



Research Article

GENETIC CHARACTERIZATION AND CHARACTER ASSOCIATIONSHIP STUDIES OF PURPLE TOMATO LINES BASED ON DIFFERENT HORTICULTURAL TRAITS WITH RESPECT TO CHECK GENOTYPES

ROY S.¹, PANDIT P.^{2*}, SAHA S.¹, PRABHAT KUMAR³ and KARAK C.¹

¹Department of Vegetable Science, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, 741252, West Bengal, India

²Department of Agricultural Statistics, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, 741252, West Bengal, India

³Department of Agricultural Statistics, Applied Mathematics and Computer Science, University of Agricultural Sciences, Bengaluru, 560065, Karnataka, India

*Corresponding Author: Email - pramitpandit@gmail.com

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Abstract: Keeping in view the health benefits of Anthocyanin flavonoid and that traditional tomatoes don't normally produce them, the study of genetic evaluation and characterization of novel breeding line-"purple tomato" genotypes are of relevant importance for nutritional security of consumers. This study aimed to characterize, evaluate as well as to establish the interrelationship between different important horticultural traits of purple tomato lines using suitable statistical tools with respect to checks to test the feasibility of commercialization of these new nutritionally rich genotypes of tomato. In this context, the present investigation was carried out with the 9 breeding lines of purple tomato, along with its two parental lines and two check genotypes (one popular cultivar and one multiple resistant hybrid) at Central Research Farm, Gayeshpur, B.C.K.V., Nadia, West Bengal during autumn-winter. The study revealed that wide variation was observed in the different traits, suggests segregation in different characters in the lines which needs to be stabilized through advancement of generations and subsequent selection. Analysis of Variance clearly showed the presence of wide genetic variability for the character concerned among the genotypes. The highest yielding purple tomato line was BCPT 7-4-4 (6.10 Kg fruit per plant). The study showed that 5 Purple tomato lines viz. BCPT 7-4-4, BCPT- 7-4-3, BCPT-7-4-2, BCPT 7-4-1, BCPT 7-1-3 significantly outclassed the popular hybrid and cultivar with respect to fruit weight. On the basis of correlation studies, the selection for number of fruits per plant, flower cluster per plant, pericarp thickness, polar diameter of fruit would be effective for developing plants with higher fruit yield in purple tomato. It was evident that Purple tomato lines can very well be placed as a line bred variety for commercial cultivation in competition with other line bred variety and even hybrids.

Keywords: Character associationship, Genetic characterization, Horticultural traits, Purple tomato

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Introduction

Tomato is of prime important member of Solanaceae family which consists of 96 genera and over 2800 species distributed in 3 subfamilies, Solanoideae (to which Solanum belongs), Cestroidae, and Solanineae [1]. It is native to Central and South America [2]. It is grown in almost every corner of the world [3]. It is a versatile vegetable for culinary purpose. Tomato is a good source of vitamins, minerals and organic acids. Fresh fruits of tomato are in great demand round the year throughout the country. These are good source of potassium, folate and vitamin E, soluble and insoluble dietary fibres. They are rich source of lycopene and Ascorbic acid [4]. Although a ripe tomato fruit contains as much as 93 to 94 percent water, yet, it has high nutritive value. The total sugar content varies from 2.5-4% in ripe fruits, ascorbic acid varies from 16-65mg/100g of fruit weight. It is a good source of vitamin A and B as well. Lycopene, the red pigment in tomato fruit is the predominant carotene, comprising up to 90% of the total carotenoids. These pigments also function as antioxidants, proven to protect the human body from oxidative damage that may lead to heart disease, cancer and ageing. However, tomato fruits do not usually produce anthocyanins unlike the fruits of the other members of Solanaceae family due to lack of expression of the *chalcone isomerase (CH1)* gene in the flavonoid biosynthetic pathway in the peel of the tomato fruit. Nine novel breeding lines "Purple Tomato" rich in both red carotenoid pigment "lycopene" and purple-violet "anthocyanin" pigment have been developed by introgressing two specific genes: Lycopene enhancing "dg" present in chromosome 1 of the genotype BCT-115 dg and Anthocyanin fruit gene "Aft" in chromosome 10 of the genotype Alisa Craig in one genotype (Aft Aft dg dg) following conventional breeding method [5].

In this breeding programme, only 9 segregates bred true with respect to dark green fruit coupled with purple anthocyanin pigmentation which established the presence of two specific genes in one genotype, "Purple tomato". Hence, the "Purple tomato" line is comprised of 9 segregating lines emanated from the same breeding scheme. With the introgression of two specific genes, lycopene and anthocyanin contents have somewhat been stabilized in those lines however, for different quantitative characters including growth characters and fruit yield components and other proximate compositions, the lines are still segregating. Such breeding programme need to be continued at least upto F6 generation with the exercise of selection till the stable desirable lines are composited to develop the variety. Accordingly, 9 promising lines of "Purple tomato" could be isolated in F4 generation.

Materials and Methods

The field experiments were carried out at Central Research Farm, Gayeshpur, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal during autumn-winter season. Topographic situation of the experimental site comes under Gangetic new alluvial plains of West Bengal with sandy loam soil. Nine F5 lines of purple tomato viz. BCPT 7-4/2-2, BCPT 7-4/2-1, BCPT 7-4-4, BCPT 7-4-3, BCPT 7-4-2, BCPT 7-4-1, BCPT 7-1-3, BCPT 7-1-2, BCPT 7-1-1, two parental lines of purple tomato viz. Alisa Craig Aft & BCT-115 dg and two check genotypes Arka Rakshak (multiple disease resistant hybrid) & Patharkuchi (popular land race) maintained at the Department of Vegetable Science, Bidhan Chandra Krishi Viswavidyalaya constituted the genotypes for the investigation. The 13 genotypes were evaluated considering different fruit quality traits and reaction to diseases.

Table-1 Analysis of variance for different vegetative growth, flowering & fruit yield components of the lines of purple tomato and other genotypes

Character	Mean sum of squares		
	Genotypes	Replication	Error
Plant height	1451.489**	8.169	6.077
No. of branches/plant	3.110**	0.389	0.127
Days to flower	69.650**	0.71	0.793
Flower clusters/plant	78.064**	0.672	0.453
Flowers/cluster	0.554**	0.161	0.108
Fruit weight	2076.085**	7.417	14.776
Polar diameter	0.988**	0.0085	0.079
Equatorial diameter	1.670**	0.203	0.038
Locule no/fruit	0.787**	0.099	0.05
Pericarp thickness	0.19**	0.054	0.027
100 seed weight	0.125**	0.043	0.032
No. of fruits/plant	1698.823**	49.476	10.345

* - Significant at 5 percent level, ** - Significant at 1 percent level

Table-2 Mean Plant growth and flowering characters of the lines of purple tomato and other genotypes

Genotypes	Traits					
	Purple tomato	Plant height (cm)	No. of branches/plant	Days to flower	Flower clusters/plant	Flowers/cluster
BCPT 7-4/2-2	66.623	5.59	41.277	8.35	5.747	43.993
BCPT 7-4/2-1	58.817	5.923	39.487	8.06	5.44	46.523
BCPT 7-4-4	73.037	6.807	34.18	10.02	5.417	61.29
BCPT 7-4-3	57.923	5.787	32.63	9.63	4.837	63.627
BCPT 7-4-2	48.25	4.87	31.603	9.047	5.03	47.907
BCPT 7-4-1	50.43	6.147	32.763	9.86	5.427	54.4
BCPT 7-1-3	40.48	4.813	38.803	6.523	4.64	34.027
BCPT 7-1-2	51.593	5.637	46.163	8.95	5.48	45.583
BCPT 7-1-1	63.907	5.863	41.293	11.047	5.857	67.78
Alisa Craig Aft (Parent)	47.76	5.713	34.78	14.413	5.963	75.597
BCT 115dg (Parent)	56.97	6.843	39.753	11.36	5.597	85.57
Arka Rakshak (Check: Hybrid)	105.103	6.693	44.273	26.403	6.133	114.01
Patharkuchi (Check: Cultivar)	114.123	8.757	43.08	15.247	5.42	101.22
Cv(%)	3.838	5.83	2.316	5.874	6.03	4.969
S.E.M	1.423	0.206	0.514	0.388	0.19	1.857
S.E.d	2.013	0.291	0.727	0.549	0.269	2.626
C.D. at 5%	4.179	0.604	1.51	1.141	0.558	5.452

Table-3 Mean fruit, seed characters and fruit yield of the lines of purple tomato and other genotypes

Genotypes	Traits						
	Purple tomato	Fruit wt. (g)	Polar diameter (cm)	Equatorial diameter (cm)	Locule no. / fruit	Pericarp thickness (cm)	100 seed weight (g)
BCPT 7-4/2-2	58.847	3.877	4.427	4.727	0.47	0.375	2.597
BCPT 7-4/2-1	66.31	4.377	4.62	3.49	0.53	0.337	3.053
BCPT 7-4-4	122.21	4.49	4.787	4.367	0.687	0.357	6.103
BCPT 7-4-3	126.203	4.253	5.213	3.923	0.77	0.345	5.613
BCPT 7-4-2	134.26	5.09	6.17	4.35	0.593	0.315	5.697
BCPT 7-4-1	106.193	4.743	6.173	4.117	0.647	0.337	5.053
BCPT 7-1-3	127.767	5.473	6.607	4.25	0.63	0.344	4.73
BCPT 7-1-2	62.763	4.82	4.513	4.03	0.52	0.336	2.853
BCPT 7-1-1	70.227	4.62	4.543	3.787	0.567	0.342	4.693
Alisa Craig Aft (Parent)	95.77	4.71	5.923	3.983	0.583	0.301	4.827
BCT 115dg (Parent)	93.73	4.973	4.977	4.02	0.55	0.339	5.497
Arka Rakshak (Check: Hybrid)	87.083	6.183	5.217	2.593	0.677	0.397	9.76
Patharkuchi (Check: Cultivar)	92.227	4.84	5.817	3.883	0.59	0.389	5.157
Cv(%)	6.165	5.834	3.691	5.667	7.624	2.62	9.014
S.E.M	3.405	0.162	0.113	0.13	0.026	0.005	0.263
S.E.d	4.815	0.229	0.16	0.183	0.037	0.007	0.372
C.D. at 5%	9.997	0.475	0.332	0.381	0.078	0.015	0.771

The genotypes were grown in randomized block design with 3 replications under autumn - winter season (planting in mid of October) keeping 30 plants in each replication in 60 x 60 spacing in both ways to study the expression of different characters in them. Five random plants per replication in each genotype were selected for recording the data on different characters. The seeds of all the genotypes, were sown on 25th September, 2017 in raised bed nursery. The seedlings were transplanted in the main field on 30 October, 2017. The quantitative traits under study were- Plant height (cm), Primary branches per plant, Days to first flowering (after transplanting), Flower clusters per plant, Flowers per cluster, Fruits per plant, Fruit weight (g), Equatorial diameter of fruit (mm), Polar diameter of fruit (mm), Locule number per fruit, Pericarp thickness (mm), 100 seed

weight (g) Total number of fruits of marketable size and maturity of the periodical harvests were considered in recording fruit yield per plant. All misshaped, small and cull fruits were discarded at the time of fruit harvest. After taking fruit weight (g), the fruits will be cut into two halves and pericarp thickness (mm) and locule number were recorded. The jelly-like materials along with the seeds were kept in small containers for fermentation. After two days, all pulpy substances and chaffy seeds which floated were discarded and the seeds which settled at the bottom of the container were collected after thorough washing in running water. Total seed number of five sampled fruits was then averaged to record seed number per fruit in each replication. Weight of 100 dry seeds from the 5 sampled fruits per replication was recorded as test weight of seed.

Table-4 Correlations among different growth, flower, fruit, seed and fruit yield of tomato

	PH	NBPP	DF	FCPP	FPC	FPP	FW	PD	ED	LN	PT	100SW	FYPP
PH	1	0.823**	0.473	0.721**	0.414	0.782**	-0.216	0.261	-0.176	-0.506	0.133	0.849**	0.490
NBPP		1	0.319	0.481	0.324	0.746**	-0.154	0.056	-0.120	-0.292	0.094	0.599*	0.289
DF			1	0.344	0.434	0.299	-0.745**	0.255	-0.463	-0.391	-0.499	0.550	-0.095
FCPP				1	0.634*	0.888**	-0.122	0.637*	0.019	-0.787**	0.260	0.512	0.791**
FPC					1	0.561*	-0.664*	0.088	-0.457	-0.432	-0.353	0.224	0.198
FPP						1	-0.081	0.457	-0.018	-0.658*	0.254	0.498	0.707**
FW							1	0.250	0.702**	0.218	0.727**	-0.240	0.435
PD								1	0.447	-0.615*	0.268	0.215	0.728**
ED									1	0.097	0.358	-0.245	0.274
LN										1	-0.267	-0.348	-0.619*
PT											1	0.112	0.665*
100SW												1	0.365
FYPP													1

*- Significant at 5 percent level, **- Significant at 1 percent level

Pulp of the cut fruits was used to make replication-wise composite sample to estimate the following fruit quality characters on fresh weight basis. The 13 genotypes were grown in autumn-winter season in randomized block design with 3 replications keeping 20 plants each for the genotype. Standard agronomic practices were followed however the plants were not sprayed with any pesticide. The genotypes were evaluated for incidence of tomato leaf curl virus disease. The disease incidence was recorded from all the plants in the block by visual evaluation of disease symptom for single plant after 60 days transplanting which was then expressed as percentage. The collected data were statistically analyzed. Mean values of each entry in each replication for all the traits were subjected to statistical analysis by using MS Excel software. For analysis of variance, Data were analyzed by using the mean values of random plants in each replication from all treatments to find out the significance of treatment effect [6]. The significance was tested by referring to the values of F table [7]. Correlation is a measure to find out linear association between two variables. The formula is given as the following,

$$r(x_1, x_2) = \frac{\text{Cov}(x_1, x_2)}{\sqrt{V(x_1) \cdot V(x_2)}}$$

Where, $r(x_1, x_2)$ = correlation between x_1, x_2

$V(x_1)$ = variance of x_1 ; $V(x_2)$ = variance of x_2

Results and Discussions

Mean sum of squares presented in [Table-1] clearly suggested significant difference among the 13 genotypes of tomato (9 purple tomato lines, 2 parental lines and 2 check variety /hybrid) for all the quantitative traits even at 1% level of significance which clearly endorsed the presence of wide genetic variability for the character concerned among the genotypes. This analysis also justified the utilization of these genotypes for such evaluation study. Coefficient of variation expressed as percentage ratio of the standard deviation to the corresponding mean of the concerned characters has been presented in the [Table-2] and [Table-3] Coefficient of variation was low, below 10 % for all the characters indicating minimum influence of environment for the expression of these characters. Range for the different fruit quality traits of purple tomato lines are discussed character wise.

Range for different characters in the “Purple tomato” lines

In the current experiment, with a view to identify the best ‘Purple tomato’ lines, 13 genotypes of tomato (nine purple tomato lines, two parental lines and two check varieties) were evaluated for different horticultural characters. Different character means of the aforesaid genotypes have been presented in the tabular form.

Plant growth and flowering characters

Plant height

Plant height ranged between 40.48 cm in BCPT 7-1-3 and 73.04 cm in BCPT 7-4-4 among the purple tomato lines. Average plant height of the purple tomato lines was higher than the parental average however, it was much lesser than the check variety/ hybrid.

Number of primary branch / plant

Number of primary branches per plant ranged between 4.81 in BCPT7-1-3 and 6.16 in BCPT 7-4-1 among the purple tomato lines. Average primary branches per plant of the purple tomato lines was higher than the parental average however, it was much lesser than the check.

Days to first flowering

Days to first flowering ranged between 31.60 in BCPT 7-4-2 and 46.16 in BCPT 7-1-2 among the purple tomato lines. Average days to first flower of the purple tomato lines were at par with that of the parental average as well as the check.

Flower cluster per plant

Flower cluster per plant ranged between 6.52 in BCPT7-1-3 and 10.02 in BCPT 7-4-4 among the purple tomato lines. Average number of flower cluster per plant of the purple tomato lines was lesser than the parental average as well as the check variety/ hybrid.

Flowers per cluster

Flower per cluster ranged between 4.64 in BCPT 7-1-3 and 5.85 in BCPT 7-1-1 among the purple tomato lines. Average number of flower per cluster of the purple tomato lines was also lesser than the parental average as well as the check variety/ hybrid.

Fruit, seed characters and fruit yield

Fruit number per plant

Fruit number per plant ranged between 34.02 in BCPT 7-1-3 and 67.78 in BCPT 7-1-1 among the purple tomato lines. Average number of fruits per plant of the purple tomato lines was lesser than the parental average as well as the check variety/ hybrid.

Fruit weight (g)

Average fruit weight ranged between 62.76 g in BCPT7-1-2 and 134.26 g in BCPT 7-4-2 among the purple tomato lines. Average fruit weight of the purple tomato lines was slightly higher than the parental average as well as the check variety/ hybrid.

Equatorial diameter (cm)

Equatorial diameter of fruit ranged between 4.43 cm in BCPT 7-4/2-2 and 6.61 cm in BCPT 7-1-3 among the purple tomato lines. Average equatorial diameter of fruit of the purple tomato lines was slightly higher than the parental average as well as the check variety/ hybrid.

Polar diameter (cm)

Polar diameter of fruit ranged between 3.87 cm in BCPT 7-4/2-2 and 5.09 cm in BCPT 7-4-2 among the purple tomato lines. Average equatorial diameter of fruit of the purple tomato lines was slightly higher than the parental average as well as the check variety/ hybrid.

Locule number per fruit

Locule number per fruit ranged between 3.49 in BCPT 7-4/2-1 and 4.73 cm in BCPT 7-4/2-2 among the purple tomato lines. Average locule number in the fruit of the purple tomato lines was slightly higher than the parental average as well as the check variety/ hybrid.

Pericarp thickness (cm)

The sampled fruits per replication were cut into two halves to measure the pericarp thickness with the help of digital slide callipers which ranged between 0.47 cm in BCPT 7-4/2-2 and 0.77 cm in BCPT 7-4-3 among the purple tomato lines. Average pericarp thickness of the fruit of the purple tomato lines was slightly higher than the parental average however, it was at par with the check variety/ hybrid.

100-seed weight (g)

100-seed weight ranged between 0.315 g in BCPT 7-4-2 and 0.375 g in BCPT 7-4/2-2 among the purple tomato lines. Average 100 seed weight of the purple tomato lines was slightly higher than the parental average however, it was lesser than the check variety/ hybrid.

Fruit yield per plant (Kg)

Total fruit weight in periodical harvest from the selected plants per replication was recorded and then averaged which ranged between 2.59 Kg in BCPT 7-4/2-2 and 6.10 Kg in BCPT 7-4-2 among the purple tomato lines. Average fruit yield, which varied widely among the purple tomato lines was almost at par with that of the parental average and the check variety, Patharkutchi. However, average fruit yield of the purple tomato lines was conspicuously lesser than the check hybrid, Arka Rakshak.

Correlation among different characters

Information generated from the studies of character association serve as the most important indicator (plant character) that ought to be considered in the selection programme. Such studies would also help us to know the suitability of multiple characters for indirect selection, because selection for one or more traits results in correlated response in several other traits (Searle, 1965). Simple correlation coefficients presented in the [Table-4] clearly suggested that fruit yield per plant was positively and significantly correlated with four characters viz., flower cluster per plant ($r = 0.791$), fruit number per plant ($r = 0.707$), and polar diameter of fruit ($r = 0.728$) and pericarp thickness ($r = 0.665$). Correlation between fruit yield per plant and fruit weight was also high and positive but not significant ($r = 0.435$). It was encouraging to note that fruit number per plant and average fruit weight was almost uncorrelated ($r = -0.081$) which suggested that it would be possible to increase fruit weight without sacrificing much the fruit number per plant. Mean sum of squares clearly suggested significant difference among the 13 genotypes of tomato (9 purple tomato lines, 2 parental lines and 2 check variety /hybrid) for all the quantitative traits even at 1% level of significance which clearly endorsed the presence of wide genetic variability for the character concerned among the genotypes. This analysis also justified the utilization of these genotypes for such evaluation study. Wide variation could be recorded among the "Purple tomato" genotypes with respect to the parental genotype and check variety / hybrid. The highest yielding purple tomato line BCPT 7-4-4 (6.10 Kg fruit per plant). The study showed that 5 Purple tomato lines viz. BCPT 7-4-4, BCPT- 7-4-3, BCPT-7-4-2, BCPT 7-4-1, BCPT 7-1-3 significantly outclassed the popular hybrid and cultivar with respect to fruit weight. On the basis of correlation studies, the selection for number of fruits per plant, average fruit weight, pericarp thickness, polar diameter of fruit would be effective for developing plants with higher fruit yield in purple tomato. It could be concluded that Purple tomato lines can very well be placed as a line-bred variety for commercial cultivation in competition with other line bred variety and even hybrids.

Conclusion

The current study on purple tomato revealed that wide variation was observed in the different traits, suggests segregation in different characters in the lines which

needs to be stabilized through advancement of generations and subsequent selection. Analysis of Variance clearly showed the presence of wide genetic variability for the character concerned among the genotypes. The highest yielding purple tomato line was BCPT 7-4-4 (6.10 Kg fruit per plant). The study showed that 5 Purple tomato lines viz. BCPT 7-4-4, BCPT- 7-4-3, BCPT-7-4-2, BCPT 7-4-1, BCPT 7-1-3 significantly outclassed the popular hybrid and cultivar with respect to fruit weight. On the basis of correlation studies, the selection for number of fruits per plant, average fruit weight, pericarp thickness, polar diameter of fruit would be effective for developing plants with higher fruit yield in purple tomato. It was evident that Purple tomato lines can very well be placed as a line bred variety for commercial cultivation in competition with other line bred variety and even hybrids.

Application of Research: The current investigation will help greatly to characterize, evaluate as well as to establish the interrelationship between different important horticultural traits of purple tomato lines using suitable statistical tools with respect to checks to test the feasibility of commercialization of these new nutritionally rich genotypes of tomato.

Research Category: Plant Breeding and Genetics.

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***Research Guide or Chairperson of research: Dr Pranab Hazra**

University: Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, 741252
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Study area / Sample Collection: Central Research Farm, Gayeshpur, B.C.K.V., Nadia, West Bengal during autumn-winter

Cultivar / Variety / Breed name: Arka Rakshak, Patharkuchi

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Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
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