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Stability analysis in tomato (*Solanum lycopersicum* L.)

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Abstract
The experimental materials consisted of 65 entries (48 hybrids, 4 female lines, 12 testers and one standard check i.e. Arka Rakshak) were evaluated in a Randomized Complete Block Design with three replications under three artificially created environments during *kharif-rabi* season of the year 2016-17 at Main Vegetables Research Station, Anand Agricultural University, Anand to estimate stability parameters in tomato. The performance of genotypes over environments could be predicted reasonably for fruit yield per plant, number of fruits per plant, fruit weight, shelf life, total soluble sugar, lycopene content and β-carotene content, as the G × E interactions and G × E (linear) components were significant for these traits. The result on stability parameters revealed that among the hybrids, AT 3 × TBK 00113 for fruit yield per plant and fruit weight; AT 3 × ATL 11-05 for number of fruits per plant and lycopene content; AT 3 × VTG 93 for shelf life, total soluble sugar lycopene content; while, GT 2 × ATL 11-05 for shelf life and β-carotene content were found stable for varying environments.

Keywords: Stability analysis, tomato

1. Introduction

Tomato (*Solanum lycopersicum* L., 2n = 2x = 24) belongs to the family Solanaceae and ranks second in importance among vegetables. The center of origin of tomato believed to be the tropical America from Peruvian and Mexican regions (Thompson and Kelly, 1957) [23]. Tomato originated in wild form in Ecuador, Peru and Bolivia of South America (center of diversity of wild tomato). In India, it was introduced by English traders of the East India Company in 1822 (Kalloo, 1988) [12].

Tomato ranks third in priority after potato and onion in India but ranks second after potato in the world. Tomato also ranks first in the list of processed vegetables in the world as number of products are prepared from tomato *viz*., ketchup, paste, soup etc. Tomato is consumed in diverse ways, including raw, as an ingredient in many dishes of cooked vegetables, sauces, salads and drinks.

India ranks second in the area and production of tomato in the world. The area, production and productivity of tomato in India during 2016-17 were 7.97 lakh hectares, 207.08 lakh tonnes and 26.0 tonnes per hectare, respectively. Odisha, Madhya Pradesh, Karnataka, West Bengal, Andhra Pradesh, Telangana, Chhattisgarh, Bihar, Gujarat and Maharashtra were the main tomato growing states in India (NHB, 2017) [18].

Tomato cultivation has become increasingly popular since the mid-nineteenth century because of its varied climatic tolerance and high nutritive value. Tomato fruit contains different classes of antioxidants such as carotenoids (β-carotene, lycopene), phenolic compound and α-tocopherol (Vitamin E). Therefore, it is one of the most important “protective foods” for its special nutritive value (Krinsky, 1994) [13]. Tomato is also known as “poor man′s apple” due to the micronutrients existing at low concentration.

Tomato has several medicinal values, i.e. the pulp and juice of the fruit were found as mild aperients, a promoter of gastric secretions and blood purifier. Several epidemiological studies indicated beneficial effects of tomato consumption in the prevention of some major chronic diseases such as cancer and cardiovascular diseases (Giovannucci, 1999) [10]. The fruit is rich in lycopene, which may have beneficial health effects and considered as the “world′s most powerful natural antioxidant” (Jones, 1999) [11].

The awareness of consumers for nutritional security demands more varieties of higher quality; thereby tomato breeding strategies focused not only for increasing fruit yield but quality continues to be of great interest. High soluble sugar and lycopene content were highly desirable not only in processing tomato cultivars but also in fresh-market cultivars due to their important contribution to the overall flavour and nutritional value of tomatoes (Cuartero and Fernandez, 1999) [6].

The breeders have long been aware of the problems of differential response of a genotype when tested under different environments; however, they were unable to quantify the same due to complexities of environments. Genotype and its interaction with prevailing environment is considered the basic factor for determining the final yield. Expression of quantitative character depends on genotypes × environment interaction which is controlled by polygenic system and greatly modified by the environmental influences. Thus, in order to have unbiased estimates of various genetic components, the experiment should be repeated over different environments. Therefore, multilocation trials are conducted for the several years to find out stability. However, economy could also be exercised by manipulating agronomic differentials like sowing dates, plants geometry, doses of fertilizer, irrigations etc. at a single sowing location. Therefore, the present investigation was carried out to knowing the stability performance of genotypes over three environments in tomato.

2. Materials and Methods

2.1 Experimental site

The field experiment was conducted at Main Vegetables Research Station, Anand Agricultural University, Anand. Geographically, Anand is located in Agro-Climatic Zone III (Middle Gujarat) of Gujarat state and situated at 22° 35’ North latitude, 72° 55’ East latitude and an altitude of 45.01 meters above mean sea level. The soil of the experimental site is sandy loam locally known as “*Goradu Soil*” and alluvial in origin, deep, well drained and fairly moisture retentive. The climatic conditions of the area represent the tropical conditions with semi-arid region.

2.2 Experimental materials

The experimental materials were developed by crossing four lines with twelve males (testers) in a line × tester mating system during the *kharif-rabi* season of the year 2015-16 (Table 1). The F_1 seeds were produced by manual hybridization i.e. hand emasculation and pollination. In tomato crop anthesis occurs between 8 to 12 A.M., hence, well developed flower buds likely to open in next morning were emasculated and covered with white colour tissue paper bags during evening hours. On the next day morning (between 7 to 10 A.M.), pollens from different male parents were collected separately and then emasculated flower buds were pollinated by the respective pollen parent. The pollinated flower buds were again covered with red colour tissue paper bags and were labeled accordingly. Simultaneously, for the seeds of parental lines, underdeveloped flower buds of each parent were selfed and seeds were collected accordingly.

Thus, the experimental materials consisted of 65 entries comprising forty eight hybrids, four female lines and twelve male lines as testers were evaluated along with one standard hybrid (Arka Rakshak) as check during *kharif-rabi* season of the year 2016-17.

2.3 Experimental details

The experimental materials were evaluated in Randomized Complete Block Design (RCBD) with three replications under three artificially created environments i.e. Early sowing (E_1), Timely sowing (E_2) and Late sowing (E_3) using three sowing dates in same year. Experimental unit having single row of 3.6 m length accommodated 8 plants using 90 cm between and 45 cm within plant distance. For the above mentioned environments E_1, E_2 and E_3, the seedlings of 65 genotypes were raised in nursery on 15th July, 2016; 5th September, 2016 and 19th October, 2016, respectively. Then, approximately four weeks old seedlings were transplanted in the field on 16th August, 2016; 3rd October, 2016 and 17th November, 2016 for environments E_1, E_2 and E_3, respectively.

2.4 Cultural practices

The recommended package of agronomical practices and plant protection measures obligatory to raise healthy crop were followed both in nursery as well as in field.

2.5 Characters studied

The observations were recorded on five randomly selected (tagged) competitive plants of each experimental unit in each replication except days to flowering and days to first fruit ripening, as were recorded on population basis. For quality traits, the observations were recorded on randomly selected sample of fruits from each genotype. The procedure adopted for recording observations of different characters is as under.

2.6 Fruit yield per plant (kg)

The ripe red fruits harvested at every picking from the randomly tagged five plants of each experimental unit were weighed in grams and weights were added for all the pickings to get the total yield and it was averaged to obtain average fruit yield in kilograms per plant.

2.7 Days to flowering

The number of days taken from transplanting to flower initiation in 50 per cent plants of the experimental unit were recorded for each genotype in each replication.

2.8 Days to first fruit ripening

The number of days taken from transplanting to ripening of the first fruit on the selected plant of the experimental unit were recorded for each genotype in each replication.

2.9 Plant height (cm)

The length of the main stem from cotyledonary node to the terminal tip was measured in centimeters as plant height at the time of last picking for each genotype in each replication.

2.10 Number of fruits per plant

The number of ripe red fruits harvested from all the tagged five plants in each experimental unit were counted at every picking and were summed to work out average number of fruits per plant.

2.11 Fruit weight (g)

At the time of third picking, 20 fruits were taken randomly from the harvested fruits of tagged plants of each experimental unit to measure fruit weight. The fruit weight was measured in grams, it was computed as the ratio of total fruit weight to number of fruits.

2.12 Number of locules per fruit

The fruits used for measurement of fruit weight were subjected for counting the number of locules per fruit, fruits were cut transversely and locule were counted for each fruit, and then average number of locules was worked out.

2.13 Number of seeds per fruit

The fruits used for measurement of number of locules per fruit were subjected for counting the number of seeds per fruit. After seed extraction, total number of seeds of 20 fruits were counted with the help of automatic seed counter and then average number of seeds per fruit was calculated.

2.14 1000 seed weight (g)
The seeds used for counting number of seeds per fruit were subjected for measurement of 1000 seed weight in grams.

2.15 Pericarp thickness (mm)
The fruits used for measurement of fruit weight and number of locules per fruit were subjected for measurement of pericarp thickness (mm). After dissecting the fruit, pericarp thickness was measured at two places per fruit with the help of Vernier Calliper and averaged over five fruits.

2.16 Fruit firmness (N)
Fruit firmness was judged as per the method reported by Nandasana (2005) [17] using Texture Analyser TA XT2i instrument, a microprocessor analysis system developed by Stable Micro Systems England. To obtain a great amount of analytical flexibility, the texture analyser was interfaced with an IBM PC with software called 'Texture Expert' which facilitate to view the data in a graphical format, finding multiple peaks, areas and averages and saving of data on the disk. The results were read directly from the saved graphs in computer directly.
For each test a single tomato fruit of fourth picking was placed centrally on blank plate secured on the heavy duty platform. The Texture Analyser measures force, distance and time. The compression test was used to evaluate the force required to rupture the tomato fruits under quasi stable loading. At the same time, the force applied and corresponding deformations was observed from computer and results were saved on the disk. In this way this test was conducted for five tomato fruits and fruit firmness (N) were calculated averaged over five fruits.

2.17 Shelf life (Days)
At the time of third picking, five fruits were taken randomly from the harvested fruits of tagged plants of each experimental unit to measure shelf life. Shelf life was measured in days and it was observed by storing the fruits at room temperature.

2.18 Moisture content (%)
For each genotype of each replication, moisture content was estimated as per procedure developed by A.O.A.C. (1980) [3] using composite sample of ripe fruits of fourth picking, it was estimated as per cent moisture.

2.19 Total soluble solids (^{0}Brix)
Total Soluble Solids (TSS) content in the fruit pulp was measured by using Zeiss hand refractometer, the refractometer reading expressed the per cent of TSS. The trait was measured from the harvest of fourth picking, randomly selected five fruits from the harvest of each experimental unit were subjected for TSS measurement, and then average was computed.

2.20 Total soluble sugar (mg/100 g)
The character was measured from the harvest of the fourth picking of every treatment of each replication. Total soluble sugar of mature tomato fruit was determined by phenol sulphuric acid method as described by Dubois (1956) [7].

2.21 Lycopene content (mg/100 ml)
The character was measured for the harvest of the fourth picking of every treatment of each replication. Nagata and Yamashita (1992) [16] developed simple method for simultaneous determination of pigments of tomato. One grams fruit sample was taken and all the pigments were extracted with 10 ml acetone-hexane solution (4:6) at once, then optical density of the supernatant at 663, 645, 505 and 453 nm were measured by spectrophotometer at the same time. Lycopene content was calculated as

$$\text{Lycopene (mg/100 ml)} = -0.0458 \times A1 + 0.2040 \times A2 + 0.3720 \times A3 - 0.0806 \times A4$$

Where, A1, A2, A3 and A4 were absorbance at 663, 645, 505 and 453 nm, respectively.

2.22 β-carotene content (mg/100 ml)
β-carotene content was also determined simultaneously with lycopene content as described by Nagata and Yamashita (1992) [16]. β-carotene content was calculated as

$$\beta\text{-carotene (mg/100 ml)} = 0.2160 \times A1 - 1.2200 \times A2 - 0.3040 \times A3 + 0.4520 \times A4$$

Where, A1, A2, A3 and A4 were absorbance at 663, 645, 505 and 453 nm, respectively.

2.23 Statistical analysis
Phenotypic stability of a genotype for the yield and different morphological characters was estimated by regression analysis according to Eberhart and Russell (1966)[9], which provides estimates of stability parameters by calculating the regression of each variety/cross in the experiment on an environmental index, and a function of the squared deviation from this regression. According to this model, a desirable variety with good stability should have high mean (μ_i), unit regression coefficient ($b_i = 1$) and the minimum (non-significant) deviation i.e. equal to zero from regression ($S^2d_i = 0$).

3. Results and Discussion
A knowledge regarding nature and relative magnitude of genotypes × environments interaction always relevant in making decisions concerning breeding methods, selection programmes and testing procedures in crop plants (Baker, 1969) [4]. In order to minimize genotypes × environments interactions and to increase precision in selection, stratification of environments has been employed; however, even with this refinement of technique, an interaction of genotypes with environments within same year remains very large (Allard and Bradshaw, 1964) [2].

3.1 Analysis of variance for phenotypic stability
The mean squares due to genotypes and environments were highly significant for all the characters except 1000 seed weight for environments (Table 2). The values of genotypes × environments interactions were significant for fruit yield per plant, number of fruits per plant, fruit weight, shelf life, total soluble sugar, lycopene content and β-carotene content when tested against the pooled error which revealed that genotypes interacted differently with environmental variations for these characters.
The mean square due to environments + (genotypes × environments) were found highly significant for fruit yield per plant, plant height, number of fruits per plant, fruit weight, fruit firmness, shelf life, total soluble sugar, lycopene content and β-carotene content. Highly significant estimates of mean square due to environments (linear) for all the characters

except 1000 seed weight indicated that environments differed considerably among different showing dates within same year. Further, the variances due to G × E were partitioned in to components (i) G × E (linear) and (ii) G × E (non-linear) i.e. pooled deviation. The significance of genotypes × environments (linear) for fruit yield per plant, number of fruits per plant, fruit weight, fruit firmness, shelf life, total soluble sugar, lycopene content and β-carotene content indicated that all the regression coefficients were not statistically at par and the variation in the performance of genotypes was due to regression of genotypes on environmental indices, hence, performance of genotypes over environments could be predicted reasonably for these traits.

The mean squares due to G × E linear component were found non-significant for days to flowering, days to first fruit ripening, plant height, number of locules per fruit, number of seeds per fruit, 1000 seed weight, pericarp thickness, moisture content and total soluble solids which suggested that prediction of performance of genotypes over environments based on regression analysis for these characters might not be reliable.

The significance of G × E (linear) and pooled deviation for lycopene content and β-carotene content suggested that importance of both linear and non-linear components in building up total G × E interaction. The non-linear components were accounted for major portion of total G × E interaction in respect of majority of the traits except fruit yield per plant, number of fruits per plant, fruit weight, shelf life and total soluble sugar.

3.2 Environmental Indices

Environment index reveals the superiority of an environment at a particular location. Breeze (1969) [5] pointed out that the estimates of environment index can provide the basis for identifying the superior environment for the expression of the maximum potential of the genotype. The positive and negative value of environmental index indicates the superior and inferior situations, respectively, for each character.

The results of estimates of environmental index (Table 3) suggested that E_2 (Timely sowing) and E_3 (Late sowing) were the most superior and the most inferior environments, respectively, for majority of the characters under study except days to flowering, days to first fruit ripening, number of locules per fruit, number of seeds per fruit and β-carotene content. The E_1 (Early sowing) was superior for fruit yield per plant, days to flowering, days to first fruit ripening, number of fruits per plant, fruit weight, number of locules per fruit, fruit firmness, shelf life, moisture content, total soluble solids, total soluble sugar, lycopene content and β-carotene content.

3.3 Stability Parameters

The stability parameters predict the performance of a genotype for its wide adaptation. The linear component [G × E (linear)] were non-significant for the characters *viz.*, days to flowering, days to first fruit ripening, plant height, number of locules per fruit, number of seeds per fruit, 1000 seed weight, pericarp thickness, moisture content and total soluble solids which indicated absence of linear response of different genotypes to changing environments for these characters. Hence, performance of genotypes could not be predicted over environments and therefore, the estimates of the stability parameters were not calculated. In case of fruit firmness, the estimates of the stability parameters were also not calculated as the G × E linear component was significant but genotypes × environments interactions were non-significant. However, the stability parameters for parents as well as hybrids were estimated for the remaining seven characters *viz.*, fruit yield per plant, number of fruits per plant, fruit weight, shelf life, total soluble sugar, lycopene content and β-carotene content to assess the stability over the environments, because of G × E linear component was significant for these traits.

Stability parameters were worked out for seven characters, which revealed that none of the genotypes was found stable for all seven characters studied. Any generalization regarding stability of genotype for all the characters was not possible.

The stability parameters for fruit yield per plant, fruit weight and total soluble sugar revealed that none of the genotype had significant squared deviation from linear regression and thus possessed stable performance over environments (Table 4). Furthermore, 3 genotypes for number of fruits per plant; 4 genotypes for shelf life; 6 genotypes for lycopene content and 7 genotypes for β-carotene content turned out to be unstable by exhibiting significant deviation from regression (S^2d_i), Whereas, 53, 38, 52, 33, 40, 34 and 32 genotypes for fruit yield per plant, number of fruits per plant, fruit weight, shelf life, total soluble sugar, lycopene content and β-carotene content, respectively had significant regression coefficients (b_i) indicating their sensitivity to environments.

Trait wise result of parents adapted to all the environments, favourable (better conditions) and unfavourable (poor conditions) environments revealed that for fruit yield per plant, only one parent (DVRT 2) was found to be adapted to all the environments, three parents (Feb 4, PAU 2372 and ATL 97-26) were found to be better for favourable environments and two parents (H 24 and ATL 11-05) were found to be better for unfavourable conditions (Table 4). For number of fruits per plant, parent PAU 2372 was specifically adapted to all the environmental and parent ACTL 10-02 found better in favourable environmental condition. In case of fruit weight, only one (KS 118) and three parents (H 24, ATL 11-05 and NTL 14-71) were found stable for all environment and favourable environments, respectively. For shelf life, NTL 14-71 was suitable for poor environments due to significant and below unit regression coefficient with least deviation from regression. While, in case of total soluble sugar, SL 120 and PAU 2372 were found stable for all environments and ACTL 10-02 was adaptable to poor environments. For lycopene content, only one parent (ATL 11-05) was specifically adapted to better environmental condition. The parents ATL 11-05 and DVRT 2 were found adaptable to all the environmental and better environmental conditions, respectively, for β-carotene content.

Among the hybrids, two hybrids (AT 3 × TBK 00113 and AT 3 × Feb 4) for fruit yield per plant; one hybrid (AT 3 × ATL 11-05) for number of fruits per plant; three hybrids (H 24 × NTL 14-71, GT 2 × ATL 97-26 and AT 3 × TBK 00113) for fruit weight; eight hybrids (GT 2 × Feb 4, GT 2 × ATL 11-05, AT 3 × VTG 93, AT 3 × NTL 14-71, DVRT 2 × TBK 00113, DVRT 2 × DARL 66, H 24 × TBK 00113 and H 24 × VTG 93) for shelf life; four hybrids (AT 3 × VTG 93, AT 3 × SL 120, DVRT 2 × VTG 93 and DVRT 2 × SL 120) for total soluble sugar; six hybrids (AT 3 × VTG 93, AT 3 × ATL 11-05, DVRT 2 × TBK 00113, DVRT 2 × ACTL 10-02, H 24 × TBK 00113 and H 24 × ATL 11-05) for lycopene content and two hybrids (GT 2 × ATL 11-05 and H 24 × ACTL 10-02) for β-carotene content were found stable for varying environments. Out of 48 hybrids, four, three, eight, ten, seven, two and nine hybrids were found suitable for better environments for fruit yield per plant, number of fruits per plant, fruit weight, shelf life, total soluble sugar, lycopene content and β-carotene content, respectively. Whereas, 12, 7, 12, 4, 9, 2 and 3 hybrids were found adaptable for poor environments for aforesaid seven characters, respectively (Table 4).

The characterization of cross combinations having high mean, high heterosis, desirable sca effects with stability over environments is of immense value for hybrid tomato breeding programme. In the present investigation, the top ranking five hybrids H 24 × TBK 00113, H 24 × ATL 11-05, H 24 × DARL 66, DVRT 2 × ATL 11-05 and H 24 × SL 120 had high *per se* performance for fruit yield per plant and some of its component traits. Aforesaid, five hybrids were found adaptable to poor environmental condition for fruit yield per plant, of which four hybrids (H 24 × TBK 00113, H 24 × ATL 11-05, DVRT 2 × ATL 11-05 and H 24 × SL 120) were also specifically adapted poor environmental condition for both number of fruits per plant as well as fruit weight (Table 5). In general, the stability for fruit yield per plant was due to the stability of yield contributing traits i.e. number of fruits per plant and fruit weight. Hence, it would be advantageous to exploit these high yielding tomato hybrids in practical plant breeding programme after critically evaluation over the environments of locations and years.

The stability parameters measured in present study has also been reported by several workers for fruit yield per plant [Duzyaman and Vural (2002) [8], Mane (2009) [14], Thapliyal and Singh (2009) [22], Al-Aysh (2013) [1], Ummyiah *et al.* (2015) [24], Marbhal *et al*. (2016) [15], Shalini (2016) [20] and Shankar *et al*. (2017) [21]; number of fruits per plant [Al-Aysh (2013) [1], Ummyiah *et al.* (2015) [24] and Shalini (2016) [20]; fruit weight [Thapliyal and Singh (2009) [22], Al-Aysh (2013) [1], Ummyiah *et al.* (2015) [24] and Marbhal *et al*. (2016) [15] and lycopene content [Panthee *et al.* (2012)[19].

Table 1: List of parental lines used in crossing programme

Sr. No.	Name	Source
Lines		
1	GT 2	Main Vegetable Research Station, AAU, Anand
2	AT 3	Main Vegetable Research Station, AAU, Anand
3	DVRT 2	Indian Institute of Vegetable Research, Varanasi
4	H 24	Indian Institute of Vegetable Research, Varanasi
Testers		
1	TBK 00113	Main Vegetable Research Station, AAU, Anand
2	Feb 4	Indian Institute of Vegetable Research, Varanasi
3	VTG 93	Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora
4	SL 120	Main Vegetable Research Station, AAU, Anand
5	ATL 11-05	Main Vegetable Research Station, AAU, Anand
6	JTL 12-07	Vegetable Research Station, JAU, Junagadh
7	NTL 14-71	ASPEE College of Horticulture and Forestry, NAU, Navsari
8	ACTL 10-02	Main Vegetable Research Station, AAU, Anand
9	PAU 2372	Punjab Agriculture University, Ludhiana
10	DARL 66	Defence Institute of Bio-Energy Research, Pithoragarh
11	ATL 97-26	Main Vegetable Research Station, AAU, Anand
12	KS 118	Department of Vegetable Science, CSAU&T, Kanpur
Standard check		
1	Arka Rakshak	Indian Institute of Horticultural Research, Bengaluru

Table 2: Analysis of variance (mean square) for phenotypic stability for different characters in tomato

Source of variation	df	Mean Square					
		FYP	**DF**	**DFFR**	**PH**	**NFP**	**FW**
Genotypes (G)	64	1857831.09**	23.55**	47.60**	6384.98**	4150.11**	1335.50**
Environments (E)	2	3599011.35**	26.41**	158.00**	6359.06**	767.72**	1787.28**
G × E	128	17409.24*	0.85	0.79	47.38	8.17**	15.23**
E + (G × E)	130	72510.81**	1.25	3.21	144.49**	19.86**	42.50**
Environment (Linear)	1	7198374.20**	52.76**	316.07**	12718.28**	1535.19**	3574.47**
G × E (Linear)	64	32194.46**	0.78	0.72	44.25	11.84**	29.24**
Pooled Deviation	65	2578.24	0.91	0.84	49.74	4.44	1.21
Pooled Error	384	37908.24	4.77	11.18	134.15	16.08	12.05
Source of variation	df	**Mean Square**					
		NLF	NSF	TW	PT	FF	SL
Genotypes (G)	64	1.428**	1761.34**	0.9205**	3.795**	126.41**	55.27**
Environments (E)	2	0.026**	420.69**	0.0008	0.040*	414.47**	329.83**
G × E	128	0.005	5.23	0.0010	0.001	1.68	1.21**
E + (G × E)	130	0.005	11.63	0.0010	0.001	8.03**	6.26**
Environment (Linear)	1	0.052**	841.57**	0.0009	0.080**	828.97**	659.61**
G × E (Linear)	64	0.004	3.97	0.0016	0.001	2.38**	1.63**
Pooled Deviation	65	0.005	6.40	0.0004	0.001	0.97	0.77
Pooled Error	384	0.015	33.57	0.0099	0.028	4.42	1.78
Source of variation	df	**Mean Square**					
		MC	TSS	TS	LC	βC	
Genotypes (G)	64	57.65**	2.465**	833398.44**	6878.23**	4611.77**	
Environments (E)	2	31.56**	0.840**	2423397.75**	22442.46**	2438.11**	
G × E	128	0.39	0.011	6948.04**	104.71**	27.25**	

E + (G × E)	130	0.86	0.023	44124.19**	448.37**	64.34**	
Environment (Linear)	1	62.46**	1.686**	4845078.20**	44887.30**	4877.37**	
G × E (Linear)	64	0.35	0.017	12204.15**	129.95**	31.92*	
Pooled Deviation	65	0.42	0.005	1692.33	78.22**	22.21*	
Pooled Error	384	6.69	0.056	6488.96	116.89	44.69	

*, ** Significant at P = 0.05 and P = 0.01 levels of probability, respectively. FYP = Fruit yield per plant, DF = Days to flowering, DFFR = Days to first fruit ripening, PH = Plant height, NFP = Number of fruits per plant, FW = Fruit weight, NLF = Number of locules per fruit, NSF = Number of seeds per fruit, TW = 1000 seed weight, PT = Pericarp thickness, FF = Fruit firmness, SL = Shelf life, MC = Moisture content, TSS = Total soluble solids, TS = Total soluble sugar, LC = Lycopene content, βC = β-carotene content.

Table 3: Estimates of environmental index (Ij) for various characters in tomato under different environments expressed as deviation from grand mean

Sr. No.	Character	E_1	E_2	E_3
1	Fruit yield per plant	0.095	0.173	-0.268
2	Days to flowering	-0.342	0.735	-0.393
3	Days to first fruit ripening	-0.774	1.795	-1.021
4	Plant height	-1.699	10.630	-8.932
5	Number of fruits per plant	0.768	2.987	-3.756
6	Fruit weight	2.320	3.684	-6.003
7	Number of locules per fruit	-0.020	0.020	-0.001
8	Number of seeds per fruit	0.131	2.476	-2.608
9	1000 seed weight	0.001	-0.003	0.002
10	Pericarp thickness	-0.009	0.028	-0.019
11	Fruit firmness	0.699	2.102	-2.801
12	Shelf life	0.566	1.915	-2.482
13	Moisture content	-0.178	-0.587	0.765
14	Total soluble solids	0.044	0.086	-0.129
15	Total soluble sugar	0.093	0.129	-0.222
16	Lycopene content	0.009	0.012	-0.021
17	β-carotene content	0.001	-0.007	0.005

Table 4: Estimates of stability parameters for various characters in tomato

Sr. No.	Genotypes	FYP			NFP			FW		
		Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
	Lines									
1	GT 2	1.24	0.88++	-12604.97	23.89	0.63	-3.67	57.06	0.83++	-3.63
2	AT 3	1.37	1.07	-10184.03	24.14	0.63	-3.09	58.83	1.31	-4.02
3	DVRT 2	2.00	1.08	-10803.79	38.44	0.56+	-3.10	53.00	1.24++	-3.65
4	H 24	1.81	0.59++	-12319.28	26.38	0.33++	-2.26	71.83	0.75++	-4.00
	Testers									
1	TBK 00113	1.34	0.55++	-12056.52	24.29	0.42++	-5.05	59.06	0.46++	-3.99
2	Feb 4	1.98	1.16++	-11871.33	36.75	0.63	0.50	60.00	1.28	-4.02
3	VTG 93	1.25	0.54++	-6900.13	23.26	0.30++	-2.75	56.94	0.69++	-3.75
4	SL 120	1.27	0.76++	-11379.35	24.38	0.62++	-4.44	56.28	1.02	5.78
5	ATL 11-05	2.19	0.47++	-5452.41	36.97	0.69++	-5.35	63.94	0.53++	-2.79
6	JTL 12-07	1.10	0.79+	-10875.22	26.18	0.60++	-5.07	44.39	1.21++	-3.95
7	NTL 14-71	1.37	0.71++	-12558.33	18.06	0.24++	-3.50	83.50	0.55++	-2.99
8	ACTL 10-02	1.08	0.25++	-9902.85	203.97	4.89++	-1.68	4.44	0.06++	-3.73
9	PAU 2372	1.80	1.32++	-12625.10	41.68	1.12	-5.09	45.11	0.86++	-3.89
10	DARL 66	1.45	0.59+	-3549.50	33.86	0.48	-0.69	43.89	0.75+	-2.91
11	ATL 97-26	1.90	1.38++	-11568.47	35.97	0.79++	-5.34	56.06	1.10++	-3.89
12	KS 118	1.51	1.13	-263.32	27.31	0.47+	-2.94	60.17	1.21	1.03
	Hybrids									
1	GT 2 × TBK 00113	1.68	1.03	-7998.69	42.08	0.78	25.81*	46.39	1.25+	-2.39
2	GT 2 × Feb 4	1.36	0.95	3105.31	26.31	0.99	-1.95	57.17	1.13	-2.39
3	GT 2 × VTG 93	1.41	1.39++	-11408.40	25.53	1.39+	-3.72	61.56	1.51	-4.01
4	GT 2 × SL 120	0.79	0.60	-2685.32	17.97	0.91	-1.07	51.22	0.68++	-3.85
5	GT 2 × ATL 11-05	1.62	0.39++	-9526.65	30.26	0.89	-5.08	58.44	0.30++	-3.98
6	GT 2 × JTL 12-07	0.95	0.87	-10631.57	28.22	1.39	8.65	34.44	0.69++	-3.75
7	GT 2 × NTL 14-71	1.49	0.65++	-9877.82	22.67	0.50++	-5.26	76.50	0.37++	-3.79
8	GT 2 × ACTL 10-02	1.09	0.18++	-10639.46	129.68	1.45	38.25**	7.11	0.11++	-3.78
9	GT 2 × PAU 2372	1.20	0.55++	-12351.67	28.81	0.39+	-2.67	42.78	0.77++	-3.92
10	GT 2 × DARL 66	1.14	1.21++	-12620.48	21.75	1.10	-4.88	57.72	1.58++	-3.67
11	GT 2 × ATL 97-26	2.08	0.83++	-12439.40	32.47	0.76++	-5.07	69.83	0.88	-0.30
12	GT 2 × KS 118	1.32	1.35++	-10350.70	28.61	1.55++	-4.57	49.83	1.43++	-3.27
13	AT 3 × TBK 00113	2.36	0.97	-12508.54	40.88	0.77++	-5.02	62.06	0.96	-3.88
14	AT 3 × Feb 4	2.52	0.96	-10118.88	44.72	0.70+	-4.56	59.39	0.33++	-3.62
15	AT 3 × VTG 93	2.34	0.86++	-12215.80	42.50	0.69	1.87	59.00	0.66++	-2.21

16	AT 3 × SL 120	1.50	1.48++	-10982.54	27.76	1.77++	-4.97	57.22	1.08	-3.08
17	AT 3 × ATL 11-05	2.90	0.40++	-11589.97	46.43	0.73	0.54	68.06	0.27++	-3.54
18	AT 3 × JTL 12-07	1.10	1.51++	-12076.48	25.83	1.46++	-4.07	41.94	1.45++	-3.64
19	AT 3 × NTL 14-71	1.41	0.98	-10187.44	22.32	0.57++	-4.14	73.39	0.65++	-3.99
20	AT 3 × ACTL 10-02	1.10	0.37++	-10715.09	131.57	2.04++	-4.67	9.50	0.26++	-3.90
21	AT 3 × PAU 2372	0.80	0.90++	-12413.48	22.83	1.21	-3.28	36.72	0.99	-2.29
22	AT 3 × DARL 66	0.97	1.67++	-12554.04	18.40	1.71++	-5.24	57.44	1.95++	-3.13
23	AT 3 × ATL 97-26	1.37	1.40++	-12470.34	31.92	0.89	3.40	48.22	1.44++	-3.69
24	AT 3 × KS 118	1.90	2.31++	-2216.17	31.31	1.45	-1.76	66.44	1.88++	4.40
25	DVRT 2 × TBK 00113	3.10	0.43++	-11661.74	50.56	0.62+	-4.19	67.11	0.31++	-3.22
26	DVRT 2 × Feb 4	2.77	0.46++	-11287.39	47.51	0.39	0.22	61.61	0.30++	-3.84
27	DVRT 2 × VTG 93	1.39	2.17++	-12012.95	16.89	1.21	-3.62	90.11	3.05++	-2.32
28	DVRT 2 × SL 120	1.61	2.16++	-11832.13	26.11	1.37++	-5.26	66.89	2.22++	-3.64
29	DVRT 2 × ATL 11-05	3.65	0.31++	-10912.77	53.63	0.48++	-4.51	72.39	0.32++	-2.71
30	DVRT 2 × JTL 12-07	1.02	1.43++	-11185.31	18.06	0.89	-5.10	60.78	2.97++	-2.23
31	DVRT 2 × NTL 14-71	2.64	1.35++	-11457.49	31.93	1.02	-3.79	95.61	0.69++	-3.94
32	DVRT 2 × ACTL 10-02	1.28	0.45+	-2220.16	189.67	2.48++	0.50	8.22	0.25++	-3.51
33	DVRT 2 × PAU 2372	1.27	0.91	-10136.89	26.29	1.55	-1.33	52.39	0.46++	-3.64
34	DVRT 2 × DARL 66	1.81	1.70++	-12192.62	27.89	1.42++	-5.22	69.28	1.13	-4.01
35	DVRT 2 × ATL 97-26	2.08	0.33++	-12337.26	31.92	0.43	-5.36	70.22	0.43++	-1.44
36	DVRT 2 × KS 118	1.48	1.71++	-12272.88	28.33	1.41	-0.60	54.50	1.80++	-2.80
37	H 24 × TBK 00113	3.90	0.55++	-11688.80	46.24	0.56++	-5.30	95.89	0.41++	-3.20
38	H 24 × Feb 4	1.06	1.64++	-12631.14	17.53	1.21++	-5.35	66.72	2.43++	-1.69
39	H 24 × VTG 93	1.08	2.10++	-3693.20	14.68	0.99	-1.16	87.67	2.81++	2.83
40	H 24 × SL 120	3.65	0.66++	-12223.02	45.46	0.52++	-5.11	85.56	0.44++	-3.44
41	H 24 × ATL 11-05	3.86	0.36++	-11876.65	46.64	0.43++	-5.35	97.22	0.36++	-3.10
42	H 24 × JTL 12-07	1.40	1.47++	-12092.95	22.79	0.57+	-3.99	67.17	2.65++	-3.56
43	H 24 × NTL 14-71	1.47	1.39++	-12356.51	16.64	0.20++	-4.90	101.61	0.57	3.69
44	H 24 × ACTL 10-02	1.46	0.79	-593.84	150.28	2.16	77.07**	10.11	0.23++	-2.85
45	H 24 × PAU 2372	2.69	0.60+	-6684.44	38.56	0.71	-0.03	74.44	0.56++	-3.74
46	H 24 × DARL 66	3.75	0.46++	-12631.33	43.78	0.48++	-5.31	93.39	0.57	-4.01
47	H 24 × ATL 97-26	2.69	1.23++	-11949.50	50.79	1.39++	-4.95	56.00	0.66++	-2.71
48	H 24 × KS 118	1.65	2.37++	-10867.31	26.67	1.87++	-4.63	64.83	2.32++	-3.33
Check										
1	Arka Rakshak	2.25	0.87++	-12573.06	31.51	0.89++	-5.34	78.94	0.64++	-3.90
Population Mean		1.79			41.03			59.62		
S. Em. ±		0.08			1.65			2.25		

Sr. No.	Genotypes	SL			TS			LC			βC		
		Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
Lines													
1	GT 2	10.53	0.80	-0.59	2.81	0.90	-55.23	0.12	0.46	87.81	0.06	0.73	24.01
2	AT 3	9.13	0.69	1.46	3.28	0.88	-1419.49	0.18	0.63+	-4.30	0.06	0.33++	-13.57
3	DVRT 2	9.09	0.70+	-0.18	3.09	0.75++	-1729.01	0.16	0.91	-4.87	0.09	1.72++	-14.84
4	H 24	10.93	1.04	-0.57	2.90	0.92	-1274.34	0.15	0.57++	-30.96	0.06	1.15+	-14.35
Testers													
1	TBK 00113	10.64	0.42+	0.64	2.54	1.23++	-1989.92	0.13	0.69	103.72	0.06	1.17	17.06
2	Feb 4	8.71	0.56	0.51	3.13	0.85++	-1730.65	0.12	0.64++	-20.28	0.06	1.23++	-14.88
3	VTG 93	11.07	0.81	-0.26	3.23	1.10	-104.96	0.19	0.64++	-14.85	0.07	1.74+	2.98
4	SL 120	12.96	0.86	-0.07	3.57	0.98	3341.07	0.14	0.87++	-38.09	0.04	0.96	-9.99
5	ATL 11-05	10.60	0.80++	-0.58	2.74	0.67	-2173.38	0.24	1.17++	-37.95	0.15	0.88	-8.09
6	JTL 12-07	9.98	1.29	0.19	2.76	1.29++	-2117.15	0.15	0.47	66.99	0.06	0.29++	-5.69
7	NTL 14-71	13.40	0.47++	-0.15	2.99	0.63++	131.80	0.13	0.57++	-34.92	0.07	0.93	-11.00
8	ACTL 10-02	7.84	0.57++	-0.58	5.10	0.44+	5748.54	0.74	1.91	334.88**	0.18	0.98	43.88
9	PAU 2372	11.64	1.57++	-0.34	3.46	0.80	4877.66	0.12	0.81++	-36.76	0.06	1.71++	-14.74
10	DARL 66	7.47	0.33	2.86*	3.09	1.17++	-2123.12	0.15	0.97	-37.59	0.09	1.40	14.43
11	ATL 97-26	9.84	0.90	0.72	2.56	1.11++	-2141.29	0.11	0.81++	-35.62	0.05	0.84	-8.16
12	KS 118	9.76	1.13+	-0.53	2.95	1.08++	-2069.93	0.14	1.05	47.85	0.08	2.77++	-12.59
Hybrids													
1	GT 2 × TBK 00113	10.69	1.43+	0.03	3.27	1.34++	-2010.63	0.24	1.73++	62.72	0.12	1.70++	-7.34
2	GT 2 × Feb 4	13.76	1.09	-0.39	3.33	1.36++	-1792.37	0.17	1.09++	-38.42	0.09	1.36+	-10.98
3	GT 2 × VTG 93	16.18	1.39++	-0.51	3.46	1.33+	295.04	0.14	1.05	80.11	0.07	1.43++	-10.77
4	GT 2 × SL 120	10.02	1.51++	-0.27	3.43	0.85	-2182.80	0.14	1.26	3.04	0.08	1.52++	-13.38
5	GT 2 × ATL 11-05	17.31	0.57	0.87	2.79	0.75++	-1975.62	0.28	1.44++	-37.86	0.16	1.06	-14.00
6	GT 2 × JTL 12-07	9.11	1.20++	-0.53	2.74	1.41	6315.73	0.11	1.77++	-34.78	0.08	2.41	67.06*
7	GT 2 × NTL 14-71	14.78	0.47+	0.65	2.79	1.02	-1488.62	0.14	0.91+	-36.92	0.08	0.95	-10.89
8	GT 2 × ACTL 10-02	10.18	0.83++	-0.56	4.55	1.28++	-1474.38	0.73	2.34	793.61**	0.19	0.37	64.13*
9	GT 2 × PAU 2372	16.53	1.56++	-0.22	3.40	1.24+	-207.54	0.10	0.37	139.07	0.06	0.65	31.92
10	GT 2 × DARL 66	10.58	1.07	0.22	3.18	1.25++	-2137.06	0.17	0.76++	-35.76	0.12	1.64+	-1.26

11	GT 2 × ATL 97-26	20.00	1.99++	-0.26	2.58	1.26++	-2112.80	0.12	1.17	185.45*	0.08	1.23	-9.46
12	GT 2 × KS 118	12.87	1.15++	-0.54	3.21	1.68++	-911.42	0.13	0.75++	-38.95	0.05	1.38++	-14.87
13	AT 3 × TBK 00113	14.47	0.94	-0.60	3.39	0.80	-2170.58	0.11	0.50++	-3.96	0.05	1.69+	-0.64
14	AT 3 × Feb 4	15.89	1.62++	0.12	3.30	0.77++	-1251.42	0.15	0.87++	-36.93	0.07	0.28	18.26
15	AT 3 × VTG 93	16.42	0.90	-0.53	3.45	1.10	-1593.48	0.22	1.09	-16.01	0.12	1.58++	-8.58
16	AT 3 × SL 120	11.56	1.11	-0.33	3.47	1.27	3711.68	0.17	1.19++	-36.71	0.06	0.72	-3.02
17	AT 3 × ATL 11-05	16.20	1.06++	-0.59	3.71	0.54++	-1582.26	0.29	0.63	14.63	0.14	0.49++	-14.13
18	AT 3 × JTL 12-07	9.84	1.28+	-0.30	2.86	1.09+	-1953.36	0.13	1.38	93.39	0.09	1.51+	-7.75
19	AT 3 × NTL 14-71	24.69	1.06	-0.52	3.29	1.66++	-1884.14	0.20	0.87	27.13	0.10	0.57++	-14.80
20	AT 3 × ACTL 10-02	8.82	0.71++	-0.55	4.08	0.59+	4207.10	0.78	1.68	322.90**	0.18	-0.07+	27.52
21	AT 3 × PAU 2372	13.80	1.34++	-0.51	3.43	1.23++	-2058.64	0.14	1.71++	-2.13	0.06	1.03	-13.70
22	AT 3 × DARL 66	9.67	1.19++	-0.57	3.05	0.87	5592.68	0.20	1.27	278.39**	0.06	-0.10+	23.93
23	AT 3 × ATL 97-26	9.51	1.12	0.62	2.88	1.14	-589.80	0.15	1.35	88.86	0.08	0.75	18.56
24	AT 3 × KS 118	15.11	1.04	2.94*	3.96	0.71++	-2152.18	0.19	0.45++	-6.87	0.11	-0.53	123.46**
25	DVRT 2 × TBK 00113	23.78	1.09	-0.54	4.46	0.50++	-115.86	0.28	0.69	17.40	0.14	1.16++	-14.71
26	DVRT 2 × Feb 4	9.87	1.02	2.01	3.69	1.15++	-2008.00	0.17	0.48	73.50	0.08	1.28++	-14.82
27	DVRT 2 × VTG 93	9.89	0.48	0.85	3.62	1.00	-1804.79	0.16	1.41	35.75	0.07	0.61	79.35*
28	DVRT 2 × SL 120	15.84	2.05++	0.43	3.48	1.17	870.02	0.14	0.76++	-35.27	0.10	1.66+	-3.06
29	DVRT 2 × ATL 11-05	12.93	1.04	-0.57	3.56	0.28++	-2143.58	0.29	0.66++	-34.61	0.15	0.28	50.13
30	DVRT 2 × JTL 12-07	13.27	1.35++	-0.45	2.96	2.00++	969.60	0.15	1.38	96.51	0.09	2.50+	57.41
31	DVRT 2 × NTL 14-71	16.13	0.69+	-0.24	3.36	0.92	-2189.04	0.16	0.84	134.07	0.08	0.42++	-11.47
32	DVRT 2 × ACTL 10-02	8.33	0.36++	-0.14	3.85	0.60++	-1556.80	0.47	1.19	87.62	0.18	1.57++	-12.82
33	DVRT 2 × PAU 2372	10.07	0.78	5.45**	3.20	0.89	1756.90	0.15	0.56++	-2.97	0.05	0.70	6.28
34	DVRT 2 × DARL 66	14.04	0.92	-0.38	3.10	1.02	-396.58	0.13	1.04	69.31	0.07	0.70	96.55*
35	DVRT 2 × ATL 97-26	8.64	0.62	1.00	3.27	0.41++	-1134.77	0.22	0.81++	-35.52	0.07	1.25++	-14.10
36	DVRT 2 × KS 118	15.02	1.41+	0.15	3.43	1.42++	-2115.60	0.18	1.45++	-26.96	0.05	0.85	-13.31
37	H 24 × TBK 00113	23.00	0.83	-0.34	3.73	0.36++	-1952.10	0.25	0.88	39.87	0.11	-0.37	59.81*
38	H 24 × Feb 4	9.82	1.26++	-0.57	3.13	0.79+	-482.50	0.17	0.64+	-8.98	0.06	0.78+	-13.35
39	H 24 × VTG 93	15.53	0.81	-0.26	2.41	1.49++	-1362.13	0.19	1.76++	-38.03	0.10	1.56+	-6.90
40	H 24 × SL 120	23.64	0.55++	-0.31	3.61	0.44	-2174.97	0.17	0.55++	-38.95	0.08	1.10	13.57
41	H 24 × ATL 11-05	16.44	0.47++	-0.52	4.03	0.30++	-1098.80	0.26	1.12	-12.49	0.11	0.53	33.11
42	H 24 × JTL 12-07	9.20	1.22+	-0.45	2.45	1.59++	4245.78	0.13	1.20++	-38.68	0.06	-0.45++	-14.78
43	H 24 × NTL 14-71	24.18	0.61	1.40	3.10	0.47++	530.30	0.16	0.23+	87.29	0.07	1.02	-7.65
44	H 24 × ACTL 10-02	10.16	0.82	-0.22	4.83	0.74	-2177.06	0.74	1.81	223.62*	0.20	0.90	-6.92
45	H 24 × PAU 2372	18.04	0.68	2.62*	3.48	0.30++	-1254.72	0.12	0.80++	-33.19	0.05	1.28++	-14.71
46	H 24 × DARL 66	8.91	0.77	2.15	3.10	1.07	-2179.21	0.18	1.12++	-37.61	0.08	0.84	-9.51
47	H 24 × ATL 97-26	11.87	1.48++	-0.31	3.06	2.00++	6426.38	0.17	0.94	-36.90	0.04	0.91	-0.16
48	H 24 × KS 118	16.16	2.11++	0.84	2.89	1.90	-2180.24	0.19	1.26++	-38.08	0.10	0.04	58.29*
Check													
1	Arka Rakshak	14.42	0.97	-0.55	3.21	0.89	-828.86	0.18	0.61+	-4.28	0.10	1.41++	-14.52
Population Mean		13.09			3.30			0.21			0.09		
S. Em. ±		0.63			0.05			0.01			0.003		

Note: Regression coefficient (b_i) and deviation from regression (S^2d_i) were calculated after multiplication of mean values of genotypes with 1000 for FYP, TS, LC and βC. Where, (1) +, ++ Significant at 0.05 and 0.01 per cent levels of probability respectively when Ho: b_i = 1. (2) FYP = Fruit yield per plant, NFP = Number of fruits per plant, FW = Fruit weight, SL = Shelf life, TS = Total soluble sugar, LC = Lycopene content, βC = β-carotene content.

Table 5: Summary of promising hybrids and parents based on their response to stability performance for various characters in tomato

Sr. No.	Characters	Adapted to all environments		Adapted to better environments		Adapted to poor environments	
		Hybrid	Parent	Hybrid	Parent	Hybrid	Parent
1	Fruit yield per plant	AT 3 × Feb 4	DVRT 2	H 24 × ATL 97-26	Feb 4 ATL 97-26 PAU 2372	H 24 × TBK 00113	ATL 11-05 H 24
		AT 3 × TBK 00113		DVRT 2 × NTL 14-71		H 24 × ATL 11-05	
		-		AT 3 × KS 118		H 24 × DARL 66	
2	Number of fruits per plant	AT 3 × ATL 11-05	PAU 2372	DVRT 2 × ACTL 10-02	ACTL 10-02	DVRT 2 × ATL 11-05	-
		-		AT 3 × ACTL 10-02		DVRT 2 × TBK 00113	
		-		H 24 × ATL 97-26		H 24 × ATL 11-05	
3	Fruit weight	H 24 × NTL 14-71	KS 118	DVRT 2 × VTG 93	-	H 24 × ATL 11-05	NTL 14-71 H 24 ATL 11-05
		GT 2 × ATL 97-26		H 24 × VTG 93		H 24 × TBK 00113	
		AT 3 × TBK 00113		H 24 × JTL 12-07		DVRT 2 × NTL 14-71	
4	Shelf life	AT 3 × NTL 14-71	-	GT 2 × ATL 97-26	-	H 24 × SL 120	NTL 14-71
		DVRT 2 × TBK 00113		GT 2 × PAU 2372		H 24 × ATL 11-05	
		H 24 × TBK 00113		AT 3 × ATL 11-05		DVRT 2 × NTL 14-71	
5	Total soluble sugar	DVRT 2 × VTG 93	SL 120 PAU 2372	GT 2 × ACTL 10-02	-	DVRT 2 × TBK 00113	ACTL 10-02
		DVRT 2 × SL 120		DVRT 2 × Feb 4		AT 3 × ACTL 10-02	
		AT 3 × SL 120		GT 2 × VTG 93		H 24 × ATL 11-05	
6	Lycopene content	DVRT 2 × ACTL	-	GT 2 × ATL 11-05	ATL 11-05	DVRT 2 × ATL 11-05	-

		10-02					
		AT 3 × ATL 11-05		GT 2 × TBK 00113		DVRT 2 × ATL 97-26	
		DVRT 2 × TBK 00113		-		-	
7	β-carotene content	H 24 × ACTL 10-02	ATL 11-05	DVRT 2 × ACTL 10-02	DVRT 2	AT 3 × ACTL 10-02	-
		GT 2 × ATL 11-05		DVRT 2 × TBK 00113		AT 3 × ATL 11-05	
		-		GT 2 × DARL 66		AT 3 × NTL 14-71	

4. Conclusion

The analysis of variance for phenotypic stability indicated that the variation due to genotypes, environments and environments (linear) were highly significant for all the characters except 1000 seed weight for latter two components. Among the hybrids, AT 3 × TBK 00113 was found stable for fruit yield per plant and fruit weight; AT 3 × ATL 11-05 for number of fruits per plant and lycopene content; AT 3 × VTG 93 for shelf life, total soluble sugar, lycopene content; while, GT 2 × ATL 11-05 had stable performance for shelf life and β-carotene content. Hence, it would be advantageous to exploit these high yielding tomato hybrids in practical plant breeding programme after critically evaluation over the environments of locations and years.

5. References

1. Al-Aysh. Genotype × environment interaction and phenotypic stability for fruit yield and its components in tomato. Research J. of Agriculture and Environmental Management. 2013; 2(11):371-377.
2. Allard RW, Bradshaw AD. Implication of genotype environmental interactions in applied plant breeding. Crop Sci. 1964; 4(5):503-508.
3. Association of Official Analytical Chemists (A.O.A.C.). Official Methods of Analysis (13th Ed.). Benjamin Franklin Station, Washington D. C, 1980, 49-50.
4. Baker RJ. Genotype-environment interactions in yield of wheat. Canad. J Pl. Sci. 1969; 49:743-751.
5. Breeze EL. The measurement and significance of genotype-environment interactions in grasses. Heredity. 1969; 24:27-44.
6. Cuartero J, Fernandez MR. Tomato and salinity. Sci. Horticulture. 1999; 78:83-125.
7. Dubois M, Gilles KA, Hamilton JK, Rebers PA, Smith F. Colorimetric method for determination of sugars and related substances. Analytical Chemistry. 1956; 28:350-356.
8. Duzyaman E, Vural H. Stability of yield performance of some processing tomato genotypes. ANADOLU, J. of AARI. 2002; 12(1):122-130.
9. Eberhart SA, Russell WA. Stability parameters for comparing varieties. Crop Sci. 1966; 6:24-40.
10. Giovannucci E. Tomatoes, tomato-based products, lycopene and cancer. Review of the epidemiological literature. J Natl. Cancer Inst. 1999; 91:317-331.
11. Jones JB. Tomato Plant Culture: In the Field, Greenhouse and Home Garden. CRC Press LLC, Florida, 1999, 11-53.
12. Kalloo G. Distant hybridization in vegetable crops. Vegetable Breeding. 1988; 1:137-170.
13. Krinsky NI. The biological properties of carotenoids. Pure Appl. Chem. 1994; 66:1003-1010.
14. Mane RS. Stability analysis in tomato (*Solanum lycopersicum* Mill.) genotypes. M. Sc. Thesis, University of Agriculture Sciences, Dharwad, 2009.
15. Marbhal SK, Ranpise SA, Bhalekar MN. Stability analysis in cherry tomato for quantitative traits. International Research J of Multidisciplinary Studies. 2015; 2(2):11-16.
16. Nagata M, Yamashita I. Simple method for simultaneous determination of chlorophyll and carotenoids in tomato fruit. J Japan. Soc. Food Sci. Technol. 1992; 39(10):925-928.
17. Nandasana JN. Studies on physiochemical and rheological changes during ripening of custard apple. M. Tech. Thesis, Junagadh Agricultural University, Junagadh, Gujarat, 2005.
18. National Horticultural Board (NHB). Area, Production and Productivity of Tomato in India. Indian Horticulture Database, NHB, Gurgaon, Haryana, 2017.
19. Panthee DR, Cao C, Debenport SJ, Rodriguez GR, Labate JA, Robertson LD, *et al*. Magnitude of genotype × environment interactions affecting tomato fruit quality. Hort Science. 2012; 47(6):721-726.
20. Shalini M. Stability analysis in tomato (*Solanum lycopersicum* L.) for yield and yield attributing traits. Environment & Ecology. 2016; 34(4):2037-2043.
21. Shankar A, Reddy RVSK, Saidaiah P, Krishna KU, Jyothi KU. Study on stability for yield and its components in tomato (*Solanum lycopersicum* L.). Int. J Curr. Microbiol. App. Sci. 2017; 6(9):804-812.
22. Thapliyal A, Singh JP. Stability analysis for growth, yield and quality characters of tomato (*Solanum lycopersicum* L.). Pantnagar Journal of Research. 2009; 7(2):179-182.
23. Thompson HC, Kelly WC. Vegetable Crops (5th Ed.). McGraw Hill Book Company, New York, 1957, 471-502.
24. Ummyiah HM, Jabeen N, Afroza B, Mushtaq F. Stability analysis and genotype × environment interaction of some tomato hybrids under Kashmir conditions. Vegetos. 2015; 28(2):36-40.