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Studies on genetic variability, heritability and genetic advance for yield and quality traits in tomato (*Solanum lycopersicum* L.)

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Abstract
A study was conducted at Vegetable Research Farm, DRPCAU, Pusa, Samastipur, Bihar during *rabi* 2015-16 to evaluate the genotypes of tomato (*Solanum lycopersicum* L.) for yield and quality. Investigation was carried out on variability for different morpho-physiological characters of 24 genotypes which were grown in Randomized Block Design with three replications. In the present investigation, genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were high for lycopene content, average fruit weight, number of fruits per plant, fruit yield per hectare, fruit yield per plant, titrable acidity, number of locules per fruit, number of primary branches per plant, ascorbic acid and plant height at maturity indicating high amount of variation for above mentioned traits in tomato revealed existence of broad genetic base, which would be amenable for further selection. High heritability (>60%) coupled with high estimates of genetic advance as percent of mean (GAM) have been observed for all the characters which is mentioned above except days to flower initiation, days to fruit initiation, days to fruit maturity at physiological stage, zinc content and iron content. This is indicating the presence of additive gene effect which may be utilized for improvement through phenotypic selection for yield improvement.

Keywords: Genotypic coefficient of variation, phenotypic coefficient of variation, heritability, genetic advance over mean

Introduction
Tomato (*Solanum lycopersicum* L.) is an important member of Solanaceous family having chromosome number 2n = 2X = 24. It originated in wild form in the Peru-Ecuador-Bolivia region of Andes (South America) and is grown in almost every corner of the world (Robertson and Labate, 2007) [26]. It is typical day neutral plant and is mainly self-pollinated, but a certain percentage of cross-pollination also occurs (Depra *et al*., 2014) [5]. Tomato is universally known as "Protective Food" (Thamburaj and Singh, 2013) [28]. It is a reservoir of diverse antioxidant molecules, such as ascorbic acid, vitamin E, carotenoids, flavonoids and phenolic acids. Tomatoes are important source of lycopene and β-carotene and valued for their colour and flavour. In tomato total antioxidant capacity ranges from 80 to 200 πmol TEAC/100 g fw (Odriozola-Serrano *et al*., 2008) [20], lycopene varies between 4.31 to 5.97 mg/100g (Kaur *et al*., 2013) [11], total phenolic content ranges from 9.20-22 mg/100g (FW) (George *et al*., 2004) [7], Ascorbic acid contents of tomatoes have been found to vary according to colour and it ranged from 23.21-40.44 and 24.38-33.87 mg/100g in red and yellow cultivars, respectively (Singh *et al*, 2010) [34]. A survey made by M.A. Stens indicated that among the main fruits and vegetables, tomato ranks 16th as the source of both vitamins A and C (Thamburaj and Singh,

2013) [28]. Dietary intake of lycopene is epidemiologically correlated with diminished risk of prostate cancer and it has been found to be superior to α-and β-carotene in inhibiting cell proliferation in various human epithelial cancer cell lines (Giovannucci, 1999) [8] and contain moderate amounts of lutein that reduces risk of lung cancer (Sies, 1991) [32].

India is a source of diversity genotypes of tomato. Identification of superior genotypes among the existing germplasm becomes extremely important for future breeding programme and also for promoting production per unit area. The development of an effective improvement programme depends upon the existence of genetic variability and knowledge of genotypic and phenotypic correlation of yield and yield attributing components. Genetic variability is the measure of the tendency of individual genotypes in a population to vary from each other. Variability depends on genetic factors, environmental factors, (edaphic & climatic factor), bioactive compounds (caused by physiological factors) *etc*. Galton (1889) [6] observed that a part of the continuous variation is due to heritability. The degree to which the variability of a quantitative character is transmitted to the progeny is referred as heritability. It provides useful biometrical concept and has been considered to be an index of effectiveness of selection because it helps in proportioning the total variation into heritable and environmental effects.

Materials and methods

The present investigation was carried out at Vegetable Research Farm, DRPCAU, Pusa, Samastipur, Bihar during *rabi* 2015-16. The experimental materials comprised of twenty-four genotypes of tomato collected from two different sources. The experiment was laid out in a randomized block design with three replications accommodating 10 plant in each. Seeds were transplanted at a spacing of 60×45 cm. The genotypes studied are sweet 72, PT-2009-08, EC-519823, EC-519778, CN-2237 A, Arka Alok, Cherry Tomato, PT-41, CLN-2123E, Utkal Pallavi, Arka Abha, EC-519770, EC-519758, CLN-1154R, CLN-2870A, Big Oval 2009, S-108, Sherozi, Nandhi, CO-3, Azad T-5, Avinash-221, Arka Meghali and Masina. All the recommended cultural practices were adopted for raising the crop successfully. The experimental details and observations to be recorded as follows: The observations were recorded on five randomly selected plants per replication for each genotype on eighteen characters:

i) Plant height at maturity (cm)
ii) Number of primary branches per plant
iii) Number of days to flower initiation
iv) Number of days to fruit initiation
v) Number of days to fruit maturity at physiological stage
vi) Diameter of fruit (cm)
vii) Length of fruit (cm)
viii) Number of locules per fruit
ix) Number of fruits per plant
x) Average fruit weight (g)
xi) Yield per plant (kg)
xii) Yield per hectare (quintal)
xiii) Total soluble solids (%)
xiv) Titrable acidity (%)
xv) Zinc content (mg/100g)
xvi) Iron content (mg/100g)
xvii) Lycopene content (mg/100g)
xviii) Ascorbic acid content (mg/100g)

Mean across the replications were calculated for each traits and the analysis of variation was carried out. Genotypic and phenotypic variation and coefficients of variation, broad sense heritability and genetic advance were estimated using the formula suggested by Panse and Sukhatme, (1967).

Result and discussion

Genetic Parameters of Variability

Genetic variability is one of the important consideration or aspects in any crop improvement which is need to study in detail. Variability is a measure by estimation of genotypic and phenotypic variance (σ^2_g and σ^2_p), genotypic and phenotypic coefficient of variation (GCV and PCV), heritability, genetic advance and genetic advance as per cent of mean. These parameters help in selection for improvement of desired characters.

Environment plays an important role in the expression of phenotype. The phenotypic variability which is observable includes both genotypic (heritable) and environmental variation (non-heritable). Hence, variability can be observed through biometric parameters like GCV, heritability (broad sense) and genetic advance. The estimation of these parameters for all characters studied has been given in table 4 and findings have been explained under following heads.

Phenotypic variability

The data in Table 3 depicted a wide range of phenotypic variability for fruit yield per hectare (22115.911) followed by average fruit weight (476.661) plant height at maturity (449.898), number of fruits per plant (213.907), and days to fruit maturity at physiological stage (163.232). The characters like days to flower initiation (57.006), days to fruit initiation (45.426) and ascorbic acid (25.925) exhibited moderated range of variability whereas zinc content (0.001), iron content (0.001), titrable acidity (0.023), fruit yield per plant (0.232), fruit diameter (0.513), fruit length (0.522), number of locules per fruit (0.721), total soluble solid (0.610), lycopene content (1.947) showed narrow range of phenotypic variability. Similar kinds of observations were also reported by Pujari *et al*. (1995) [25], Mittal *et al*. (1996) [15], Dar *et al.* (2011) [3], Dar and Sharma (2011) [3], Shankar *et al.* (2013) [30], Meitei *et al.* (2014) [14].

Genotypic variability

The scrutiny of Table 3 revealed that wide range of genotypic variability was present for yield per hectare (18540.885) followed by average fruit weight (462.312), plant height at maturity (386.919), number of fruits per plant (207.504) and days to fruit maturity at physiological stage (123.261). The character like days to flower initiation (31.386), ascorbic acid (24.912) and days to fruit initiation (24.282) exhibited moderate range of variability However, the remaining traits showed low variability.Similar kinds of observations were also reported by Pujari *et al*. (1995) [25], Mittal *et al*. (1996) [15], Dar *et al.* (2011) [3], Dar and Sharma (2011) [3], Shankar *et al.* (2013) [30], Meitei *et al.* (2014) [14].

Phenotypic and Genotypic Coefficient of Variation (PCV and GCV)

A perusal of Table 3 revealed that phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the traits under investigation. The narrow difference between PCV and GCV were recorded for most of the traits except iron content, yield per plant, yield per hectare, days to flower initiation and days to fruit initiation. A wide range of PCV was observed for the traits under investigation ranged from 6.681 (iron content) to 68.895

(lycopene content). The high PCV was recorded for the traits lycopene content (68.895), followed by average fruit weight (48.639), number of fruits per plant (47.557), fruit yield per hectare (40.297), fruit yield per plant (40.278), titrable acidity (32.253), number of locules per fruit (28.991), number of primary branches per plant (27.574), ascorbic acid (25.673) and plant height at maturity (24.083) whereas fruit diameter (18.913), fruit length (18.706), total soluble solid (17.021), days to flower initiation (12.143), days to fruit maturity at physiological stage (11.734), and zinc content (11.096) showed moderate PCV value. However the traits days to fruit initiation (8.471) and iron content (6.681) depicted low PCV value.

GCV ranged from 1.701 (iron content) to 68.425 (lycopene content). The highest GCV was recorded for the traits lycopene content (68.425), followed by average fruit weight (48.004), number of fruits per plant (46.839), fruit yield per hectare (36.897), fruit yield per plant (36.874), titrable acidity (31.361), number of locules per fruit (27.914), number of primary branches per plant (26.525), ascorbic acid (25.167) and plant height at maturity (22.338) whereas fruit diameter (17.019), fruit length (16.614) and total soluble solid (16.183) days and to fruit maturity at physiological stage (10.197) showed moderate GCV value. However, the traits zinc content (9.774), days to flower initiation (9.010), days to fruit initiation (6.193) and iron content (1.701) showed low PCV value.Similar kinds of observations were also reported by Pujari *et al.* (1995) [25], Mittal *et al.* (1996) [15], Dar *et al.* (2011) [3], Dar and Sharma (2011) [3], Shankar *et al.* (2013) [30], Meitei *et al.* (2014) [14].

Heritability and Genetic Advance as per cent of Mean

The heritability in broad sense and genetic advance as per cent of mean was worked out for all the characters, have been presented in table 4 and their performance adjudged on the basis given by Robinson *et al.* (1949) [27] for heritability and Johnson *et al.* (1955) [9] for genetic advance as per cent of mean.

Category	Heritability (broad sense)	Genetic Advance as per cent of mean
High	> 60%	> 20%
Moderate	30 %-60%	10% -20%
Low	< 30%	< 10%

On the basis of above characterization it was clear from table that all traits showed high heritability except days to flower initiation, days to fruit initiation and iron content. The highest heritability in broad sense was recorded for lycopene content (98.6), average fruit weight (97.4), number of fruits per plant (97.0), ascorbic acid (96.1), titrable acidity (94.5), number of locules per fruit (92.7), number of primary branches per plant (92.5), plant height at maturity (86.0) fruit yield per hectare (83.8), fruit yield per plant (83.8), fruit diameter (17.019), fruit length (78.9), zinc content (77.6) and days and to fruit maturity at physiological stage (75.5). Days to flower initiation (55.1) and days to fruit initiation (53.5) showed moderate heritability. Iron content showed low heritability. High estimates of heritability for these traits were also observed by Singh and Singh (1993) [33], Kumari and Subramanian (1994) [12], Nair and Thamburaj (1995) [17], Pujari *et al.* (1995) [25], Mittal *et al.* (1996) [15], Das *et al.* (1998) [4], Prasad and Rai (1999) [23], Sharma *et al*. (2006) [31], Mehta and Asati (2008) [13], Dar and Sharma (2011) [3], Mohamed *et al.* (2012) [16], Chernet *et al.* (2013) [2], Saleem *et al.* (2013) [29], Nwosu *et al.* (2014) [19].

A perusal of genetic advance as per cent of mean (Table 3) revealed that it ranges from 0.892 to 139.993. The result showed that all attributes exhibited high genetic advance as per cent of mean except days to flower initiation, days to fruit initiation, days to fruit maturity at physiological stage, zinc content and iron content. Days to flower initiation, days to fruit maturity at physiological stage, zinc content showed medium genetic advance as per cent of mean. Days to fruit initiation and iron content exhibited low genetic advance as per cent of mean.Similar kind of results were observed in tomato for the traits like plant height and fruit yield per plant by Singh and Singh (1993) [33], Pujari *et al.* (1995) [25], Mittal *et al.* (1996) [15], Das *et al.* (1998) [4], Prasanth *et al*. (2007) [24], Mehta and Asati (2008) [13], Mohamed *et al.* (2012) [16] and Ahirwar *et al.* (2013) [1].

Table 1: Analysis of Variance for eighteen characters in tomato

Sl. No.	Characters	Mean Sum of Squares		
		Replication	Treatment	Error
1	Plant height at maturity (cm)	9.0079	1223.7344**	62.9790
2	Primary branches per plant	0.1006	9.1632**	0.2400
3	Days to flower initiation	9.7445	119.7771**	25.6200
4	Days to fruit initiation	5.1610	93.9897**	21.1440
5	Days to fruit maturity at physiological stage	18.3425	409.7549**	39.9710
6	Fruit diameter(cm)	0.1038	1.3441**	0.0976
7	Fruit length (cm)	0.2100	1.3467**	0.1103
8	No. of locules per fruit	0.0055	2.0578**	0.0526
9	No. of fruits per plant	4.0061	628.9152**	6.4031
10	Yield per plant (kg)	0.0009	0.6202**	0.0375
11	Yield per hectare (quintal)	81.6176	59197.6808**	3575.0258
12	Average fruit weight (g)	5.2533	1405.2842**	12.3488
13	Total Soluble Solid (%)	0.0018	1.7134**	0.0586
14	Titrable acidity (%)	0.0021	0.0660**	0.0012
15	Zinc (mg/100g)	0.0002	0.0029**	0.0003
16	Iron (mg/100g)	0.0001	0.0013	0.0011
17	Lycopene (mg/100g)	0.0325	5.7891**	0.0265
18	Ascorbic acid (mg/100g)	0.5863	75.7494**	1.0125

**-P = 0.01

Table 2: Mean, Range and coefficient of variation for eighteen characters in tomato

Sl. No.	Characters	Mean	Range		CV
			Min.	Max.	
1	Plant height at maturity (cm)	88.08	63.55	125.23	9.01
2	Primary branches per plant	6.50	4.18	9.70	7.53
3	Days to flower initiation	62.18	54.20	79.60	8.14
4	Days to fruit initiation	79.56	71.05	91.73	5.78
5	Days to fruit maturity at physiological stage	108.88	92.02	134.44	5.81
6	Fruit diameter (cm)	3.79	2.75	4.85	8.25
7	Fruit length (cm)	3.86	2.74	4.83	8.60
8	No. of locules per fruit	2.93	1.92	4.97	7.83
9	No. of fruits per plant	30.76	6.98	77.50	8.23
10	Yield per plant (kg)	1.20	0.57	1.82	16.21
11	Yield per hectare (quintal)	369.04	176.13	562.24	16.20
12	Average fruit weight (g)	44.89	13.14	105.11	7.83
13	Total Soluble Solid (%)	4.59	3.70	6.96	5.28
14	Titrable acidity (%)	0.47	0.23	0.74	7.53
15	Zinc (mg/100g)	0.30	0.25	0.35	5.25
16	Iron (mg/100g)	0.51	0.46	0.55	6.46
17	Lycopene (mg/100g)	2.03	0.47	5.49	8.04
18	Ascorbic acid (mg/100g)	19.83	11.64	31.48	5.07

Table 3: Genetic parameter ofeighteen characters in tomato

Sl. No.	Character	σ^2_g	σ^2_p	GCV	PCV	H^2 (b.s)	G.A as % of mean
1	Plant height at maturity	386.919	449.898	22.334	24.083	86.000	42.666
2	No. of primary branches/plant	2.974	3.214	26.525	27.575	92.500	52.562
3	No. of days to flower initiation	31.386	57.006	9.010	12.143	55.100	13.770
4	No. of days to fruit initiation	24.282	45.426	6.193	8.471	53.500	9.328
5	No. of days to fruit maturity at physiological stage	123.261	163.232	10.197	11.734	75.500	18.253
6	Diameter of fruit (cm)	0.416	0.513	17.019	18.913	81.000	31.550
7	Length of fruit (cm)	0.412	0.522	16.614	18.706	78.900	30.398
8	No. of locules/fruit	0.668	0.721	27.914	28.991	92.700	55.368
9	No. of fruits/plant	207.504	213.907	46.839	47.556	97.000	95.032
10	Average fruit weight (g)	464.312	476.661	48.004	48.639	97.410	97.600
11	Fruit yield/plant (kg)	0.194	0.232	36.874	40.278	83.800	69.541
12	Fruit yield/hectare quintal	18540.885	22115.911	36.897	40.298	83.800	69.594
13	Total soluble solid	0.552	0.610	16.183	17.021	90.400	31.694
14	Titrable acidity (%)	0.022	0.023	31.361	32.253	94.500	62.816
15	Zinc content (mg/100g)	0.001	0.001	9.774	11.096	77.600	17.738
16	Iron content (mg/100g)	0.000	0.001	1.701	6.681	6.500	0.892
17	Lycopene content (mg/100g)	1.921	1.947	68.425	68.895	98.600	139.993
18	Ascorbic acid content (mg/100g)	24.912	25.925	25.167	25.673	96.100	50.822

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