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RESEARCH ARTICLE

Correlation matrix and stability analysis for morpho-physiological characteristics in extant cultivars of tomato (*Solanum lycopersicum* L.)

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Abstract

The data was generated from twenty morphological and disease traits for estimating the correlation and path coefficient analysis, stability and diversity analysis. In results of genotypic & phenotypic correlation and path coefficient analysis, the maximum and positive correlation of yield was stand with the fruit average weight of 10 fruits (0.311 & 0.302), number of fruits/plant (0.275 & 0.291), fruit weight (0.253 & 0.241cm), fruit size of scar around peduncle end (0.213 & 0.202) and fruit number of locules (0.264 & 0.252), while, the yield was negatively correlated with some horticultural traits along with ToLCV (-0.582 & -0.557) and early blight (-0.375 & -0.360). Some characters showed low heritability (<1.00) with high genetic advances like Stem length of internode between 1st and 4th inflorescence (0.967 & 18.866), time of 50% flowering (0.997 & 13.799), fruit average weight of 10 fruits (0.999 & 48.535), number of fruits/plant (0.987 & 19.721), time of maturity from seed sowing (0.940 & 15.822), ToLCV (0.985 & 31.765) and early blight (0.992 & 37.786) which were exhibited additive gene action. Out of 24, a total 11, 13, 14 and 12 cultivars showed less than or equal to one (b<1 or b=1) regression coefficient for ToLCV (0.39-0.99), early blight (0.11-0.89), SLI (0.50-1.00) and number of fruits/plant (0.58-1.00), respectively.

Keywords: Tomato; ToLCV and early blight resistance; correlation; heritability and genetic advance; genetic diversity.

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Introduction

Tomato (*Solanum. lycopersicum*) has a rich diversity of genetic resources across the world (Singh et al., 2021). The tomato crop is affected by numerous viral, fungal, and bacterial diseases, but tomato leaf curl (ToLCV) and early blight (EB) diseases are the most destructive and hamper tomato production (Singh et al., 2015; Singh et al., 2017; Singh et al., 2020). Cultivated tomatoes are inherently susceptible to these diseases and are always directly correlated with yield-related traits (Singh et al., 2020). The phenotypic traits of tomatoes are determined by their diverse genetic structure, environment, and interaction between genotypes and environment. The varietal improvement demands are not only important for utilizing the appropriate traits but also essential for protecting the distinctiveness of varieties. The appearance of phenotypic plant characters is controlled by the genetic constitution of a gene and the interaction between genotypes and the environment (Singh et al., 2020; Singh et al., 2021). The genetic variance of a quantitative trait is composed of an additive variance (heritable) and non-additive variance and also includes epistasis (non-allelic gene interaction) and dominance (Al-Aysh et al., 2012).

The phenotypic yield and disease inherent can be classified as either qualitative (where variation is controlled by one gene) or quantitative (where variation is continuous and controlled by several genes) in tomatoes according to their heritability (Al-Aysh et al. 2012; Singh et al. 2015; Singh et al., 2020). The information on the nature of total phenotypic variability, along with the scale of heritability for any quantitative character during the improvement of tomato crops, is more important for a breeder (Al-Aysh et al. 2012), whereas the correlation matrix between heritability and genetic advance helps in determining the influence of the environment (Singh et al., 2020; Singh et al., 2021). Correlation coefficient analysis is a statistical measure that offers a perception of the genetic variability existing in populations and gives the direction of a relationship between two or more variables for genetic improvement in yield traits (Singh et al., 2021). The path analysis, on the other hand, measures the direct and indirect effects of a set of dependent variables on an independent variable, which helps in the selection of the best genotypes (Kumar et al., 2013; Khapte and Jansirani, 2014). A stability test refers to the static genetic behavior of genotypes in a diverse environment. Hence, stable phenotypic characters of a genotype have great importance due to changes in the environmental condition from year to year and region to region (Singh et al., 2021). The performance of stable genotypes for quantitative characteristics such as stabilizing yield traits and disease characteristics depends upon the level of genotype × environmental interaction (Kumar et al., 2013. Singh et al., 2020; Singh et al., 2021). The development of a resistant, yielder and consistent genotype depends on the genotypes and, environmental interactions, and phenotypic stability. The phenotypic stability is important for the selection of better varieties for breeding purposes in a wide range of environments. Therefore, this is a need to get information about the relationship between morphological and disease characteristics for improving the yield capacity in different environments for genetic improvement of tomatoes.

Materials and Methods

About 82 extant cultivars of tomato were collected from diverse climatic zones of India (Singh et al., 2020, 2021). All the cultivars were grown in a randomized block design in three replications (30 plants in a replication) at the vegetable research experimental farm of ICAR-Indian Institute of Vegetable Research (IIVR), Varanasi. All the standard agronomical practices were applied to grow a good crop.

Twenty morpho-physiological characters *viz*., stem length of internode between the 1st and the 4th inflorescence (SLI) in centimetre, leaf length (LL) in centimetre, leaflet length (LtL) in centimetre, leaf width (LW) in centimetre, leaflet width (LtW) in centimetre, flower calyx size (FCS) in centimetre, jointed peduncle length (JPL) from abscission layer to calyx in centimetre, time of 50% flowering (TFF) in days, fruit average weight of 10 fruits (FAW) in gram, number of fruits/plant (NFPP), fruit length (FL) in centimetre, fruit width (FW) in centimetre, fruit size of scar around peduncle end (FSSAPE) diameter in centimetre, fruit size of core in cross section (FSCCS) in relation to the total diameter in millimetre, fruit thickness of the pericarp (FTP) in centimetre, fruit number of locules (FNL), time of maturity from seed sowing (TMFSS) in days, were observed according to DUS test guidelines of tomato (Singh et al., 2021) as well as, tomato leaf curl virus (ToLCV) and early blight (EB) were recorded on leading stages (Singh et al., 2020). For the measurement of yield/plant in kilogram (kg), the number of fruits per plant was multiplied by the average fruit weight (g) and divided by 1000 (Singh et al., 2015). For tomato leaf curl virus (ToLCV) and early blight (EB) diseases, the data was recorded on a 6-points (0–5) scale from the first appearance of the symptoms (Singh et al., 2012; Singh et al., 2015; Singh et al., 2020).

Statistical analysis

A statistic software INDOSTAT version 8.5 (www.indistat.com) was used for analyzing the genotypic and phenotypic correlation coefficient, correlation between heritability and genetic advances, path analysis (direct and indirect effect) and stability analysis by using 20 morpho-physiological traits of 82 tomato extant cultivars. The genotypic and phenotypic correlation coefficient was estimated as described by Singh and Choudhary (1985). The correlation between heritability and genetic advance was determined by Johnson *et al.* (1955) and Singh and Choudhary (1985). The path analysis (for direct and indirect effect) was estimated as per the method of Wright (1921) and elaborated by Dewey and Lu (1959). Among the 82 extant cultivars of tomato, only 24 were selected for the stability test on the basis of their resistance and high yield ability. The data from four years was analyzed for isolation of stable genotypes for yield-related traits *viz.,* SLI, NFPP and FYPP, along with disease incidence of ToLCV and EB. The statistical model involved the estimation of the mean (m), regression coefficient (b), and deviation from regression (s^2di) for the expression of genotypes × environmental interaction (Eberhart and Russell, 1966). A dendrogram was constructed for diversity analysis by using twenty characteristics from 82 extant cultivars of tomato. The cluster was constructed on the basis of the Euclidian distance coefficient and unweighted pair-group method of arithmetic means (UPGMA) using NTSYS-PC software version 2.11s (Rohlf, 2005).

Results and Discussion

Correlation between genotypic and phenotypic traits

The correlation coefficient helps to find out the relationship between various plant characters. The results of genotypic

Table 1: Genotypic (G) and phenotypic (P) coefficient of correlation (M) among different characters ('C' for 1-20) in tomato.

C	*M*	*SL*	*LL*	*LLL*	*LW*	*LLW*	*FCS*	*JPL*	*DFF*	*AFW*	*NFPP*	*FL*	*FW*	*FSD*	*FSC*	*FPT*	*FNL*	*TM*	*ToLCV*	*EB*
SL	G	*1.000*																		
	P	1.000																		
LL	G	0.022	1.000																	
	P	0.028	1.000																	
LLL	G	0.015	0.418	1.000																
	P	0.013	0.402***	1.000																
LW	G	-0.102	0.755	0.503	1.000															
	P	-0.094	0.702***	0.467***	1.000															
LLW	G	-0.126	0.553	0.594	0.748	1.000														
	P	-0.120	0.520***	0.575***	0.676***	1.000														
FCS	G	-0.078	0.399	0.192	0.416	0.176	1.000													
	P	-0.076	0.385***	0.184**	0.377***	0.167**	1.000													
JPL	G	-0.005	-0.006	-0.023	-0.100	-0.030	0.163	1.000												
	P	-0.011	0.000	-0.026	-0.086	-0.029	0.163*	1.000												
DFF	G	-0.242	0.111	0.150	0.084	0.233	0.142	0.104	1.000											
	P	-0.235***	0.114	0.145*	0.080	0.206***	0.139*	0.101	1.000											
AFW	G	0.047	0.281	0.242	0.278	0.146	0.415	0.436	0.317	1.000										
	P	0.046	0.276***	0.236***	0.261***	0.140*	0.405***	0.426***	0.309***	1.000										
NFPP	G	0.085	-0.271	-0.279	-0.282	-0.247	-0.249	-0.314	-0.367	-0.730	1.000									
	P	0.083	-0.259***	-0.274***	-0.261***	-0.235***	-0.243***	-0.306***	-0.357***	-0.725***	1.000									
FL	G	-0.135	0.301	0.265	0.253	0.213	0.132	0.337	0.275	0.522	-0.585	1.000								
	P	-0.131*	0.291***	0.259***	0.235***	0.198**	0.130*	0.324***	0.268***	0.517***	-0.577***	1.000								
FW	G	0.020	0.185	0.144	0.109	0.070	0.273	0.503	0.212	0.833	-0.565	0.363	1.000							
	P	0.017	0.178**	0.142*	0.102	0.069	0.264***	0.486***	0.202**	0.819***	-0.552***	0.357***	1.000							
FSD	G	0.001	0.063	0.116	0.046	-0.016	0.285	0.550	0.175	0.572	-0.357	0.180	0.707	1.000						
	P	0.003	0.063	0.115	0.046	-0.015	0.269***	0.531***	0.173**	0.566***	-0.351***	0.174**	0.687***	1.000						
FSC	G	0.035	0.134	0.203	0.067	0.075	0.344	0.439	0.160	0.545	-0.383	0.309	0.677	0.837	1.000					
	P	0.028	0.123	0.197**	0.055	0.069	0.326***	0.417***	0.146*	0.532***	-0.372***	0.298***	0.644***	0.806***	1.000					
FPT	G	-0.039	0.151	0.200	0.046	0.059	0.086	0.401	-0.026	0.285	-0.181	0.382	0.334	0.531	0.595	1.000				
	P	-0.042	0.1383*	0.191**	0.042	0.044	0.080	0.381***	-0.022	0.276***	-0.176**	0.366***	0.317***	0.510***	0.586***	1.000				
FNL	G	0.092	-0.096	-0.067	-0.137	-0.135	0.135	0.176	-0.031	0.378	-0.168	-0.164	0.513	0.348	0.384	-0.055	1.000			
	P	0.092	-0.094	-0.065	-0.122	-0.131*	0.133*	0.171**	-0.029	0.376***	-0.166**	-0.159*	0.499***	0.341***	0.373***	-0.047	1.000			
TM	G	0.014	0.043	0.128	0.134	0.195	0.214	-0.118	0.166	0.254	-0.220	0.196	0.197	-0.003	0.128	0.035	-0.025	1.000		
	P	0.018	0.048	0.122	0.126*	0.184**	0.203**	-0.103	0.156*	0.246***	-0.209***	0.186**	0.189**	-0.003	0.124	0.035	-0.022	1.000		
ToLCV	G	-0.081	0.019	-0.111	-0.109	0.023	-0.113	0.227	0.075	-0.103	-0.183	0.219	0.031	0.035	-0.051	-0.039	-0.087	-0.033	1.000	
	P	-0.078	0.019	-0.107	-0.102	0.021	-0.108	0.219***	0.072	-0.102	-0.179**	0.214***	0.029	0.036	-0.048	-0.039	-0.086	-0.033	1.000	
EB	G	-0.080	-0.016	-0.084	-0.006	-0.022	-0.091	-0.014	0.211	-0.098	-0.115	0.137	-0.079	-0.029	-0.050	-0.049	-0.007	-0.029	0.464	1.000
	P	-0.079	-0.014	-0.083	-0.005	-0.021	-0.088	-0.012	0.205**	-0.098	-0.114	0.134*	-0.078	-0.028	-0.049	-0.048	-0.008	-0.029	0.457***	1.000
YPP	G	0.028	-0.093	-0.068	-0.043	-0.189	0.168	0.039	-0.120	0.311	0.275	-0.143	0.253	0.213	0.151	0.166	0.264	0.054	-0.582	-0.375
	P	0.028	-0.077	-0.068	-0.036	-0.173	0.159	0.034	-0.116	0.302	0.291	-0.141	0.241	0.202	0.144	0.151	0.252	0.057	-0.557	-0.360

*,**,***Significance Levels at P=<0.05, <0.01, <0.005 and <0.001 for phenotypic (if correlation r => 0.1251, >0.1639, >0.1784 and >0.2085); SL=Stem: Length of internode between 1st and 4th inflorescence (cm); LL=Leaf: Length (cm); LLL=Leaflet: Length (cm); LW=Leaf: Width (cm); LLW=Leaflet: Width (cm); FCS=Flower: Calyx size (cm); JPL=Jointed peduncle: Length (from abscission layer to calyx) (cm); DFF=Time of flowering (50% of the plants with at least one open flower from seed sowing) (days); AFW=Fruit: Average weight of 10 fruits (g); NFPP=Number of fruits/plant; FL=Fruit: Length (cm); FW=Fruit: Width (cm); FSD=Fruit: Size of scar around peduncle (diameter) (cm); FSC=Fruit: Size of core in cross section (in relation to total diameter) (mm); FPT=Fruit: Thickness of the pericarp (cm); FNL=Fruit: Number of locules; TM=Time of maturity (from seed sowing); ToLCV=PDI (%) for ToLCV; EB=PDI (%) for EB; YPP=Yield/plant (Kg).

Table 2: Path coefficient analysis (PC) for genotypic (G) and phenotypic (P) showing direct (diagonal) and indirect effect (off diagonal) of different characters ('C'=1-20) on fruit yield in tomato.

C	PC	*SL*	*LL*	*LLL*	*LW*	*LLW*	*FCS*	*JPL*	*DFF*	*AFW*	*NFPP*	*FL*	*FW*	*FSD*	*FSC*	*FPT*	*FNL*	*TM*	*ToLCV*	*EB*
SL	G	-0.149	-0.003	-0.002	0.015	0.019	0.012	0.001	0.036	-0.007	-0.013	0.020	-0.003	0.000	-0.005	0.006	-0.014	-0.002	0.012	0.012
	P	-0.148	-0.004	-0.002	0.014	0.018	0.011	0.002	0.035	-0.007	-0.012	0.019	-0.003	0.000	-0.004	0.006	-0.014	-0.003	0.012	0.012
LL	G	-0.001	-0.056	-0.023	-0.042	-0.031	-0.022	0.000	-0.006	-0.016	0.015	-0.017	-0.010	-0.004	-0.007	-0.008	0.005	-0.002	-0.001	0.001
	P	-0.001	-0.043	-0.017	-0.030	-0.022	-0.017	0.000	-0.005	-0.012	0.011	-0.013	-0.008	-0.003	-0.005	-0.006	0.004	-0.002	-0.001	0.001
LLL	G	-0.001	-0.013	-0.031	-0.016	-0.018	-0.006	0.001	-0.005	-0.008	0.009	-0.008	-0.004	-0.004	-0.006	-0.006	0.002	-0.004	0.003	0.003
	P	0.000	-0.012	-0.030	-0.014	-0.018	-0.006	0.001	-0.004	-0.007	0.008	-0.008	-0.004	-0.004	-0.006	-0.006	0.002	-0.004	0.003	0.003
LW	G	0.004	-0.030	-0.020	-0.040	-0.030	-0.017	0.004	-0.003	-0.011	0.011	-0.010	-0.004	-0.002	-0.003	-0.002	0.006	-0.005	0.004	0.000
	P	0.003	-0.024	-0.016	-0.035	-0.023	-0.013	0.003	-0.003	-0.009	0.009	-0.008	-0.004	-0.002	-0.002	-0.002	0.004	-0.004	0.004	0.000
LLW	G	0.003	-0.015	-0.016	-0.020	-0.027	-0.005	0.001	-0.006	-0.004	0.007	-0.006	-0.002	0.000	-0.002	-0.002	0.004	-0.005	-0.001	0.001
	P	0.004	-0.015	-0.017	-0.020	-0.029	-0.005	0.001	-0.006	-0.004	0.007	-0.006	-0.002	0.000	-0.002	-0.001	0.004	-0.005	-0.001	0.001
FCS	G	0.001	-0.003	-0.001	-0.003	-0.001	-0.007	-0.001	-0.001	-0.003	0.002	-0.001	-0.002	-0.002	-0.002	-0.001	-0.001	-0.002	0.001	0.001
	P	0.001	-0.007	-0.003	-0.007	-0.003	-0.017	-0.003	-0.002	-0.007	0.004	-0.002	-0.005	-0.005	-0.006	-0.001	-0.002	-0.004	0.002	0.002
JPL	G	0.000	0.000	0.002	0.007	0.002	-0.012	-0.074	-0.008	-0.032	0.023	-0.025	-0.037	-0.041	-0.033	-0.030	-0.013	0.009	-0.017	0.001
	P	0.001	0.000	0.002	0.006	0.002	-0.011	-0.067	-0.007	-0.029	0.021	-0.022	-0.033	-0.036	-0.028	-0.026	-0.011	0.007	-0.015	0.001
DFF	G	0.019	-0.009	-0.012	-0.007	-0.019	-0.011	-0.008	-0.080	-0.026	0.030	-0.022	-0.017	-0.014	-0.013	0.002	0.003	-0.013	-0.006	-0.017
	P	0.018	-0.009	-0.011	-0.006	-0.017	-0.011	-0.008	-0.079	-0.024	0.028	-0.021	-0.016	-0.014	-0.011	0.002	0.002	-0.012	-0.006	-0.016
AFW	G	0.051	0.308	0.266	0.305	0.160	0.455	0.478	0.348	1.097	-0.801	0.573	0.914	0.628	0.597	0.313	0.415	0.278	-0.113	-0.107
	P	0.051	0.307	0.266	0.289	0.156	0.449	0.472	0.343	1.110	-0.805	0.574	0.909	0.628	0.590	0.307	0.417	0.273	-0.113	-0.108
NFPP	G	0.072	-0.231	-0.238	-0.240	-0.210	-0.212	-0.268	-0.313	-0.623	0.853	-0.499	-0.482	-0.305	-0.327	-0.155	-0.144	-0.188	-0.156	-0.098
	P	0.074	-0.230	-0.243	-0.231	-0.208	-0.215	-0.271	-0.316	-0.642	0.885	-0.511	-0.488	-0.310	-0.329	-0.156	-0.147	-0.185	-0.159	-0.101
FL	G	0.008	-0.018	-0.016	-0.015	-0.012	-0.008	-0.020	-0.016	-0.031	0.034	-0.058	-0.021	-0.011	-0.018	-0.022	0.010	-0.012	-0.013	-0.008
	P	0.009	-0.019	-0.017	-0.015	-0.013	-0.009	-0.021	-0.018	-0.034	0.038	-0.065	-0.023	-0.011	-0.019	-0.024	0.010	-0.012	-0.014	-0.009
FW	G	-0.002	-0.022	-0.017	-0.013	-0.008	-0.032	-0.059	-0.025	-0.097	0.066	-0.042	-0.117	-0.083	-0.079	-0.039	-0.060	-0.023	-0.004	0.009
	P	-0.002	-0.020	-0.016	-0.012	-0.008	-0.030	-0.055	-0.023	-0.093	0.062	-0.040	-0.113	-0.078	-0.073	-0.036	-0.056	-0.021	-0.003	0.009
FSD	G	0.000	0.005	0.010	0.004	-0.001	0.024	0.046	0.015	0.048	-0.030	0.015	0.059	0.083	0.070	0.044	0.029	0.000	0.003	-0.002
	P	0.000	0.003	0.006	0.003	-0.001	0.014	0.029	0.009	0.030	-0.019	0.009	0.037	0.054	0.043	0.027	0.018	0.000	0.002	-0.002
FSC	G	-0.005	-0.021	-0.031	-0.010	-0.011	-0.053	-0.067	-0.025	-0.083	0.059	-0.047	-0.104	-0.128	**-0.153**	-0.091	-0.059	-0.020	0.008	0.008
	P	-0.003	-0.014	-0.022	-0.006	-0.008	-0.036	-0.046	-0.016	-0.059	0.041	-0.033	-0.071	-0.089	**-0.110**	-0.064	-0.041	-0.014	0.005	0.005
FPT	G	-0.006	0.022	0.029	0.007	0.009	0.013	0.058	-0.004	0.042	-0.026	0.056	0.049	0.077	0.087	**0.146**	-0.008	0.005	-0.006	-0.007
	P	-0.005	0.017	0.023	0.005	0.005	0.010	0.046	-0.003	0.033	-0.021	0.044	0.038	0.062	0.071	**0.121**	-0.006	0.004	-0.005	-0.006
FNL	G	0.006	-0.006	-0.004	-0.009	-0.009	0.009	0.012	-0.002	0.025	-0.011	-0.011	0.034	0.023	0.026	-0.004	**0.066**	-0.002	-0.006	-0.001
	P	0.004	-0.004	-0.003	-0.006	-0.006	0.006	0.008	-0.001	0.018	-0.008	-0.008	0.023	0.016	0.018	-0.002	**0.047**	-0.001	-0.004	0.000
TM	G	0.000	0.001	0.004	0.004	0.006	0.006	-0.004	0.005	0.008	-0.007	0.006	0.006	0.000	0.004	0.001	-0.001	**0.029**	-0.001	-0.001
	P	0.001	0.002	0.004	0.004	0.006	0.006	-0.003	0.005	0.008	-0.006	0.006	0.006	0.000	0.004	0.001	-0.001	**0.031**	-0.001	-0.001
ToLCV	G	0.022	-0.005	0.030	0.030	-0.006	0.031	-0.062	-0.020	0.028	0.050	-0.059	-0.009	-0.009	0.014	0.010	0.024	0.009	**-0.271**	-0.126
	P	0.019	-0.005	0.026	0.025	-0.005	0.027	-0.054	-0.018	0.025	0.044	-0.053	-0.007	-0.009	0.012	0.010	0.021	0.008	**-0.246**	-0.113
EB	G	0.003	0.001	0.004	0.000	0.001	0.004	0.001	-0.009	0.004	0.005	-0.006	0.003	0.001	0.002	0.002	0.000	0.001	-0.020	**-0.043**
	P	0.003	0.001	0.003	0.000	0.001	0.003	0.001	-0.008	0.004	0.004	-0.005	0.003	0.001	0.002	0.002	0.000	0.001	-0.017	**-0.038**
YPP	G	0.028	-0.093	-0.068	-0.043	-0.189	0.168	0.039	-0.120	0.311	0.275	-0.143	0.253	0.213	0.151	0.166	0.264	0.054	-0.582	-0.375
	P	0.028	-0.077	-0.068	-0.036	-0.173	0.159	0.034	-0.116	0.302	0.291	-0.141	0.241	0.202	0.144	0.151	0.252	0.057	-0.557	-0.360
Partial R^2	G	-0.004	0.005	0.002	0.002	0.005	-0.001	-0.003	0.010	0.341	0.235	0.008	-0.030	0.018	-0.023	0.024	0.018	0.002	0.158	0.016
	P	-0.004	0.003	0.002	0.001	0.005	-0.003	-0.002	0.009	0.335	0.258	0.009	-0.027	0.011	-0.016	0.018	0.012	0.002	0.137	0.014
	G	R Square = 0.7816 Residual Effect = 0.4674																		
	P	R Square = 0.7634 Residual Effect = 0.4865																		

SL=Stem: Length of internode between 1st and 4th inflorescence (cm); LL=Leaf: Length (cm); LLL=Leaflet: Length (cm); LW=Leaf: Width (cm); LLW=Leaflet: Width (cm); FCS=Flower: Calyx size (cm); JPL=Jointed peduncle: Length (from abscission layer to calyx) (cm); DFF=Time of flowering (50% of the plants with at least one open flower from seed sowing) (days); AFW=Fruit: Average weight of 10 fruits (g); NFPP=Number of fruits/plant; FL=Fruit: Length (cm); FW=Fruit: Width (cm); FSD=Fruit: Size of scar around peduncle (diameter) (cm); FSC=Fruit: Size of core in cross section (in relation to total diameter) (mm); FPT=Fruit: Thickness of the pericarp (cm); FNL=Fruit: Number of locules; TM=Time of maturity (from seed sowing); ToLCV=PDI (%) for ToLCV; EB=PDI (%) for EB; YPP=Yield/plant (Kg).

Table 3: Correlation matrix (M) between heritability broad sense 'h²' (H) and genetic advancement at 5% (G) for different characters ('C' for 1-20) of tomato.

C	*M*	*SL*	*LL*	*LLL*	*LW*	*LLW*	*FCS*	*JPL*	*DFF*	*AFW*	*NFPP*	*FL*	*FW*	*FSD*	*FSC*	*FPT*	*FNL*	*TM*	*ToLCV*	*EB*	*SL*
SL	H	0.967	0.758	1.100	0.994	0.991	0.979	0.396	0.994	0.998	0.997	1.006	1.160	0.398	1.198	0.873	0.973	0.747	1.007	0.995	0.962
	G	18.866	1.692	1.108	3.776	1.926	0.831	0.151	7.559	6.600	5.678	2.245	0.880	0.087	0.910	0.606	1.940	1.834	7.063	7.598	0.571
LL	H	0.758	0.965	1.008	0.988	1.005	0.997	0.758	0.926	0.998	1.020	1.004	0.999	0.970	1.042	1.041	1.001	0.838	0.985	1.126	1.155
	G	1.692	8.975	3.843	7.085	2.809	1.312	16.356	3.404	11.151	7.085	2.311	1.713	0.693	1.148	0.904	1.388	2.304	2.331	2.473	0.789
LLL	H		1.008	0.977	0.997	0.981	1.011	0.848	0.997	0.999	0.998	0.999	0.986	0.980	0.995	1.001	1.009	1.010	1.018	0.992	0.965
	G		3.843	3.794	3.766	1.864	0.594	0.216	2.670	6.715	4.604	1.401	0.974	0.610	0.895	0.660	0.752	2.847	3.716	3.480	0.400
LW	H			0.997	0.876	0.995	1.011	1.063	0.958	0.999	1.003	0.996	0.989	0.930	1.120	0.984	1.041	0.962	0.990	1.179	1.088
	G			3.766	6.900	2.921	1.210	0.706	2.710	9.979	6.431	1.897	1.178	0.519	0.756	0.433	1.517	3.931	5.048	1.371	0.466
LLW	H				0.995	0.924	0.993	0.965	1.041	1.001	1.002	1.022	0.969	0.992	1.022	1.256	0.989	0.992	1.044	0.987	1.016
	G				2.921	1.494	0.358	0.169	2.163	3.323	2.762	0.809	0.430	0.144	0.350	0.256	0.676	2.218	1.080	1.134	0.434
FCS	H					0.993	0.957	0.956	0.977	1.002	0.996	0.981	0.994	1.027	1.007	1.022	0.992	0.997	1.010	1.014	1.001
	G					0.358	0.463	0.217	0.903	3.089	1.525	0.344	0.473	0.344	0.411	0.154	0.373	1.282	1.311	1.286	0.224
JPL	H						0.956	0.955	0.982	1.000	0.996	1.005	0.993	1.001	1.005	0.996	1.006	1.078	1.005	1.079	1.091
	G						0.217	0.623	0.899	3.672	1.989	0.646	0.745	0.548	0.539	0.380	0.499	1.149	2.158	0.598	0.131
DFF	H							0.982	0.946	0.997	0.994	0.986	1.005	0.973	1.045	1.103	1.055	1.000	1.008	0.994	0.977
	G							0.899	12.059	13.799	9.479	2.548	2.148	1.343	1.465	0.448	0.950	5.792	5.486	9.923	0.960
AFW	H								0.997	0.999	1.000	0.998	0.998	1.000	0.999	1.001	1.001	0.999	1.004	0.997	0.996
	G								13.799	48.535	26.534	6.997	8.392	4.874	5.224	2.808	6.354	14.175	12.694	13.391	3.085
NFPP	H									1.000	0.987	0.995	1.000	0.999	1.000	0.989	1.000	1.014	1.004	1.001	0.908
	G									26.534	19.721	4.729	4.422	2.460	2.803	1.423	2.708	8.505	10.794	9.311	1.771
FL	H										0.995	0.977	0.986	1.014	1.003	1.000	1.010	1.011	1.005	1.005	0.966
	G										4.729	1.912	1.098	0.550	0.787	0.648	0.839	2.503	3.692	3.180	0.411
FW	H											0.986	0.964	1.000	1.008	1.002	1.002	0.992	1.056	0.991	0.996
	G											1.098	1.711	1.026	1.109	0.575	1.403	2.354	1.356	2.280	0.527
FSD	H												1.000	0.977	1.002	0.996	1.002	0.714	0.950	1.022	1.008
	G												1.026	0.845	0.861	0.507	0.809	0.157	0.950	0.986	0.341
FSC	H													1.002	0.953	0.963	0.999	0.975	1.024	0.992	0.991
	G													0.861	1.008	0.580	0.933	1.450	1.313	1.400	0.313
FPT	H														0.963	0.938	1.139	0.948	0.955	0.996	1.026
	G														0.580	0.551	0.281	0.558	0.818	1.029	0.247
FNL	H															1.139	0.989	1.077	0.998	0.903	1.010
	G															0.281	2.184	0.977	2.464	0.738	0.609
TM	H																1.077	0.940	0.960	0.957	0.892
	G																0.977	15.822	4.089	4.132	0.708
ToLCV	H																	0.960	0.985	1.002	1.004
	G																	4.089	31.765	23.748	3.440
EB	H																		1.002	0.992	1.002
	G																		23.748	37.786	3.002
YPP	H																			1.002	0.936
	G																			3.002	0.612

SL=Stem: Length of internode between 1st and 4th inflorescence (cm); LL=Leaf: Length (cm); LLL=Leaflet: Length (cm); LW=Leaf: Width (cm); LLW=Leaflet: Width (cm); FCS=Flower: Calyx size (cm); JPL=Jointed peduncle: Length (from abscission layer to calyx) (cm); DFF=Time of flowering (50% of the plants with at least one open flower from seed sowing) (days); AFW=Fruit: Average weight of 10 fruits (g); NFPP=Number of fruits/plant; FL=Fruit: Length (cm); FW=Fruit: Width (cm); FSD=Fruit: Size of scar around peduncle (diameter) (cm); FSC=Fruit: Size of core in cross section (in relation to total diameter) (mm); FPT=Fruit: Thickness of the pericarp (cm); FNL=Fruit: Number of locules; TM=Time of maturity (from seed sowing); ToLCV=PDI (%) for ToLCV; EB=PDI (%) for EB; YPP=Yield/plant (Kg).

and phenotypic correlations coefficient in the present investigation indicated that the FYPP was positively correlated with SLI, FCS, JPL, FAW, NFPP, FW, FSSAPE, FSCCS, FTP, FNL and TMFSS at both genotypic and phenotypic level. The yield was negatively correlated with remaining traits, *e.g.,* LL, LtL, LW, LtW, TFF, FL, and PDI% for ToLCV and EB at both genotypic and phenotypic levels (Table 1). Previously, it has been studied that the positive correlation of yield per plant with stem length, number of fruits, and time of maturity is responsible for increasing the yield capacity (Kumar et al., 2013; Khapte and Jansirani, 2014; Singh et al., 2021), while, negative correlation of yield per plant with leaf size, fruit size and disease traits (ToLCV and EB) have been reported for yield hindrance (Singh et al., 2012; Singh et al., 2015). In the present investigation, it was also observed that the disease parameters like ToLCV and EB had a negative correlation with SLI, LL, LW, FCS, FAW, NFPP, FSCCS, FTP, FNL, and TMFSS at both genotypic and phenotypic levels. The negative correlation of yield components with ToLCV and EB diseases reflected the yield loss (Singh et al., 2015). As well as a number of locules had maximum positive and significant correlation with FW (0.513 & 0.499). However, the FL and FW showed maximum significant positive correlation with FAW (0.522 & 0.517 and 0.833 & 0.819) at both genotypic and phenotypic levels (Table 1). This study confounded that the number of locules of tomato fruits is associated with the fruit weight, size of core in cross-section, and size of scar around the peduncle end. The fruit length, fruit weight and fruit size were associated with the fruit weight (Kumar et al., 2013; Khapte and Jansirani, 2014; Singh et al., 2020; Singh et al., 2021).

Path coefficient analysis

The path coefficient analysis measures the direct and indirect effects of a set of associations between dependent variables on independent variables. In the case of the direct effect of various characters, FAW, NFPP, FTP, FSSAPE, FNL, and TMFSS had a positive direct effect on FYPP at genotypic and phenotypic levels (Table 2). On the other hand, the remaining traits showed negative direct effects on FYPP. Previously, similar results were reported for positive and negative direct effects on FYPP with yield-related traits in tomatoes (Khapte and Jansirani, 2014). In the case of maximum and positive indirect effect (off-diagonal) on fruit yield/plant was observed for FAW (0.311 & 0.302) and NFPP (0.275 & 0.291). In addition, the maximum negative indirect effect on fruit yield/plant was observed for ToLCV (-0.582 & 0.557) and EB (-0.375 & 0.360) at the genotypic and phenotypic levels (Table 2). Earlier, Singh *et al.* (2015) reported similar results and found a significant contribution to yield through plant height, flower clusters, leaves/plant, number of fruits/plant, and negative path for diseases. Whereas high and positive indirect effects on average fruit weight through LL, LtL, LW, FL, FW, FSSAPE, FSCCS, FTP, FNL, and TMFSS (Table 2). On the other hand, a high and negative indirect effect was observed towards NFPP through LtW. Generally, most of the characters revealed an indirect effect on FYPP responded the similar results with correction efficiency of genotypic and phenotypic levels (Table 1) and corroborated the findings reported by Kumar *et al.* (2013) and Khapte and Jansirani (2014). Similar findings of the positive and negative indirect effects have been discussed by Kumar et al. (2013) and Khapte & Jansirani (2014).

Correlation between heritability and genetic advance

The correlation matrix between broad-sense heritability and genetic advance at 5% is presented in Table 3. The results of heritability indicated that the correlation matrix was positive and high for fruit yield/plant with all the morphological traits. Some traits *viz.,* LtW, FCS, JPL, FL, FSSAPE and FTP were found with high genetic advance and high heritability (>1). The characters with high heritability and genetic advance may be affected by environmental conditions (Singh et al., 2020). Most of the characters exhibited low genetic advance

Table 4: Analysis of variance for stability analysis of 24 tomato genotypes for disease traits (ToLCV and EB) and yield-related traits (SLI, NFPP, YPP)

Variance	df	PDI (%) for ToLCV	PDI (%) for EB	SLI	NFPP	YPP
Rep within Env.	8	4.196 ***	9.934 ***	12.832 ***	0.762 ***	0.005 ***
Varieties	23	809.902 ***	463.865 ***	464.341 ***	367.078 ***	0.136 ***
Env.+ (Var.* Env.)	72	44.097 ***	17.834 ***	1.820 ***	0.954 ***	0.014 ***
Environments	3	886.664 ***	314.940 ***	33.455 ***	20.161 ***	0.343 ***
Var.* Env.	69	7.463 ***	4.917 ***	0.444**	0.119 ***	0.000*
Environments (Lin.)	1	2659.993 ***	944.821 ***	100.366 ***	60.482 ***	1.029 ***
Var.* Env.(Lin.)	23	22.245 ***	13.882 ***	0.334**	0.320 ***	0.000*
Pooled Deviation	48	0.069	0.416	0.479	0.017	0.000
Pooled Error	184	2.719	1.376	2.278	0.947	0.003
Total	95	229.502	125.821	113.799	89.594	0.044

*,**,***Significance Levels at P=<0.05, <0.01, <0.005 and <0.001; PDI (%) for ToLCV=Percent disease incidence for tomato leaf curl virus; PDI (%) for EB= Percent disease incidence for early blight; SLI= Stem length of internode between 1st and 4th inflorescence (cm); NFPP=Number of fruits per plant; YPP= Fruit yield per plant

Table 5: Stability analysis in 24 tomato genotypes under different environments for disease traits (ToLCV, EB) and yield-related traits (SLI, NFPP and YPP).

Genotypes	*PDI (%) for ToLCV*			*PDI (%) for EB*			*SLI*			*NFPP*			*YPP (kg)*		
	m	b	S^2di	m	b	S^2di	m	b	S^2di	m	b	S^2di	m	b	S^2di
Arka Alok	26.64	0.63	-2.72	38.99	1.99	-1.57	46.93	1.35	-2.57	19.53	0.73	-0.91	1.36	1.00	-0.03
ArkaVikash	52.72	1.54	-2.67	15.51	0.74	-1.65	33.05	0.94	-2.24	26.93	1.00	-0.94	1.27	1.00	-0.03
Azad T-6	55.30	1.39	-2.76	15.27	0.73	-1.64	26.47	0.77	-2.72	30.26	1.13	-0.94	1.17	1.00	-0.03
Bhagyashree	24.94	0.55	-2.74	25.84	1.29	-1.73	17.33	0.50	-2.72	31.59	1.18	-0.94	1.30	1.00	-0.03
CO-3	40.40	0.99	-2.78	29.74	1.50	-1.72	26.10	0.75	-2.72	28.60	1.06	-0.94	1.53	1.00	-0.03
Colambia	22.45	0.52	-2.69	16.13	0.16	5.80	30.69	0.89	-2.72	22.28	0.83	-0.94	1.64	1.00	-0.03
CTS-06	50.23	1.25	-2.77	15.92	0.76	-1.65	17.32	0.50	-2.72	15.71	0.58	-0.59	1.18	1.00	-0.03
DCT-2	46.66	1.16	-2.78	23.18	1.15	-1.73	61.03	1.49	2.98	54.86	2.04	-0.93	1.34	1.00	-0.03
FEB-2	35.31	0.86	-2.77	10.13	0.46	-1.53	24.27	0.70	-2.72	29.93	1.11	-0.94	1.36	1.00	-0.03
Floradade	67.05	1.70	-2.68	26.72	1.34	-1.73	27.00	0.78	-2.72	19.29	0.72	-0.94	1.58	1.00	-0.03
Kalyanpur T-1	52.59	1.32	-2.77	23.05	1.14	-1.73	49.91	1.44	-2.72	27.27	1.01	-0.94	1.57	1.00	-0.03
Kashi Sharad	36.47	0.89	-2.77	2.97	0.11	-1.53	33.75	0.97	-2.72	19.29	0.72	-0.94	1.46	1.00	-0.03
Kashi Vishesh	59.17	1.49	-2.74	25.81	1.29	-1.73	34.61	1.00	-2.72	27.60	1.03	-0.94	1.49	1.00	-0.03
Manileima	49.28	1.23	-2.78	18.19	0.89	-1.69	34.78	1.01	-2.72	17.96	0.67	-0.94	1.25	1.00	-0.03
Mukthi	48.53	1.21	-2.78	30.80	1.55	-1.71	47.35	1.37	-2.72	46.88	1.74	-0.94	1.37	1.00	-0.03
NDT-1	34.23	0.83	-2.76	16.55	0.80	-1.66	49.16	1.36	2.38	16.96	0.63	-0.94	1.46	1.00	-0.03
Pant T-3	38.88	0.95	-2.78	51.78	2.67	-1.13	28.90	0.83	-2.72	40.23	1.50	-0.94	1.36	1.00	-0.03
Pant T-5	50.50	1.26	-2.77	11.48	0.53	-1.56	32.72	0.94	-2.72	18.62	0.69	-0.94	1.60	1.00	-0.03
Patharkuchi	42.30	1.04	-2.78	13.98	0.66	-1.62	32.05	0.93	-2.72	28.60	1.06	-0.94	1.28	1.00	-0.03
PVB-1	17.84	0.39	-2.65	9.85	0.44	-1.52	30.99	0.89	-2.72	22.94	0.85	-0.94	1.38	1.00	-0.03
PVB-2	18.92	0.40	-2.69	23.15	1.15	-1.73	32.92	0.95	-2.72	21.95	0.82	-0.94	1.80	1.00	-0.03
Sel-12	60.47	1.53	-2.73	10.13	0.46	-1.53	48.30	1.39	-2.67	30.26	1.13	-0.94	1.01	1.00	-0.03
Swarna Deepti	43.00	1.06	-2.78	31.27	1.58	-1.70	36.04	1.04	-2.72	29.59	1.10	-0.94	1.39	1.00	-0.03
Swarna Naveen	18.16	0.60	-2.16	13.21	0.62	-1.60	41.76	1.21	-2.72	17.96	0.67	-0.94	1.09	1.00	-0.03
Population Mean	41.34			20.82			35.14			26.88			1.39		

PVB= Punjab Varkha Bahar; PDI (%) for ToLCV=Percent disease incidence for tomato leaf curl virus; PDI (%) for EB= Percent disease incidence for early blight; SLI= Stem length of internode between 1st and 4th inflorescence (cm); NFPP=Number of fruits per plant; YPP=Yield per plant (Kg); m= mean; b= regression coefficient; S2di= deviation from regression.

and heritability (<1) and showed significant results (Table 3). Similar findings were reported in Singh *et al.* (2020) and Rani and Anitha (2011). In this study, FYPP was found to have positive and high genetic advance and heritability correlation matrix with FAW (0.999 & 48.535), ToLCV (0.985 & 31.765), EB (0.992 & 37.786) followed by NFPP, SLI, TMFSS and time of flowering. Highly heritable characteristics, along with high genetic advance, can be further improved through individual plant selection (Rani and Anitha, 2011; Singh et al., 2020; Singh et al., 2021). It was also observed that many characters had high genetic advances with moderate heritability, linked to additive gene action and very useful in selection. The study of association between the traits helps in the selection of cultivars and also proffers a way for simultaneous selection of more than one trait. Similar results in tomatoes were observed by Singh *et al.* (2020). However, some morphological characters showed high and moderate heritability with a low genetic advance by using a strong correlation matrix with yield/plant (Table 3). Rani and Anitha (2011) suggested that the high heritability with low genetic advance is due to the presence of non-additive gene effects and high genotypic and environmental interaction.

Stability analysis

A total of 24 extant tomato cultivars were used for stability test analysis with the disease traits (ToLCV and EB) and high values of yield-related traits (SLI, NFPP, and FYPP). The stability analysis revealed that the estimates of genotypes, environment and G × E variances were highly significant for most of the characters (Table 4**.** The estimates of the mean (m), deviation from regression (s^2di), and regression coefficient (b) for resistant incidence and related yield traits were calculated for the stability test (Table 5)**.** In the stability test, six cultivars ('Columbia', 'Feb-2', 'Kashi Sharad,' 'NDT-1', 'Punjab Varkha Bahar-1' and 'Swarna Naveen') were common and occupied less than '1' average response (b<1) for ToLCV and EB diseases, while, the seven cultivars ('Columbia,' 'CTS-06', 'Flora-Dade,' 'Kashi Sharad,' 'Pant T-5', 'Punjab Varkha Bahar-1' and 'Punjab Varkha Bahar-2') gave less than '1' average response (b<1) for SLI and NFPP. In contrast, the fruit yield traits showed an equal to '1' regression coefficient (b=1) and close to '0' deviation from the regression (s^2di=0) for all the cultivars. Those cultivars taken less than or equal to the '1' average response (b<1 or b=1) are stable in each

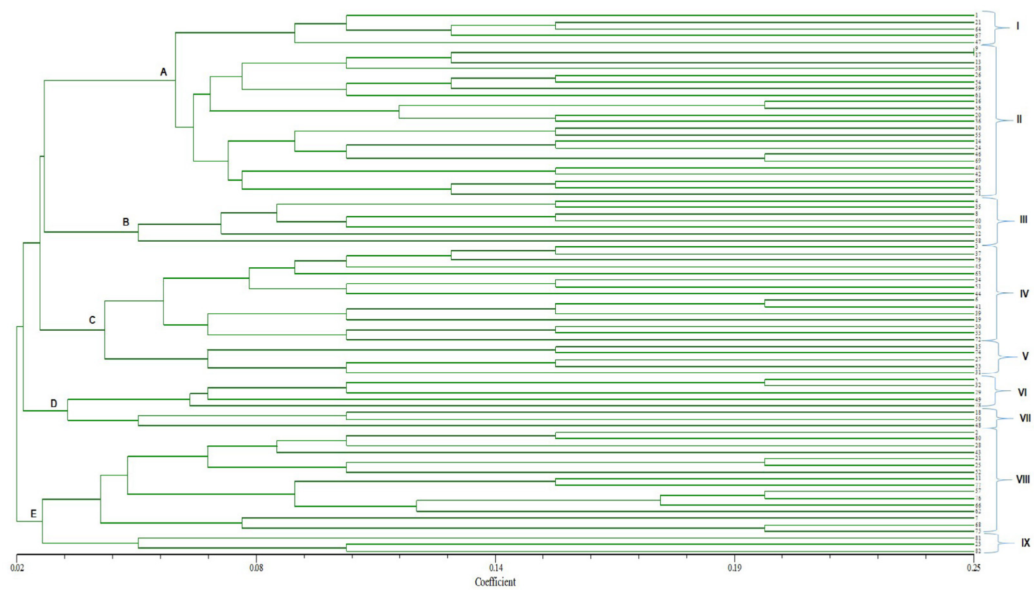

Figure 1: UPGMA dendrogram with Euclidean distance coefficient range generated by 82 extant cultivars of tomato (1=Ageta-32; 2=Angoorlata; 3=Arka Abha, 4=Arka Ahuti; 5=Arka Alok; 6=Arka Meghali; 7=Arka Saurabh; 8=Arka Vikash; 9=Azad T-2 (KS-2); 10=Azad T-3=; 11=Azad T-5 (KS-7); 12=Azad T-6 (KS-118); 13=Best of All; 14=Bhagyashree; 15=BT-11; 16= BT-136; 17=CO-3 (Marutham); 18=Columbia; 19=TS-06; 20=DARL-66; 21=DCT-1; 22=DCT-2; 23=Dhanshree; 24=Dhrubya; 25=DMT-1; 26=Feb-2; 27=Flora-Dade; 28=GT-1; 29=GT-2; 30=Hisar Anmol (H-24); 31=Hisar Arun (Sel-7); 32=Hisar Lalit (NT-8); 33=JT-3; 34=Kalyanpur T-1; 35=Kashi Adarsh; 36=Kashi Amrit; 37=Kashi Anupam; 38=Kashi Hemant (Sel-1); 39=Kashi Sharad (IIVRSel-2); 40=Kashi Vishesh (H-86); 41=Kashmiria; 42=KS-16; 43=Manileima (Sel-2); 44=Marglobe; 45=Mukthi; 46=NDT-1; 47=NDT-3; 48=NDT-4; 49=NDT-8; 50=NDTVR-73; 51=Pant T-3; 52=Pant T-5; 53=Patharkuchi; 54=PNR–7; 55=Prestige; 56=Punjab Chhuhara; 57=Punjab Keshari; 58=Punjab Ratta; 59=Punjab Upma; 60=Punjab Varkha Bahar-1; 61=Punjab Varkha Bahar-2; 62=Pusa Gaurav; 63=Pusa Ruby; 64=Pusa Upma; 65=Pusa-120; 66=Roma; 67=Sel-12; 68=Sioux; 69=Solan Vajra; 70=Swarna Deepti; 71=Swarna Gola; 72=Swarna Lalima; 73=Swarna Naveen; 74 =Utkal Deepti (BT-2); 75=Utkal Kumari (BT-10); 76=Utkal Pallavi (BT-1); 77=Utkal Pragyan (BT-116-3-2); 78=Utkal Raja (BT-20-2-1); 79=Utkal Upahar (BT-120); 80=Utkal Urvashi (BT-12); 81=Vaibhaw; 82 =VL Tamatar-4) based on 20 morpho-physiological characters.

environment (Kumar et al., 2013; Adewale and Adebo, 2018; Leal et al., 2019; Singh *et al.,* 2021). The results of the low or equal regression coefficient (b) (b=<1) and close to '0' deviation from regression ($s^2di=0$) indicated the most stable and adaptive genotypes of tomato and can be grown successfully in ToLCV- and EB-disease-infested area (Eberhart and Russell, 1966; Singh et al., 2012; Singh et al., 2015; Singh et al., 2020).

Genetic diversity

A dendrogram constructed using 20 morphological traits of 82 extant cultivars of tomato (Figure 1). In the dendrogram, five major clusters, 'A,' 'B,' 'C,' 'D,' and 'E' were formed, grouping 28, 7, 20, 8, and 19 cultivars, respectively. These five clusters are classified into nine groups: I, II, III, IV, V, VI, VII, VIII, and IX, with a coefficient range of 0.02 to 0.25%. In cluster 'A' and group I, the cultivars 'Ageta-32' and 'NDT-3' were diverse, while the cultivars 'Azad T-2' and 'CO-3' were very close. Similarly, in clusters 'B,' 'D' and 'E' the cultivars 'Punjab Ratta,' 'NDT-4' and 'Vaibhaw' were diverse, while the cultivars 'Dhanshree' and 'VL Tomato-4' were closely related. These closeness and diverse natures in cultivars may be due to their genetic differences or different pedigree and morphological characters. The diverse characters had more emphasis on deciding the selection of parents for an appropriate hybridization program in tomato (Adewale and Adebo, 2018; Leal et al., 2019; Singh et al., 2021).

Conclusion

It is concluded that the yield per plant in tomato cultivars was positively and significantly correlated with SLI, FCS, JPL, FAW, NFPP, FW, FSSAPE, FSCCS, FTP, FNL, and TMFSS. Path coefficient analysis revealed that the highest positive direct and indirect effects were noticed in FAW and NFPP. However, the disease traits were negatively correlated, both directly and indirectly on yield. Thus, these traits can be used as selection keys in tomatoes to elevate the yield capacity. In the case of correlation between heritability and genetic advance, some characters showed moderate or low heritability with high genetic advance and some other characters showed high heritability with high genetic advance, which indicated both additive and non-additive gene action. The genotypes 'Columbia,' 'Feb-2', 'Kashi Sharad,' 'NDT-1', 'Punjab Varkha Bahar-1,' and 'Swarna Naveen' were either with low or equal regression coefficients (b<1 or b=0) for ToLCV and EB diseases. The equal regression coefficient (b=0) and close to zero deviation from regression ($s^2di=0$) were exhibited for yield per plant. Thus, these cultivars can be grown successfully in disease-infested areas. The cultivars 'Agata-32', 'Kashi Hemant,' 'Punjab Ratta,' 'NDT-4' and 'Vaibhav' from sub-groups I, II, III, VII, and IX exhibited genetically diverse relationships with each other. Consequently, these stable and diverse genotypes could be utilized in resistant breeding programs of tomatoes to improve the desirable yield traits.

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Conflict of interest

The authors have no conflict of interest to declare.

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सारांश

टमाटर में सहसंबंध और पथ गुणांक विश्लेषण के साथ-साथ स्थिरता एवं विविधता विश्लेषण का अनुमान लगाने के लिए बीस रूपात्मक और रोग लक्षणों का अध्ययन किया गया। आनुवंशिक एवं प्रारूपी रूप सहसंबंध और पथ गुणांक विश्लेषण के परिणामों में उपज का अधिकतम और सकारात्मक सहसंबंध 10 फलों के फल औसत वजन (0.311 और 0.302), प्रति पौध फलों की संख्या (0.275 और 0.291), फल वजन (0.253 और 0.241 सेमी), फल के डंठल के अंत के आसपास निशान का आकार (0.213 और 0.202) और फल के आतंरिक की संख्या (0.264 और 0.252) था, जबकि, उपज कुछ लक्षणों के साथ नकारात्मक रूप से सहसंबंधित थी, जैसे कि टमाटर पर्ण कुन्चन विषाणु (-0.582 और -0.557) और अगेती झुलसा (-0.375 और -0.360) था। आनुवंशिकता और आनुवंशिक उन्नति के बीच सहसंबंध के परिणामों में, उपज का सकारात्मक सहसंबंध सभी बागवानी और रोग लक्षणों के साथ था। कुछ लक्षणों ने उच्च आनुवंशिक उन्नति के साथ कम पैत्रिकता (<1.00) दिखाई दिया जैसे कि पहले और चौथे पुष्पक्रम के बीच इंटरनोड तना की लंबाई (0.967 और 18.866), 50% फूल आने का समय (0.997 और 13.799), 10 फलों का औसत वजन (0.999 और 48.535), प्रति पौधा फलो की संख्या (0.987 और 19.721), बीज बोने से परिपक्वता का समय (0.940 और 15.822), टमाटर पर्ण कुन्चन विषाणु (0.985 और 31.765) और अगेती झुलसा (0.992 और 37.786) जो योगात्मक जीन क्रिया प्रदर्शित किया था। चौबीस में से, कुल 11, 13, 14 और 12 किस्मों में क्रमशः टमाटर पर्ण कुन्चन विषाणु (0.39-0.99), अगेती झुलसा (0.11-0.89), पहले और चौथे पुष्पक्रम के बीच इंटरनोड तना की लंबाई (0.50-1.00) और प्रति पौध फलों की संख्या (0.58-1.00) के लिए एक से कम या बराबर (b<1 या b=1) प्रतिगमन गुणांक दर्शाया गया।