a	15.40c	15.46b	**
Thickness (mm)	22.63a	16.27c	16.40b	**
Geo. mean diameter (mm)	23.51a	16.40c	16.97b	**
Sphericity (%)	92.00a	92.55a	87.41b	**
Surface area (mm^2)	1738.48a	846.80c	906.27b	**
Mass (g)	4.12a	3.45b	3.01c	**

*: 0,05, **: 0,01, ns: not-significant

As can be inferred from the table, genotypes had significant effects on pomological properties at 1% level. LA1982 genotype had the greatest fruit length (25.55 mm), width (22.55 mm) and thickness (22.63 mm) and LA2744 genotype had the least fruit length (17.73 mm), width (15.40 mm) and thickness (16.27 mm). With regard to mean sphericity, LA2744 genotype was prominent and the differences in sphericity of LA2744 and LA0462 genotypes were not found to be significant. In breeding studies, LA1982 could be used in breeding studies for larger tomatoes and LA2744 could be recommended in breeding studies for smaller tomatoes. Fruit strength parameters of three different wild tomato genotypes are provided in Table 3.

Table 3. Strength parameters of three different wild tomato genotypes

	LA1982	LA2744	LA0462	Sig. Level
Rupture force (N)	23.378a	19.131b	21.952a	**
Deformation (mm)	4.791a	3.561c	4.299b	**
Stress (Nmm^{-2})	1.190a	0.974b	1.118a	**
Energy (Nmm)	56.342a	34.104c	47.165b	**
Hardness (Nmm^{-1})	4.966	5.410	5.143	ns
Poisson ratio	0.285	0.291	0.284	ns
Strain (%)	6.955c	9.910a	7.852b	**
Modulus of elasticity (Nmm^{-2})	0.259a	0.220b	0.217b	**

**: 0,01, ns: not-significant

Statistical analyses revealed that except for hardness and Poisson ratio, genotypes had significant effects on strength parameters at 1% significance level. As can be inferred from the table, LA1982 was the hardest genotype with a hardness value of 23.378 N and LA2744 was the softest genotype with a hardness value of 19.131 N. Considering the other strength parameters, LA1982 had greater strength values than the other two genotypes. LA1982 was identified as the best genotype with regard to strength parameters to be used in breeding studies. Barrrett et al. (2007) conducted a study with tomatoes and reported pH values of tomato samples as between 4.32–4.70 and total acidity of tomato samples as between 0.21–0.37%. Present findings partially comply with and slightly greater than the results of earlier studies. Such differences were attributed to differences in genotypes and growing conditions. Davies and Hobson, (1981) reported dry matter content of tomato samples as between 5–9%. Barrrett et al. (2007) reported total dry matter content of tomatoes as between 5.43–7.16%. Present findings were similar with those earlier ones. Thompson et al. (2000) reported lycopene content of tomato samples as between 41–90 mg kg^{-1}fw. Abushita et al. (2000) worked on 10 different types of table and 15 different types of industrial tomatoes and reported lycopene contents as between 51.8–84.7 mg kg^{-1} for table tomatoes and between 51.4–116.1 mg kg^{-1} for industrial tomatoes. Bobinaite et al. (2009) investigated lycopene, beta carotene, ascorbic acid, color and texture of 9 different tomato genotypes and reported significant differences in carotenoid, ascorbic acid and physical properties of tomato genotypes. Researchers reported lycopene contents as between 39 - 105 mg kg^{-1}. Erba et al.(2013) experimented different nitrogen doses and different ripening levels and reported lycopene content of tomatoes as between 3.24 - 65.78 mg kg^{-1}. In another study conducted in Turkey, lycopene contents were reported as between 25.6 - 86.3 mg kg^{-1} for table tomatoes and between 24.5 - 101.8 mg kg^{-1} for cherry tomatoes (Anonymous, 2018). Present findings were similar with those earlier ones. Measurements on physical parameters of the genotypes revealed that LA1982 had the longest fruits with a fruit length of 25.55 mm and LA2744 had the shortest fruits with a fruit length of 17.73 mm. Considering the other physical parameters, except for sphericity, LA1982 was found to be prominent. With regard to sphericity values, LA2744 had the closest shape to sphere with a sphericity value of 92.55%. Effects of wild tomato genotypes on pomological properties were found to be significant at 1% significance level. Similar findings were also reported in a breeding study for a table tomato cultivar (Reddy and Srinivas, 2017). Except for firmness and poison ratio, genotypes had significant effects on strength properties. Rupture force, deformation, stress, energy, strain and modules of elasticity of the genotypes were found to be significantly different at 1% level. Li et al. (2011) indicated that strength properties varied with the varieties. There were not any previous studies about strength parameters of wild tomato genotypes.

CONCLUSIONS

Various breeding programs have been conducted on tomatoes and such programs were not able to reveal a significant genetic diversity. Therefore, cultivated tomato has a narrow genetic diversity. It is now thought that cultivated tomatoes have less than 5% genetic diversity as compared to their wild relatives (Miller andTanksley, 1990). Wild tomato species, especially self-incompatible S. chilence and S. peruvianum species have a broad genetic diversity (Rick, 1988). In order to protect and increase the diversity of tomatoes, special attention has been paid on preservation of tomato collections, cultivars and wild tomato species. Also, mutations were used to increase genetic diversity. Such a narrow genetic diversity in cultivated tomatoes has forced the breeders to start up with wild tomato germplasm as a new allelic source, thus wild germplasm has been primarily used as a source of major strengths.

In present experiments, LA1982 genotype was found to be prominent for all parameters in general, but especially for pomological and strength parameters. Therefore, LA1982 genotype was considered as a significant gen source for breeders trying to develop new highly resistant varieties.

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