Mean performance and genetic variability exploration for fruit yield and its attributing traits in tomato (*Solanum lycopersicum* L.)

ABSTRACT

The present study was conducted to access the relative performance, genetic variability, genetic advance and heritability in thirty genotypes of tomato crop. The crop was sown under Randomized Block Design (RBD) in three replications at Regional Research Station Karnal, CCS Haryana Agricultural University, during the *Autumn Winter* season of 2021-22. The observations were recorded for eight parameters pertaining to the fruit yield and its attributing traits in tomato. Statistics from analysis of variance showed substantial differences among the genotypes that unveils the plausible presence of significant genetic variability which could be positively exploited in crop improvement programs. The results obtained in the experiment showed that Pusa Ruby (38 days) was earliest to flower in 50% plants followed by EC-631351 (40 days). Genotype Selection 7 took the least (66) number of days to first picking and genotype Kashi Hemant took the maximum (155 days) number of days to last picking. Genotype EC-615056 recorded the maximum (57.71 g) average fruit weight and genotypes namely EC-631457, EC-631357 and Pusa Early Dwarf observed highest fruit yield per plant. Narrow differences were recorded for the phenotypic and genotypic coefficients of variation for all the characters, which denotes that environment had very little influence in expression of the characters and phenotype truly represents the genotype. High to moderate magnitude of genotypic coefficient of variation and phenotypic coefficient of variation was recorded for almost all the characters in our investigation. Plant characters days to first picking, days to 50% flowering, days to last picking, plant height at harvest recorded high (>70%) magnitude of heritability in broad sense implying least influence of environment over these characters. High heritability coupled with high genetic advance was observed for characters like days to 50% flowering and plant height at harvesting.

Keywords: heritability, genetic advance, genetic variability, average fruit weight, fruit yield per plant.

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L. 2n=2x=24) is one of the most important solanaceous vegetable crops grown throughout the world because of its wider adaptability, high yielding potential and suitability for variety of uses in fresh as well as processed food industries. The majority of the tomatoes grown are consumed fresh, with fewer than 1% of whole production are being processed into products. Roughly 100 ml of tomato juice contains 20 percent of the daily required amount of vitamin A. The red pigment in tomato (lycopene) is now being considered as the "world's most powerful natural antioxidant" [1]. India is the world's second-largest Tomato producer after China, with 0.830 million hectares under cultivation, 20.300 million metric tonnes of annual production, and an overall average productivity of 24.44 tonnes per hectare [2]. After potato and onion, tomato is India's third most important vegetable crop in terms of area (15.8 percent) and production (10.3 percent) [3]. Tomatoes are grown on 0.021 million hectares in Haryana, yielding 0.440 million metric tonnes of fruit, accounting for

2.53 percent of the national area and 2.16 percent of the national yield, with eight major growing districts: Karnal, Yamunanagar, Mewat, Kurukshetra, Gurugram Ambala, Sonipat, and Faridabad [2].

Tomato, as a largely autogamous crop plant, face significant problems in terms of increasing productivity and yield. The first prerequisite for plant breeders to be able to deliver genetic improvement to a crop is genetic variability [4]. Simply stated, variability is an assessment of the degree of genetic variation among individuals within a population. A thorough understanding of the existing genetic diversity is required to begin a crop improvement project. Furthermore, there is a greater chance of having a superior genotype if genetic factors account for the majority of population diversity and environmental factors account for a small portion. However, adequate improvement cannot be achieved with little variability, the breeder will need to use breeding techniques like as hybridization, polyploidy, and mutation breeding to supplement the germplasm or increase variability. The nature of the interaction between genotypes and environmental variation in such a population highlights the significance of dividing the observed variability into heritable (additive variance) and non-heritable (non-additive variance) traits using appropriate genetic parameters like genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability, and genetic advance. The degree of genotypic variability can be measured using the genotypic and phenotypic coefficients of variation, while the influence of the environment on character expression and the potential for improvement following selection can be assessed using heritability and genetic advance. Genetic advance is defined as the effectiveness of selection at any given degree of selection intensity. When heritable variations are evaluated alongside genetic advance, they become more reliable. The concept of heritability is useful in assessing whether phenotypic differences between plants are due to genetic makeup or are simply a result of environmental influences. To measure the variability estimates of these genetic parameters help the breeder in selection of elite genotypes from diverse genetic populations selected for experimental material.

2. MATERIAL AND METHODS

Location of the experiment

The experiment was carried out at Chaudhary Charan Singh Haryana Agricultural University (CCSHAU), Regional Research Station, Karnal, Haryana, India during the *Autumn Winter* season of 2021. The experimental location stands at 29º 43' in the North and 76º 58' East, at 243 meters elevation above mean sea level. The experiment was laid out under Randomized Block Design (RBD) in three replications.

Experimental material

The experimental material for the present study consisted of thirty genotypes of tomato which were mostly obtained from Indian Council of Agricultural Research-National Bureau of Plant Genetic Resources Regional Station (ICAR-NBPGR RS), Hyderabad and other ICAR institutes. (Table 1).

Table-1: List of tomato genotypes along with their source of collection

Sr. No.	Genotype	Source
1	EC-615056	NBPGR RS, Hyderabad
2	EC-617064	NBPGR RS, Hyderabad
3	EC-631351	NBPGR RS, Hyderabad
4	EC-631357	NBPGR RS, Hyderabad
5	EC-631359	NBPGR RS, Hyderabad
6	EC-631404	NBPGR RS, Hyderabad
7	EC-631406	NBPGR RS, Hyderabad
8	EC-631407	NBPGR RS, Hyderabad
9	EC-631411	NBPGR RS, Hyderabad
10	EC-631412	NBPGR RS, Hyderabad
11	EC-631427	NBPGR RS, Hyderabad
12	EC-631457	NBPGR RS, Hyderabad
13	EC-635530	NBPGR RS, Hyderabad
14	EC-635533	NBPGR RS, Hyderabad
15	EC-636877	NBPGR RS, Hyderabad
16	EC-638302	NBPGR RS, Hyderabad
17	EC-654284	NBPGR RS, Hyderabad

18	EC-654289	NBPGR RS, Hyderabad
19	EC-687416	NBPGR RS, Hyderabad
20	EC-687601	NBPGR RS, Hyderabad
21	EC-687604	NBPGR RS, Hyderabad
22	EC-698849	NBPGR RS, Hyderabad
23	Arka Vikas	IIHR, Bengaluru
24	Kashi Hemant	IIVR, Varanasi
25	PHS	IARI, New Delhi
26	Pusa Early Dwarf	IARI, New Delhi
27	Pusa Gaurav	IARI, New Delhi
28	Pusa Ruby	IARI, New Delhi
29	S-12	PAU, Ludhiana
30	Selection 7	CCS HAU, Hisar

Experimental details and observations recorded

The tomato seedlings were transplanted at a spacing of 60 cm row to row and 45 cm plant to plant in four rows of 2.25m length for each entry per replication. Eight parameters for fruit yield and its attributing traits were to be observed and recorded. Observations were recorded on five randomly plants in each genotype per replication were selected, summed up and divided by five to get mean value for eight parameters of tomato genotypes. *viz*., days to 50% flowering (days), number of branches per plant, days to first picking (days), days to last picking (days), plant height at harvest (cm), number of fruits per plant, average fruit weight (g) and fruit yield per plant (kg).

Data analysis

Coefficients of variation at genotypic and phenotypic level among various characters were computed using the formula suggested by Burton and Devane [5].

$$\text{Genotypic coefficient of variability (GCV \%)} = \frac{\sigma^2 g \text{ X } 100}{\bar{X}}$$

$$\text{Phenotypic coefficient of variability (PCV \%)} = \frac{\sigma^2 p \text{ X } 100}{\bar{X}}$$

Where,
GCV = Genotypic coefficient of variation
PCV= Phenotypic coefficient of variation
$\sigma^2 g$ = Genotypic variance
$\sigma^2 p$ = Phenotypic variance

List 1. Categorization of GCV and PCV [13]

Category	High	Moderate	Low
GCV and PCV	>20%	10-20%	<10%

Heritability per cent (in broad sense) was estimated using the formula given by Burton and Devane [5], Johnson *et al.* [6] and Hanson *et al.* [7].

$$h^2_{bs} = \frac{\sigma_g}{\sigma_p} \text{ x } 100$$

List 2. Categorization of heritability [14]

Category	High	Moderate	Low
Heritability in broad sense	>70%	50-70%	<50%

The expected magnitude of genetic advance (over mean) was computed using the expression suggested by Hanson *et al.* [7].

Genetic advance (G.A.) = $k\sigma_p h^2$
Where,
GA = Genetic advance

σ_p = Phenotypic standard deviation
h^2 = Heritability in broad sense
k = Selection intensity

List 3. Categorization of Genetic Advance [6]

Category	High	Moderate	Low
Genetic Advance as percent of mean	>20%	10-20%	<10%

GCV, PCV, heritability and genetic advance as percent of mean were computed using OP Stat [25] for accurate calculations.

3. RESULTS AND DISCUSSION

To evaluate the relative performance and assess the genetic variability within the selected thirty tomato genotypes, parameters, *viz.,* mean performance, range, variance and coefficients of variation were computed for various fruit yield and its attributing traits under the purview of this study. The perusal of recorded observations revealed highly significant and substantial differences among all the thirty tomato genotypes for fruit yield and its attributing traits (Table 2). This signifies the presence of adequate variability for fruit yield and its attributing traits, which can be utilized in crop improvement programs by selecting thirty genotypes through traits studied hereby such as days to 50% flowering (days), number of branches per plant, days to first picking (days), days to last picking (days), plant height at harvest (cm), number of fruits per plant, average fruit weight (g) and fruit yield per plant (kg) in tomato crop. This might be due to the presence of wide variation among the thirty tomato genotypes collected from various resources. The findings of present investigation are in accordance with Rai *et al.* [8] and Jatav *et al.* [9] in tomato crop also studied the significant differences for most of fruit yield and its attributing traits.

Table 2. Analysis of variance (ANOVA) for fruit yield and its attributing traits in tomato

Sr. No.	Characters	Mean Squares		
		Replication ($2^{\#}$)	Genotype ($43^{\#}$)	Error ($86^{\#}$)
1.	Days to 50% flowering (days)	2.000	29.000	58.000
2.	Number of branches per plant	693.767	112.453**	2.262
3.	Days to first picking (days)	108.116	4.130**	0.788
4.	Days to last picking (days)	604.161	133.329**	2.606
5.	Plant height at harvest (cm)	546.486	131.349**	5.632
6.	No. of fruits per plant	28353.425	2741.837**	85.266
7.	Average fruit weight (g)	1803.703	80.167**	10.962
8.	Fruit yield per plant (kg)	206.323	223.310**	29.637

*Where, * = Significant at 5%, ** = Significant at 1%, #: degree of freedom*

The mean performance values (Table 3) of different genotypes revealed that minimum number of days to 50% flowering were taken by Pusa Ruby (38 days) followed by EC-631351 (40 days) and Selection 7 (41 days). The earliness of the traits is an inherent capacity of the genotypes which transfer from one generation to the other as noted by Jatav *et al.* [9]. The result shows that the tomato genotypes showing earliness for days to 50% flowering were also found early to first harvest and given higher yield. Genotypes Selection 7 (66 days), EC-631351 (66 days) and Pusa Ruby (68 days) were found earliest in fruiting and similar observations were recorded similar to Rai *et al.* [8]. Early flowering and considerable early maturity were the important factors in augmenting total production and economic returns from the promising tomato genotypes. Kashi Hemant (155 days), EC-631427 (149 days) and Pusa Gaurav (146 days) were longer duration genotypes for fruiting. Similarly, Dharva *et al.* [10] reported that this longer harvest period is an advantage if market price fluctuate income tends to even out the early harvest.

The mean values for growth parameter revealed that genotypes EC-698849, EC-631411 and EC-631359 (9) each were reported superior for number of branches per plant. The results of present study are in agreement with those of Chaudhari *et al.* [11] who recorded higher branches in tomato genotypes. Results suggested that higher number of branches resulted into higher number of leaves as well as high photosynthetic activity which enhance the fruit yield. Genotypes EC-687601

(168 cm), EC-698849 (164 cm) and EC-687604 (144 cm) were found superior in plant height at maturity. Kumar *et al.* [12] also reported that the higher plant height in tomato associated with the higher yield.

The mean values for fruit yield traits revealed that genotypes EC-654284 (42) and EC-654289, EC-631457 and EC-687601 (41) each gave maximum number of fruits per plant and for average fruit weight genotypes EC-615056 (57.71 g) Arka Vikas (57.74 g), EC-631357 (56.49 g) and Pusa Early Dwarf (52.02 g) were found to be the best performers among the evaluated germplasm, similar findings were reported by Rai *et al.* [8] in tomato. The maximum fruit yield per plant (kg) was recorded under the genotypes EC-631457 (2.069 kg), EC-631357 (1.926 kg), EC- 617064 (1.802 kg), EC-654284 (1.781 kg) and EC-687601 (1.766 kg). These results are in accordance with Rai *et al.* [8] in tomato. The per se performance indicates that the tomato genotypes with high mean value could be utilized for commercial exploitation.

Table 3: Mean performance values of different tomato genotypes for fruit yield and its attributing traits

Sr. No.	Genotypes	DFF	NB	DFP	DLP	PH	NFP	AFW	FYP
1.	EC-615056	44	8	68	129	73	28	57.71	1.664
2.	EC-617064	46	7	74	133	114	36	49.71	1.802
3.	EC-631351	40	7	66	127	96	34	40.59	1.407
4.	EC-631357	44	7	73	132	136	33	56.49	1.926
5.	EC-631359	45	9	69	129	73	35	37.18	1.294
6.	EC-631404	48	7	76	137	100	31	39.62	1.234
7.	EC-631406	55	8	82	142	70	35	32.63	1.138
8.	EC-631407	45	8	72	132	90	34	44.24	1.473
9.	EC-631411	49	9	75	136	143	32	48.10	1.553
10.	EC-631412	45	6	70	133	113	32	32.76	1.077
11.	EC-631427	54	7	90	149	155	39	32.35	1.280
12.	EC-631457	56	8	84	143	93	41	49.90	2.069
13.	EC-635530	53	7	78	141	124	28	51.32	1.461
14.	EC-635533	53	8	81	140	108	28	44.00	1.215
15.	EC-636877	62	7	78	139	132	29	47.43	1.403
16.	EC-638302	49	5	76	138	79	26	39.29	1.017
17.	EC-654284	53	7	81	139	82	42	41.40	1.781
18.	EC-654289	47	6	74	135	68	41	24.86	1.021
19.	EC-687416	49	6	76	136	112	25	49.49	1.274
20.	EC-687601	51	8	78	139	168	41	42.87	1.766
21.	EC-687604	46	5	74	135	144	37	34.94	1.323
22.	EC-698849	57	9	86	145	164	36	35.60	1.299
23.	Arka Vikas	48	8	73	136	94	24	57.54	1.385
24.	Kashi Hemant	61	5	88	155	76	26	45.49	1.121
25.	PHS	42	4	75	132	77	37	33.11	1.237
26.	Pusa Early Dwarf	53	8	85	139	113	38	52.02	1.903
27.	Pusa Gaurav	59	7	86	146	103	35	43.78	1.527
28.	Pusa Ruby	38	6	68	129	123	38	37.29	1.411
29.	S 12	51	6	68	125	70	37	30.58	1.128
30.	Selection 7	41	6	66	131	65	36	32.89	1.217
	Overall mean	49	7	76	137	105	34	42.17	1.414
	CD at 5%	2.46	1.46	2.64	3.89	15.13	5.43	8.92	0.30
	SE(m)	0.87	0.51	0.93	1.37	5.33	1.91	3.14	0.105
	SE(d)	1.23	0.73	1.32	1.94	7.54	2.70	4.45	0.148
	CV (%)	3.05	12.56	2.11	1.74	8.78	9.79	12.91	12.82

Where, ***DFF:*** *Days to 50 % flowering;* ***NB:*** *Number of branches per plant;* ***DFP:*** *Days to first picking (days);* ***DLP:*** *Days to last picking (days);* ***PH:*** *Plant height (cm);* ***NFP:*** *Number of fruits per plant;* ***AFW:*** *Average fruit weight (g);* ***FYP:*** *Fruit yield per plant (kg).*

Genetic variability, heritability and genetic advance

The degree of available genetic variability determines the pace and quantum of genetic improvement in any crop plant and to estimate the magnitude of such variability, values of phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), broad sense heritability and genetic advance as percent of mean are very helpful. From the findings of present experiment, it was evident that genotypic and phenotypic coefficients of variation showed a wide range of values (Table 4) (Fig 1) for all the characters under the study. In general, narrow difference between PCV and GCV for any character denotes that environment had very little influence in expression of that character and phenotype truly represents the genotype whereas, wide difference among PCV and GCV indicates high susceptibility of that character towards environmental fluctuations.
In the present investigation, it was noticed that values of PCV were slightly higher than corresponding values of GCV in respect of all the characters under study implying the influence of environment in their expression to some degree or other. Similar results with higher values of PCV than corresponding values of GCV were reported by Pooja *et al.* [15] in tomato. High to moderate magnitude of PCV and GCV was recorded for almost all the characters in our investigation. The statistics of range, variance and coefficients of variation infers that there exists a wide spectrum of variation and henceforth, the germplasm possessed ample scope of improvement in fruit yield and its attributing traits through selection, hybridization and various other plant breeding techniques. Results of Shanker *et al.* [16], Mahebub *et al.* [17] and Hussain *et al* [18] who recorded wide variability in genetic parameters of tomato.

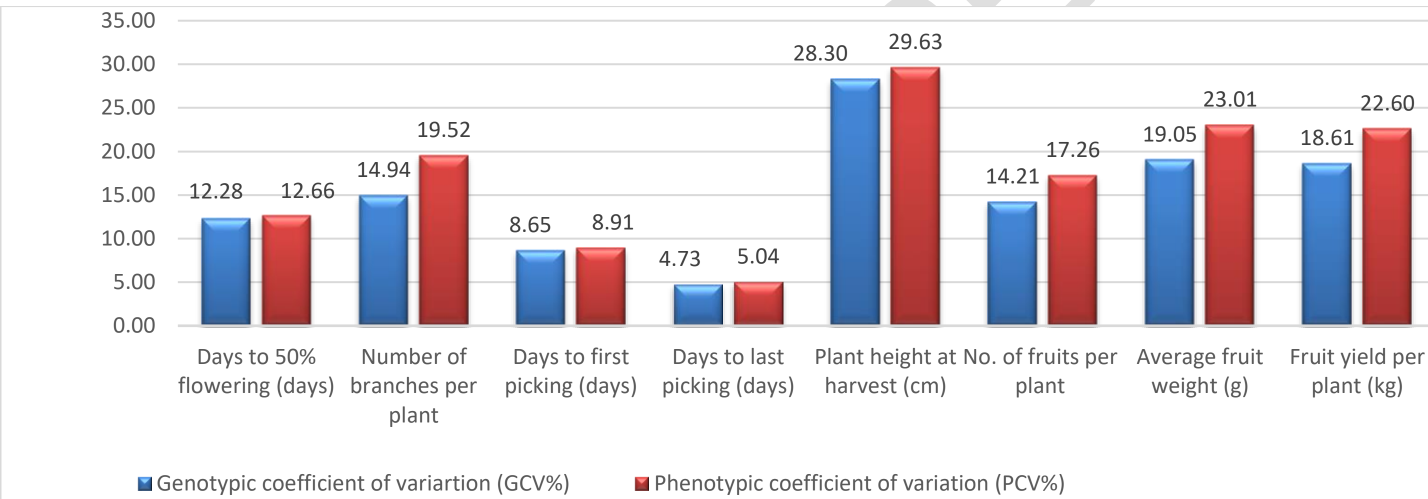

Fig. 1. Graph representing the values of Coefficients of variation (GCV & PCV) for various fruit yield and its attributing traits in tomato

Heritability is the degree to which variability present in a character can be transferred from one generation to another. Hence, it plays an important role in determining whether the phenotypic difference found among various individuals are new to difference in their genetic makeup or simply a result of environmental factors. It is also a proven fact that higher the values of heritability lesser will be the environmental influence on a particular character, denoting better chances of selecting genetically superior individuals. Plant characters days to first picking, days to 50% flowering, days to last picking, plant height at harvest recorded high (>70%) magnitude of heritability in broad sense implying least influence of environment over these characters hence, selection based on them would be more effective. The results from this study are in agreement with Singh *et al.* [19] and Nevani *et al.* [20] who recorded high heritability in tomato crop. Moderate to low heritability was observed in number of branches per plant, number of fruits per plant, average fruit weight, fruit yield per plant, Similarly, results were also reported by Dutta *et al.* [21] and Raut *et al.* [22] in tomato. The effectiveness of selection at any given level of selection intensity is regarded as genetic advance. The study of heritability estimates coupled with genetic advance is more dependable than heritability alone in envisaging the consequential effects of selection [6]. High heritability is not always necessarily associated with high genetic advance. The results from present investigation recorded high values of GCV, PCV and high heritability along with high genetic advance for the trait plant height at harvest. The above-mentioned association of high GCV, heritability and genetic advance may be contributed due to the presence of additive gene action which makes simple selection most suited breeding method for improvement in this trait. The findings of present study are in conformity of Dutta *et al.* [21] in tomato. However, plant trait days to 50% flowering exhibited high estimates of heritability coupled with high genetic advance but moderate to low estimates of GCV indicating moderate variability which still can be improved through selection. The results are in concurrence with Mahebub *et al.* [17]. Contrary to both the above-mentioned situations, plant characters like number of branches per plant, days to first picking, days to last picking, number of fruits per plant, average fruit weight and fruit yield per plant exhibited high to moderate estimates for heritability, moderate to low estimates of genetic advance and GCV marking the plausible presence of non-additive gene action, necessitating hybridization or heterosis breeding in place of selection. Such observations on tomato were also recorded by Aralikatti *et al.* [23], Meena *et al.* [24] and Raut *et al.* [22] who reported presence of non-additive gene action.

Table 4. Grand mean, range, variance, coefficients of variation (GCV & PCV), heritability and genetic advance as % of mean for various fruit yield and its attributing traits in tomato

Characters	Mean	Range		Coefficient of variation		Heritability % (BS)	Genetic advance (% of mean)
		Max.	Min.	Genotypic	Phenotypic		
Days to 50% flowering (days)	49.34	61.86	37.93	12.28	12.66	94.20	24.56
Number of branches per plant	7.07	9.03	4.47	14.94	19.52	58.57	23.55
Days to first picking (days)	76.30	89.80	66.20	8.65	8.91	94.36	17.31
Days to last picking (days)	136.82	154.80	125.47	4.73	5.04	88.15	9.15
Plant height at harvesting (cm)	105.17	168.20	64.73	28.30	29.63	91.22	55.67
Number of fruits per plant	33.81	42.40	24.13	14.21	17.26	67.79	24.09
Average fruit weight (g)	42.17	57.71	24.86	19.05	23.01	68.54	32.49
Fruit yield per plant (kg)	1.41	2.07	1.02	18.61	22.60	67.82	31.58

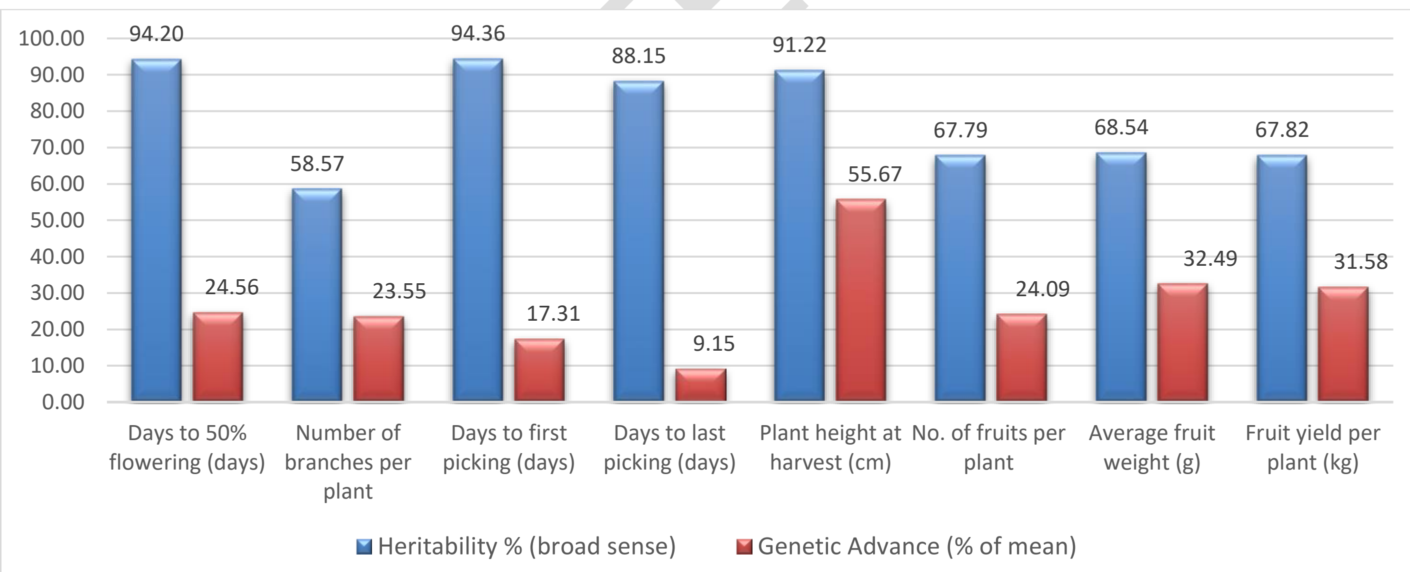

Fig. 2. Graph representing values of Heritability and Genetic advance for various fruit yield and its attributing traits in tomato

4. CONCLUSION

The tomato genotypes EC-631457 (2.069 kg), EC-631357 (1.926 kg), EC- 617064 (1.802 kg), EC-654284 (1.781 kg) and EC-687601 (1.766 kg) were higher fruit yielder, whereas Pusa Ruby, EC-631351, Selection 7, EC-631357 and EC- 615056 were found superior in terms of earliness. Genotypes EC-631351, EC-631357 and EC- 615056 can be purified and used as parental lines for future crosses as these genotypes are early along with high yield. High values of GCV and high heritability along with high genetic advance for plant height at harvest may be contributed due to the presence of additive gene action which makes simple selection most suited breeding method for improvement in this trait. Days to 50% flowering exhibited high estimates of heritability coupled with high genetic advance but moderate to low estimates of GCV indicating moderate variability which still can be improved through selection. Plant characters like number of branches per plant, days to first picking, days to last picking, number of fruits per plant, average fruit weight, fruit yield per plant exhibited high to moderate estimates for heritability, moderate to low estimates of genetic advance and GCV marking the plausible presence of non-additive gene action, necessitating hybridization or heterosis breeding in place of selection.

REFERENCES

1. Jones JB. The field, green house and house garden, Tomato plant culture (CRC Press, LLC 2000, Boca Raton, Florida, 1999).1998; p.199.
2. Anonymous. Area, production and productivity of tomato in Haryana. 2021-2022- Ist advanced estimates. Available: https://www.indiastat.com/table/haryana-state/agriculture/selected-state-wise-area-production-productivity-t/1424759.
3. Anonymous. Food and Agriculture Organisation of the United Nations. 2018. Available: http://faostat3.fao.org/home/E.
4. Patel SA, Kshirsagar DB, Attar AV and Bhalekar MN. Study on genetic variability, heritability and genetic advance in tomato. International Journal of Plant Sciences. 2013;8(1):45-47.
5. Burton GW and Devane EH. Estimating heritability in tall fescue (*Festuca arundinancea*) from replicated clonal materials. Agronomy Journal. 1953;45:478-481.
6. Johnson HW, Robinson HF and Comstock RE. Estimates of genetic and environmental variability in soybean. Journal of Agronomy. 1955;47:314-318.
7. Hanson CH, Robinson HF and Comstock RE. Biometrical studies of yield in segregating population of Korean Lespedeza. Agronomy Journal. 1956;48:268-272.
8. Rai AK, Vikram A and Pandav A. Genetic Variability Studies in Tomato (*Solanum lycopersicum* L.) for Yield and Quality Traits. International Journal of Agriculture, Environment and Biotechnology. 2016;9(5):739-744.
9. Jatav PK, Chikkeri SS, Kumar NM, Bharathkumar MV, Panghal VPS and Duhan DS. Performance of elite genotypes of tomato (*Solanum lycopersicum* Mill.) for yield and quality traits under Hisar Condition, Haryana, India. International Journal of Current Microbiology and Applied Sciences. 2017;*6*(8):2698-2706.
10. Dharva PB, Patel AI, Vashi JM and Chaudhari BN. Heterosis studies for yield and its attributing traits in tomato (*Solanum lycopersicum L.*). International Journal of Chemical Studies. 2018;6(3):1911-1916.
11. Chaudhari GN, Fahrudin B, Ramegowda GK, Ramachandra RK, Bhat AS and Lingaiah HB. Genetic plasticity for yield and yield related traits in minicore accessions of tomato (*Solanum lycopersicum* L.). International Journal of Chemical Studies. 2019;7(1):184-188.
12. Kumar D, Kumar R, Kumar S, Bhardwaj ML, Thakur MC, Kumar R, Thakur KS, Dogra BS, Vikrm A, Thaukr A and Kumar P. Genetic variability, correlation and path coefficient analysis in tomato. International Journal of Vegetable Science. 2013;19:313-323.
13. Sivasubramanian J and Madhavamenon P. Genotypic and phenotypic variability in rice. Madras Agricultural Journal.1973;12:15-16.
14. Robinson HF. Quantitative genetics in relation to breeding on centennial of Mendelism. Indian Journal of Genetics.1966;26:171-187.
15. Pooja HM, Gasti VD, Bhavidoddi A, Yashavantakumar HK, Prashantha A and Srikantaprasad D. Geneticc variability, heritability and genetic advance in determinate types of tomato (*Solanum lycopersicum* L.). The Pharma Innovation Journal. 2022;1(4):222-225.

16. Shanker A, Reddy RVSK, Sujatha M and Pratap M. Genetic variability studies in F_1 generation of tomato (*Solanum lycopersicum* L.). IOSR Journal of Agriculture and Veterinary Science. 2013;4(5):31-34.
17. Mahebub, Ashok P, Babu MR and Sasikala K. Studies on genetic vatiabiltiy in tomato (*Solanum lycopersicum* L.) for growth, yield and quality traits. The Pharma Innovation Journal. 2021;10(10):1741-1743.
18. Hussain K, Lone S, Malik A, Masoodi KZ, Nazir N, Ali G and Farwah S. International Journal of Agricultural and Applied Science. 2021;2(2):60-64.
19. Singh N, Ram CN, Deo C, Yadav GC and Singh DP. Genetic variability, heritability and genetic advance in tomato (*Solanum lycopersicum* L.). Plant Archives. 2015;15(2):705-709.
20. Nevani S and Sridevi O. Genetic variability studies in tomato (*Solanum lycopersicum* L.) for yield and quality traits. Jouranl of Farm Sciences. 2022;35(1):33-36.
21. Dutta P, Hazari S, Karak C and Talukdar S. Study on genetic variability of different tomato (*Solanum lycopersicum*) cultivars grown under open field condition. International Journal of Chemical Studies. 2018;6(5):1706-1709.
22. Raut N, Patil HB, Basavaraj N, Jagadeesha RC, Fakrudin B, Cholin S and Raghavendra S. Assessment of genetic variability in tomato (*Solanum lycopersicum* L.) for yield and yield attributing traits. The Pharma Innovation Journal. 2021;10(4):399-403
23. Aralikatti O, Kanwar HS, Chatterjee S, Patil S and Khanna A. Genetic variability, heritability and genetic gain for yield and quality traits in tomato (*Solanum lycopersicum* L.). International Journal of Chemical Studies. 2018; 6(5):3095-3098.
24. Meena RK, Kumar S, Meena ML and Verma S. Genetic variability, heritability and genetic advance for yield and quality attributes in tomato (*Solanum lycopersicum* L.). Journal of Pharmacognosy and Phytochemistry.2018;7(1):1937-1939.
25. Sheoran OP, Tonk DS, Kaushik LS, Hasija RC and Pannu RS. Statistical Software Package for Agricultural Research Workers. Recent Advances in information theory, Statistics & Computer Applications by DS Hooda & RC Hasija Department of Mathematics Statistics, CCS HAU, Hisar. 1998; :139-143.