

Research Article

Co-efficient of variability, correlation and path analysis of biochemical traits in tomato (*Lycopersicon esculentum* Mill) for commercial importance

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Citation

Salma Anjum, Abdul Ghafoor, Maqsood Ahmed, Abdul Hamid, Syed Zulfiqar Ali Shah, Raja Mohib Muazzam Naz and Kashif Khaqan. Co-efficient of variability, correlation and path analysis of biochemical traits in tomato (*Lycopersicon esculentum* Mill) for commercial importance. Pure and Applied Biology. Vol. 9, Issue 1, pp46-55. <http://dx.doi.org/10.19045/bspab.2020.90006>

Received: 01/06/2019

Revised: 24/08/2019

Accepted: 03/09/2019

Online First: 16/09/2019

Abstract

Systematic study on twenty genotypes of tomato was carried out to delineate potential variability by using coefficient path analysis based on biochemical traits. Both exotic lines and local genotype were examined for biochemical variation for improvement of tomato. Among these moisture content, ash, protein content, fiber, carbohydrate, total soluble solids percentage varied from 88.88-94.10, 0.20-0.64, 0.2-1.8, 0.3-1.27, 0.40-5.90, 3.70-6.60% respectively in the fruits. Maximum genotypic and phenotypic variations were found for moisture and found to be highly heritable whereas, minimum for ash content. Furthermore, genotypic coefficient of variation and phenotypic coefficient of variation values showed positive and significant association of carbohydrates with protein and fiber; however, total soluble solids directly related to ash content (0.0239). Correlation and path analysis confirmed the variability in fruit traits and superiority in fruit nutrition of the tomato germplasm that would be useful for the breeder to exploit the selection and evolution of new tomato varieties.

Keywords: Biochemical variation; Exotic lines; Germplasm; Proximate analysis; Tomato accessions

Introduction

Tomato (*Lycopersicon esculentum* Mill, $2n=2x=24$) belongs to Solanaceae family and has a valuable industry worldwide [1]. It was first introduced in Europe from Central and Southern America at the beginning of 16th century, and in 17th century the species gained popularity as an edible product spread

rapidly throughout the World [2]. Tomato crop is cultivated all over the world over an area of more than 0.5 million hectares with a production more than 7.90 million tones and now is the 2nd largest vegetable crop of the world. Total area under tomato cultivation in Pakistan is 53.4 thousand hectare with total production of 561.9 thousands tones and

average yield of 10.5 tones ha^{-1} . It is grown all over the Pakistan in different seasons and is successfully being grown in a variety of climatic conditions [3].

Tomato is an essential part of the human diet and the second-most used up vegetable after potato. Although, tomatoes are usually consumed fresh, over 80% of tomato consumption comes from processed products such as tomato juice, paste, puree, ketchup and sauce [4, 5] which showed the potential health benefits of a diet rich in tomato products. Tomato has been identified as a functional and nutraceutical food and one of the main sources of minerals, vitamins and antioxidants in many countries [6]. It is used in various forms (both fresh and processed) an important condiment in most of the diets and it is a very cheap source of vitamins [7]. Tomato fruit contains a large quantity of water (95%), protein 1.9 g, energy 23 Kcals, Fats 0.1 g, carbohydrate 3.6g, Fiber 0.7g, Vitamin A 320 IU, β -carotene 1920 mg, thiamine 0.7 mg, riboflavin 0.01 mg, niacin 0.4 mg and ascorbic acid 31 mg/100g and all these food components have great importance in the metabolic activities of human body [8]. It is also a good source of vitamins A, C and E, minerals and tomato fruit contains lycopene, which is one of the most powerful antioxidant. Epidemiological studies showed the protective role of lycopene against different types of cancers like stomach and prostate cancer [9, 10].

With the increasing need of consumers for both quality and diversity of tomato products, there is a need to extensively collect, exploit and evaluate unknown tomato germplasm. Tomato plays a key horticultural role to enhance agricultural productivity, alleviate poverty and facilitate food security [11]. Furthermore, a study on the phenotypic and genotypic correlation of the yield components and their contribution to the yield in path analysis is imperative in order to understand the genetic background and the

breeding value of the available tomatoes. In view of these, twenty genotypes of tomato were studied for their nutritional constituents to determine the degree of correlation and their direct and indirect effect on yield. Morphological, agronomic as well as biochemical traits have been widely used in the evaluation of variability in various crops [12]. Exploitation of such traits increases our knowledge of the genetic variability available and strongly facilitates breeding for wider geographic adaptability with respect to biotic and abiotic stress.

Materials and methods

Experimental design

In present study, chemical and biochemical diversity was investigated among twenty accessions of tomato. To assess variability, twenty genotypes were collected from the Institute of Agri- Biotechnology and Genetic Recourses (IABGR), National Agricultural Research Centre (NARC), Islamabad. The experimental material included one check variety (Reogrande), seventeen genotypes collected from gene bank of IABGR and two genotypes (local landraces) collected from Azad Kashmir Pakistan. Experiment was planted in the field of NARC and fruit was analyzed at Pakistan Council for Scientific and Industrial Research center (PCSIR), Peshawar. Seeds were sown on 3rd week of January and transplanted under field conditions at NARC (longitude 73° 08 east and latitude 33° 42 north with an altitude of 510 meters above sea level) during 3rd week of March for two years in Randomized Complete Block Design with three replications (Meteorological information of cropping season can be seen on Fig. 1). Each genotype were planted with 75 cm inter row spacing, whereas plant distance were kept at 50 cm. All cultural practices were done according to the need of plant [13].

Biochemical analysis

Fully ripe fruits were harvested from the field of NARC (National Agricultural Research

Centre Islamabad) and were stored in cold ice-box to avoid physio-chemical changes during transportation from field area to PCSIR (Pakistan Council of Scientific and Industrial Research) Laboratory at Peshawar for chemical analysis. Edible portion (pulp) of fruit was analyzed for following parameters with the methods described below;

Moisture content

The total moisture content was determined according to method of [14]. Two gram fruit sample was taken in a Petri dish and placed it in an oven at 130 °C for 1 hr. After 1 hr, sample was removed from oven and placed in a desiccator up to room temperature until the constant weight of sample obtained. Moisture % was calculated from weight loss.

Ash

The ash content was determined by the method of [14]. Weigh the sample was taken in a crucible and placed in open flame to start burning for removal of smoke and smell. When smoke was finished, it kept in a furnace at 600°C for three hrs. After that it was removed, kept in a dessicator and then measured. Again kept in furnace for one hr and weighed again. Ash % was calculated from weight loss.

Crude fat

Oil contents from the tomato were used for the analysis of lipid content according to the standard methods [15]. Samples were dried in an oven at 105 °C for 6-12 hrs. 10 g of dried sample was used for extraction of oil in Soxhlet apparatus (30-40 °C) for 6 hrs using petroleum ether as a solvent. The solvent was removed under vacuum and the residual oil was dried over anhydrous Na₂SO₄. Experiment was repeated three times. Analytical grade chemicals were used for extraction of oil.

Crude fiber

The crude fiber content was determined by the method of [14], 2 g sample was taken from oil extracted sample and 200 ml H₂SO₄

(0.255 N) was added. It was heated and kept for 30 mints at room temperature. The sample was filtered through a cloth and residues were collected in another beaker carefully. About 200 ml NaOH (0.313 N) was added in it and heated till boiling. Then residues were collected in crucible and placed in an oven at 130°C for 2 hrs. After drying, the sample was weighed and kept in furnace for 3 hrs at 550-600°C. The sample was weighed after ashing.

Crude protein

Protein content was estimated by Kjeldhal Method as described by [14]. The sample was weighed and transferred to the digestion flask. Two-three gram digestion mixture was added and digested with 25 ml of sulfuric acid. The flask was removed, cooled and transferred the material to the 250 ml volumetric flask and rinsed with small portion of water and then make up the volume. 50 ml material was taken and 10 ml strong alkali was added until alkaline. The material was distilled into 25 ml of 4% boric acid solution using methyl red as an indicator. Finally the material was titrated with 0.1 N H₂SO₄ solutions.

Carbohydrate

The total carbohydrate was estimated by Difference Method as described by [16].

Total soluble solid

The Ttotal soluble solids were determined according to the Association of Official Analytical Chemists [14] using a digital refractometer at room temperature. One drop of extracted juice from each sample was placed on absolutely dry refractometer prism and readings were recorded in percent (%).

Statistical analysis

The data weres expressed as means ± SD and were analyzed using the analysis of variance (ANOVA) tec hnique and differences among character means were compared by using LSD Test [17]. Variance and covariance analyses were carried out along with phenotypic, genotypic and environmental correlations with the help of computer

software following the techniques described by Singh and Chaudhary [18]. Heritability was estimated as a ratio between genotypic and phenotypic variability. Path analysis was also carried out to determine the relationship among the yield components [19].

Results and discussion

Tomato is the excellent source of nutrients and variability in their components enhance the potential for exploitation of crop improvement. In the present study, chemical composition of fruit samples of twenty accessions were analyzed which includes moisture, crude protein, fats, total soluble solids, ash and carbohydrate contents (Table 1). Food nutrients and mineral composition of various tomato cultivars were previously assessed by Thybo *et al.* [20]. The variation in the nutritive values of different varieties of tomato used in this study might be due to the environmental condition in which they are grown [21]. Water is the major component of almost all soft fruits. Rainfall and water supply during maturation stage is a limiting factor for fruits. The moisture content percentage ranged from 88.88-94.10% in fruits, collected from twenty accessions (Table 1). Significant variation in moisture percentages exhibited in all accessions ranged from 88.88 to 94.1% which may be due to variability in weather conditions and handling of fruits (transportation from point of harvesting to laboratory). Similar results were observed by Suarez *et al.* [22] who reported that tomato fruit contained 94.1% moisture.

A significant difference in ash content percentages were recorded ranged from 0.20 to 0.64% from fruit samples of tomato accessions (Table 1). Similar variation for ash percentage was also reported by Suarez *et al.* [22] who estimated ash content (0.65%) in six tomato cultivars growing in Tenerife island region. Tomato provides cheap source of nutrients to human being and protein as major component of food helps in the building up of

new cells in the body and enhances growth [21]. Our results showed significantly greater percentage of protein contents (1.8%) in fruit sample of 17869 and minimum protein content (0.20%) was determined in fruit sample of 19909 accessions as compared to other accessions (Table 1). Overall these mean values for protein content varied significantly from each other. The mean protein content obtained in this study was slightly higher than the findings of Suarez *et al.* [22] who found protein content ranged from 0.15-0.80%. This increase in protein content may be as a result of the stimulation of amino acid incorporation into proteins during fruit ripening as well as soil and environmental conditions [23]. The increase is thus an indication of high amino acid synthesis in such fruits [24]. Our results for protein content are somewhat in agreement to the data found in some food composition charts [25]. Fat is very important component of food and rarely found in fruits. In present investigation, fruits of tomato were assessed for their nutritional composition, quantity of fat content was present in fruit of tomato varied from 0.20- 0.70% among different accessions of tomato (Table 1). Range of fat content in present investigation was lower (1.61-1.18%) than the findings of Olaniyi *et al.* [21].

Results indicated that significant fiber content was 0.30% and non significant was 1.27% present in samples of tomato (Table 1). Obtained results are in line with the findings of Suarez *et al.* [22] who found that total fiber contents in tomatoes varied from 0.53-1.82 %; however, range of fiber contents were slightly higher than reported by Moreiras *et al.* [25]. Variation among present results regarding this parameter might be due to genetic factors. This hypothesis is supported by the finding of Claye *et al.* [26], who determined variation in rate (13-87 %) of fiber source in different varieties. Crude fiber content is more useful

in relieving constipation and other diseases such as carcinoma of the colon and rectum, atherosclerosis and diverticulosis [26]. It has been observed that a high incidence of colon cancer was found to be related to the lack of fiber in Western diets [27].

The mean values of total carbohydrate ranged from 0.40-5.90% (Table 1) which was slightly higher than the literature (0.3-.5%) [25]. These higher values of total carbohydrate might be due to genetic variability. The soluble solid content is a parameter determinant of fruit quality [28] and is an important criteria for selecting tomato genotypes for processing and canning. A significant difference in TSS percentages were recorded from minimum to maximum i.e. 3.70% to 6.60% from fruit samples of accessions (Table 1). Similar investigation for TSS percentage was also reported by [13] who reported TSS contents (6.5%) in fourteen tomato genotypes. Our results are also consistent with Fridman *et al.* [29] and Hossain *et al.* [30] who reported total soluble solids ranged from 4-7.4% and 4.79-6.02% respectively in tomato fruit samples in different varieties.

Maximum genetic variance was found in moisture contents followed by carbohydrates and total soluble solids. Phenotypic variation was found maximum for moisture and minimum for ash. GCV and PCV were maximum for protein contents, while it was minimum for moisture content (Table 2).

Heritability was high for most of the characters and low for fat. The character with high values of GCV and heritability suggests that improvement of these would be effective through phenotypic selection. Heritability was higher than 80% for most of the parameters showing heritable variation among genotypes (Table 2). The data from various biochemical characters were recorded and subjected to statistical analysis. The analysis of variance for six characters revealed significant differences among the genotypes for all the traits indicating the very high heritability within the genotype. Heritability and genetic advance are important selection parameters. Correlation coefficients showed associations among characteristics. It is not sufficient to describe this relationship when the causal association among characteristics is needed [31]. If there is genetic correlation between two traits direct selection of one of them will cause change in the other. When more than two variables are involved, the correlations do not give the complete picture of their interrelationships [30]. The path analysis has been used by plant breeders [32, 33] to assist in identifying traits that are useful as selection criteria to improve crop yield because it identifies the causes, measures the relative importance of the association and is used to determine the amount of direct and indirect effect of the causal components on the effect component [19].

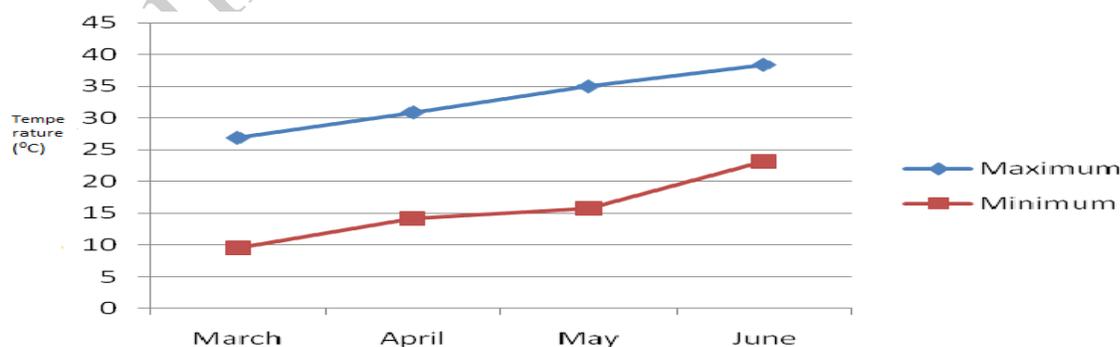


Figure 1. Meteorological information (means of maximum/minimum temperatures) of cropping season

Table 1. Mean values of biochemical traits among different accessions tomato fruit(†)

| S No. | Name of accessions | Moisture (%) | Ash (%) | Protein (%) | Crude fat (%) | Crude Fiber (%) | Carbohydrate(%) | TSS (%) |
|-------|--------------------|---------------|---------------|---------------|----------------|--------------------|------------------|--------------|
| 1 | TOM ROUND | 94.10±2.1 a | 0.50±0.01 b | 0.50±0.02 ghu | 0.34± 0.02de | 0.34±0.06 ef | 1.70±0.5 k | 5.9±0.3 b |
| 2 | 006233 | 91.92±4.2 bcd | 0.50±0.024 b | 1.20±0.1 cd | 0.60±0.03abc | 1.24±0.034 a | 5.0±1.2 bcd | 3.7±0.24 e |
| 3 | 99-sc39-20-11-24-D | 93±6.1 abc | 0.40±0.012 bc | 0.60± 0.13ghi | 0.70±0.01 a | 0.60±0.3 c-f | 3.2±0.13 ghi | 5.23±0.14 c |
| 4 | 17856 | 88.88±5.2 d | 0.50±0.026 b | 1.44±0.06 bc | 0.64±0.01 ab | 0.50± 0.2def | 4.70±1.1 cde | 6.5± 0.2a |
| 5 | 17865 | 91.20±1.2 cd | 0.40±0.03 bc | 1.0± 0.04def | 0.20±0.03 e | 1.27±0.1 a | 5.90±1.5 a | 5.40±0.13 c |
| 6 | 006231 | 92.07±4.6 bcd | 0.64±0.034 a | 1.50±0.03 abc | 0.30±0.02 de | 1.24±0.23 a | 3.90±1.1 fg | 6.60±0.23 a |
| 7 | 10585 | 93.83±5.6 abc | 0.50±0.02 b | 1.0±0.1 def | 0.64±0.04 ab | 0.60±0.12 c-f | 4.0±0.13ef | 5.40±0.31 c |
| 8 | PL64755601GL | 93.96±4.3 abc | 0.20±0.035 d | 0.74±0.04 fgh | 0.2±0.013 e | 0.30±0.004 f | 3.0±0.1 hi | 5.40±0.23 c |
| 9 | 17889 | 92.92±4.9 a-d | 0.40±0.014 bc | 1.20±0.021 cd | 0.44±0.01 bcd | 0.80±0.2 bcd | 4.30±0.12 def | 5.10±0.2 cd |
| 10 | 17903 | 93.99±3.8 ab | 0.20±0.04 d | 0.44± 0.03hij | 0.27±0.031 de | 0.77±0.1 bcd | 2.70±0.32 ij | 4.70±0.24 d |
| 11 | BARI-5 | 92.41±3.2 a-d | 0.40±0.06 bc | 1.10± 0.01de | 0.47±0.01 bcd | 0.80±0.034 bcd | 5.0±0.1 bcd | 6.40±0.21 ab |
| 12 | Walter | 93.72±4.3 abc | 0.50±0.03 b | 1.44±0.023 bc | 0.2±0.039 e | 1.00±0.009 ab | 3.20±0.20 ghi | 5.10±0.23 cd |
| 13 | 19909 | 93.24±1.4 abc | 0.50±0.032 b | 0.20±0.03 j | 0.34± 0.01de | 0.64±0.3 cde | 2.70±0.09 ij | 5.20±0.13 c |
| 14 | 10787 | 93.98±5.1 abc | 0.64±0.01 a | 1.0±0.02 def | 0.34±0.02de | 0.90±0.1 bc | 3.2±0.12 ghi | 5.10±0.87 cd |
| 15 | 17867 | 93.25±6.1 abc | 0.40±0.02 bc | 0.30±0.002 ij | 0.267±0.01 de | 1.0±0.2 ab | 3.7± 1.1fgh | 5.3±0.45 c |
| 16 | Poonch | 93.83±5.9 abc | 0.20±0.03 d | 0.80±0.03 efg | 0.44±0.012 bcd | 0.3±0.09f | 2.17±0.98 jk | 5.3±1.1 c |
| 17 | Kashmir | 93.76±4.3 abc | 0.30±0.01 c | 0.7±0.05 fgh | 0.40±0.03 cde | 0.4± 0.03ef | 0.4±0.12 | 5.3±0.2 c |
| 18 | 17869 | 91.94±4.7 bcd | 0.40± 0.02bc | 1.8±0.04 a | 0.67±0.02 ab | 1.0±0.1 ab | 4.7± 0.03cde | 5.9±0.34 b |
| 19 | Cherry tomato | 92.26±3.8 bcd | 0.64±0.01 a | 1.1±0.02 de | 0.44±0.04bcd | 0.8± 0.007bcd | 5.6±0.01 ab | 3.7± 0.98e |
| 20 | Reogrande (Check) | 92.05±2.1 bcd | 0.50±0.02 b | 1.6±0.035 ab | 0.37±0.02 de | 0.77±0.0023 bcd | 5.27±0.03 abc | 5.3±0.87 c |
| | LSD (0.05) | 4.086 | 0.0904 | 0.2858 | 0.1953 | 0.27± | 0.6703± | 0.3870± |

†Means with different letters in column are significantly different at $P < 0.05$ using LSD.
 Each value is the mean of three replicates

Genotypic correlation indicated that ash and fiber showed negative and significant association with moisture (Table 3). A negative and highly significant correlation of protein and carbohydrates with moisture, protein, fat, carbohydrates and total soluble solids showed positive relationship with ash. Fiber was positive and significantly correlated with ash content (Table 3). Correlation studies for chemical analysis of tomato have been studied by Jones and Scott [34] and Kader *et al.* [35]. Total soluble solids were negatively correlated with all other characters except ash content. Phenotypic correlation indicated that ash content and fiber content showed negative and significant correlation with moisture content. A negative and highly significant association of protein content, moisture content and carbohydrates content were at phenotypic level. Ash content was observed positively correlated with all characters. Carbohydrates content was positively and significantly correlated with protein while it was highly significant correlated with fiber content (Table 4). This correlation has been observed in other fruits such as bananas by Forster *et al.* [36].

In path coefficient analysis, six variables were included and total soluble solids were used as dependent variable. Present studies revealed that moisture has negative relation to total soluble solids at phenotypic level (-0.1708). The direct effect of said character with total soluble solids was negative (-1.338). The results indicated that direct selection via protein content (0.1525), fat content (0.1311), fiber content (0.2609) and carbohydrates content (0.6096) will be

effective (Table 5). The results regarding the direct and indirect effects for protein contents contributed negatively towards total soluble solids with a direct effect of (-0.1919) indicating no relationship between them and direct selection of this trait will be not effective. The technique of path analysis was originally proposed by Wright [37] and used by Dewey and Lu [19] in plant breeding experiments. It is simply a standardized partial regression coefficient and as such measures the influence of each variable upon the resultant variable directly as well as indirectly by portioning the genetic correlation coefficients. This would eventually provide a single selection criterion of high total soluble solids for future tomato breeding programs. Similar, type of study was also conducted by Jitendra and Devendra [38] on correlation and path analysis and revealed that fruit weight had direct effect on fruit yield. The major causes of association are either due to pleiotropic gene action or linkage or both. The phenotypic correlation includes a genotypic and environmental effect which provides information about total association between the observable characters. The phenotypic correlations were normally of genetic and environmental interaction which provided information about the association between the two characters. Genotypic correlation provide information about measure of genetic association between the characters and normally used in selection, while environmental as well as genetic architecture of a genotype plays a great role in achieving higher yield combined with better quality [38].

Table 2. Coefficients of variability for biochemical characters in tomato fruit

| Characters | Grand Mean | CV% | Error | F-value | σ_g | Σp | GCV% | PCV% | H% |
|--------------|------------|------|-------|---------|------------|------------|-------|-------|-----|
| Moisture | 91.7 | 2.2 | .60 | 30.43 | 4.28 | 4.87 | 2.21 | 2.36 | 88 |
| Ash | 0.4 | 29.3 | 0 | 95.39 | 0.016 | 0.016 | 29.32 | 29.32 | 100 |
| Protein | 1.0 | 48.2 | 0.03 | 37.70 | 0.19 | 0.215 | 44.85 | 47.23 | 91 |
| Fat | 0.4 | 37.9 | 0.08 | 11.18 | 0.02 | 0.029 | 37.30 | 44.02 | 72 |
| Fiber | 0.8 | 40.1 | 0.03 | 29.64 | 0.09 | 0.103 | 39.42 | 42.08 | 88 |
| Carbohydrate | 3.7 | 37.7 | 0.11 | 70.98 | 1.94 | 2.05 | 37.40 | 38.46 | 95 |
| TSS | 5.4 | 14.7 | 0.12 | 64.44 | 0.61 | 0.65 | 14.61 | 15.06 | 94 |

Table 3. Genotypic correlation matrix among biochemical characteristics of tomato fruit

| Variables | Moisture | Ash | Protein | Fat | Fiber | Carbohydrates |
|---------------|-----------|----------|----------|---------|-----------|---------------|
| Ash | -0.4915 * | | | | | |
| Protein | -0.794 ** | 0.3838 | | | | |
| Fat | -0.2878 | 0.1976 | 0.0481 | | | |
| Fiber | -0.5408 * | 0.4485 * | 0.4253 | -0.2503 | | |
| Carbohydrates | -0.837 ** | 0.4062 | 0.587 ** | 0.1459 | 0.6283 ** | |
| TSS | -0.1957 | 0.0055 | 0.2253 | -0.0607 | -0.1733 | -0.0811 |

Correlation marked with * are significant when probability level was ($P \leq 0.05$) and ** when probability was ($P \leq 0.01$)

Table 4. Phenotypic correlation matrix among various chemical characteristics of tomato

| Variables | Moisture | Ash | Protein | Fat | Fiber | Carbohydrates |
|---------------|------------|--------|----------|---------|-----------|---------------|
| Ash | -0.4611 * | | | | | |
| Protein | -0.6888 ** | 0.3644 | | | | |
| Fat | -0.2345 | 0.1674 | 0.0798 | | | |
| Fiber | -0.4828 * | 0.4201 | 0.3755 | -0.1774 | | |
| Carbohydrates | -0.7512 ** | 0.3951 | 0.5389 * | 0.0686 | 0.5805 ** | |
| TSS | -0.1708 | 0.0053 | 0.2015 | -0.03 | -0.1526 | -0.0787 |

Correlation marked with * are significant when probability level was ($P \leq 0.05$) and ** when probability was ($P \leq 0.01$)

Table 5. Direct (Parenthesis) and indirect effect matrix

| Variables | Moisture | Ash | Protein | Fat | Fiber | Carbohydrates | TSS |
|---------------|-----------|---------|----------|----------|-----------|---------------|---------|
| Moisture | (-1.338) | -0.0117 | 0.1525 | 0.1311 | 0.2609 | 0.6096 | -0.1957 |
| Ash | 0.6576 | (0.024) | -0.0737 | -0.0901 | -0.2164 | -0.2959 | 0.0055 |
| Protein | 1.0627 | 0.0092 | (-0.192) | -0.0219 | -0.2052 | -0.4276 | 0.2253 |
| Fat | 0.385 | 0.0047 | -0.0092 | (-0.457) | 0.1208 | -0.1063 | -0.0607 |
| Fiber | 0.7236 | 0.0107 | -0.0816 | 0.1141 | (-0.482) | -0.4576 | -0.1733 |
| Carbohydrates | 1.1198 | 0.0097 | -0.1127 | -0.0665 | -0.3031 | (-0.728) | -0.0811 |

(NOTE: Dependent variable is TSS. The last columns shows genotypic correlation of independent variables with TSS)

Conclusion

The results of present study demonstrated high phenotypic and biochemical variation among different accessions of tomato grown under similar conditions. The study also

revealed the high nutritive value of different tomato genotypes, which highlights its importance in different food industries. The results of variability, coefficient and path analysis encouraged us to exploit these

tomato genotypes through selection and breeding for economic activity to poor populations in developing countries.

Authors' contributions

Conceived and designed the experiments: A Ghafoor, M Ahmed, A Hamid & SZA Shah, Performed the experiments: S Anjum & K Khaqan, Analyzed the data: S Anjum, A Ghafoor & RMM Naz, Contributed reagents/materials/ analysis tools: M Ahmed, A Hamid & SZA Shah, Wrote the paper: S Anjum & RMM Naz.

Acknowledgements

The research was conducted at the Lab of Evaluation and Characterization of Germplasm Resources of Plants, Department of Plant Genomics and Biotechnology, NARC, Islamabad, Pakistan. The authors are grateful for the cooperation of Head of Department and lab. staff.

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