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Sampling technique for optimum worth of the fruit characters in tomato (*Solanum lycopersicum*)

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ABSTRACT

Different fruit characters including quality characters of tomato (*Solanum lycopersicum* L.) are influenced by environment and other factors hence, the present investigation was carried out employing nine genotypes to determine the fruit sampling technique through the study on the variation in different fruit characters in the genotypes, in different clusters of the main stem and different fruits of the same cluster in the same genotype. Considering the variation in fruit characters with the year, genotypes, cluster position and fruit position in the cluster it was suggested to repeat the evaluation of the genotypes and to sample the first and last fruit of the third cluster for recording fruit weight, polar and equatorial diameter and pericarp thickness and to use the composite sample from these fruits for estimation of proximate compositions of fruits, viz. TSS, β carotene and lycopene contents following standard methods to ascertain the genotypic worth for different quantitative and quality characters of fruit in tomato.

Key words: Cluster, Fruit position, Genotype, Sampling, Tomato

Tomato (*Solanum lycopersicum* L.) is one of the major vegetable crops for fresh consumption as well as for processing purpose in India and world as a whole. A typical tomato fruit contains intermediate levels of vitamin C, carotenoids, provitmin A, but because of the volume of fresh tomato and tomato products which are consumed, tomatoes make important contribution to the dietary intake (Stommel 2007, Causse *et al*. 2007). Carotenes constitute 70 to 95% of the total carotenoid content of tomato. Lycopene, the red pigment in tomato fruit is the predominant carotene, comprising up to 90% of the total carotenoids, while the amounts of the provitamin A carotenoid, β-carotene are 2 to 15% (Stommel 2007). It has been amply justified that total soluble solids content which contain 50% carbohydrates (Helyes *et al*. 2006) is the most important indicator of the taste of tomato and the fruits containing soluble solids above 4.5 °Brix could be placed in the most desirable rank (Clement *et al.* 2008). Different studies have shown genotypes to be the most important determining factor for different chemical compositions of the tomato fruits like, lycopene, β carotene, TSS, sugar , ascorbic acid , etc. contents although the contents were also influenced by environment and other factors like, growing conditions and cultivation environments, harvest date, degree of fruit maturity, plant nutrient content in fruits and ripening stage (Garcia and Barrett 2006, Tomlekova *et al*. 2007, Ilahy and Hdider 2007, Bobinaite *et al*. 2009). Such environmental influence on different fruit quality characters gives reason to doubt that determination of genotypes possessing high fruit quality (high TSS, lycopene and β carotene contents, etc.) based on one only screening procedure at times might not be correct (Tomlekova *et al*. 2007) which warrants the framing of fruit sample technique. In this backdrop, the present investigation was carried out employing nine divergent genotypes to determine the fruit sampling technique through the study on the variation in different fruit characters in different clusters of the main stem and different fruits of the same cluster in the same genotype.

MATERIALS AND METHODS

The field experiments were conducted in two consecutive years (2009-10 to 2010-11) at the Central Research Farm, Gayeshpur, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India situated at 22°572 N latitude and 88°202 E longitude with an average altitude of 9.75 m above the mean sea level employing nine homozygous and widely divergent line varieties and breeding lines of tomato, viz. Berika, FEB2, BCT115, CLNB, CLN R, Patharkutchi, BCT53, BCT119 and BCT 111*rin* (Table 1).

These nine genotypes were grown during autumn-winter

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Table 1 Genotypes of tomato employed in the investigation

Genotype (Variety/line)	Specific character or gene in it	Source
Berika	High lycopene containing line variety	Institute of Physiology and Genetics, Bulgarian academy of Science, Sofia, Bulgaria
FEB 2	Early blight resistant variety	Indian Agricultural Research Institute, New Delhi, India
BCT 115	Dark green and high pigmented line containing *dg* gene	United States Department of Agriculture, USA.
BCT 119	high pigmented line containing *hp* gene	United States Department of Agriculture, USA
CLN B	Heat tolerant line	AVRDC, Taiwan
CLN R	Heat tolerant line	AVRDC, Taiwan
BCT 53	High yielding line developed by selection from a material collected from Assam, India	Dept. of Vegetable crops, BCKV, Mohanpur, West Bengal, India
BCT 111 *rin*	Very slow ripening genotype containing *rin* gene	M. K. Banerjee, former Professor, Dept. of Vegetable Science, HAU, Hisar
Patharkutchi	Old ,adapted and popular local cultivar of West Bengal, India	Dept. of Vegetable crops, BCKV, Mohanpur, West Bengal

season in both the years under the average day temperature range of 22.5º to 31.9ºC and night temperature range of 8.4º to 22.4ºC, the average day/night being 27.6º/15.1ºC in randomized block design with 3 replications keeping 20 plants per plot at 60 cm × 60 cm spacing. Five random plants per replication were selected to record the observations on 8 fruit characters, viz. fruit weight, equatorial diameter of fruit, polar diameter of fruit, locule number, pericarp thickness, TSS, β carotene and lycopene contents of fruit. In the 5 randomly selected plants in each genotype per replication, different fruit characters were recorded from the first and the last fruit in each of the first 5 cluster of the main stem separately. So, the total of 25 first and last fruits in 5 selected plants per genotype per replication were harvested periodically at advanced turning stage and kept in the room temperature condition till the fruits did ripe completely. Ten ripe fruits randomly selected from the sample of 25 first and last fruits each per replication were taken to record fruit weight (g), equatorial diameter (cm) and polar diameter (cm) while pericarp thickness (cm) and locule number were recorded after cutting those fruits into two halves. Five randomly selected cut fruits were used to make composite sample per replication for estimation of three fruit quality traits, viz. TSS (^{0}Brix), β carotene (mg/100 g fresh weight), lycopene (mg/100 g fresh weight) using refractrometer and following standard spectrophotometric method as described by Sadasivam and Manickam (1996) in the laboratory of the Department of Vegetable Crops. Analyses of variance were calculated in the form of three-factor analysis (genotype, flower cluster and fruit position) over two years following Gomez and Gomez (1984).

RESULTS AND DISCUSSION

In the main analysis of variance, differences among 9 genotypes and 5 flower clusters in the main stem and between 2 year and 2 fruit position in the cluster were highly significant for all the 8 fruit and fruit quality characters (Table 2) indicating highly significant influence of both genotypes and fruit position for the expression of all the fruit characters. In the sub-analysis also, all the interaction effects, viz. year × genotype, year × cluster, genotype × cluster, year × genotype × cluster, year × fruit position, genotype × fruit position, year × genotype × fruit position, cluster × fruit position, year × cluster × fruit position, genotype × cluster × fruit position and year × genotype × cluster × fruit position were significant (Table 2).

The range of means for 8 fruit characters in two years irrespective of the genotypes, cluster and fruit position in the cluster (Table 3) indicated significant differences for fruit characters in two years of investigation. Significant differences in the fruit characters with the years has got support from the earlier report of Darrigues *et al*. (2008) that the year effect and within field environmental effects was highly significant for both lycopene and β–carotene content of tomato fruits. Zanfini *et al*. (2007) reported that all the factors, viz. geographical location, varieties, harvest time and ripening stage influenced lycopene and β carotene and phytoene levels in all the varieties. Our findings with the support of the earlier two amply justified the necessity of multiyear and multilocation evaluation trial for determination of fruit characters of a tomato genotype.

The means for 8 characters in 9 genotypes irrespective of the year, cluster and fruit position in the cluster (Table 4) indicated BCT 115 possessing *dg* gene in it had the heaviest fruit (95.47 g) followed by FEB2 (90.27 g) and Berika (86.49 g). Polar diameter and equatorial diameter of BCT 115 was almost same giving round shaped fruit. Locule number per fruit was highest in BCT 111*rin* (4.42) and the lowest in Berika (2.00). Berika had the thickest pericarp of 7.47 mm while CLN R had the lowest (3.68 mm). The locally adaptable cultivar "Patharkutchi" with 4.03 locules per fruit had the maximum TSS content of 5.57 °Brix while Berika having 2.00 locules per fruit had the 4.84°Brix value indicating non-revelation of one to one relationship between low locule number and high TSS content in the fruits. Berika emerged as the highest carotenoid containing genotype followed by Patharkutchi and BCT 115. Berika and Patharkutchi do not contain any classically defined major

Table 2 Analysis of variance for year, genotype, flower cluster, fruit position and the respective interactions for different fruit characters

Sources of variation	df	Mean squares							
		Fruit weight	Polar diameter	Equatorial diameter	Locule number	Pericarp thickness	TSS content	β carotene content	Lycopene content
Year	1	13.49**	28.67**	109.04**	0.02**	11.24**	0.03**	0.91**	7.51**
Genotype	8	38105.23**	3418.97**	4425.60**	53.57**	60.69**	19.49**	13.53**	161.59**
Cluster	4	41012.24**	2577.42**	2783.72**	0.29**	54.05**	1.34**	0.12**	6.01**
Fruit position	1	103171.02**	4775.41**	6600.02**	7.68**	113.75**	0.02**	1.48**	28.94**
Year × Genotype	8	441.88**	70.84**	98.06**	0.36**	8.57**	1.56**	1.69**	10.29**
Year × Cluster	4	649.81**	24.03**	89.50**	0.58**	0.88**	0.08**	0.18**	1.59**
Year × Fruit position	1	18.21**	7.05**	1.754**	1.12**	0.51**	0.21**	0.17**	0.94**
Genotype × Cluster	32	2707.50**	131.20**	136.59**	0.93**	2.48**	1.38**	1.03**	12.48**
Genotype × Fruit position	8	2081.03**	90.15**	61.28**	3.51**	5.304**	1.13**	0.49**	7.31**
Cluster × Fruit position	4	231.96**	69.13**	27.43**	0.76**	0.18**	0.64**	0.31**	1.03**
Year × Genotype × Cluster	32	209.13**	37.58**	37.19**	0.24**	0.84**	0.23**	0.32**	2.95**
Year × Genotype × Fruit position	8	89.11**	26.69**	8.235**	0.20**	0.92**	0.14**	0.06**	3.18**
Year × Cluster × Fruit position	4	135.29**	23.20**	35.87**	0.25**	0.67**	0.06**	0.09**	1.78**
Genotype × Cluster × Fruit position	32	704.97**	54.12**	56.57**	0.46**	1.07**	1.06**	0.25**	2.77**
Year × Genotype × Cluster × Fruit position	32	130.26**	42.48**	25.87**	0.21**	0.65**	0.22**	0.19**	1.91**
Error	356	1.43	1.06	0.68	0.03	0.09	0.03	0.09	0.06

** Significant at P = 0.01

Table 3 Mean for fruit characters in two years irrespective of the genotypes, cluster and fruit position in cluster

Year	Fruit weight (g)	Polar diameter (mm)	Equatorial diameter (mm)	Locule number	Pericarp thickness (mm)	TSS (° Brix)	β carotene (mg/100g)	Lycopene (mg/100g)
1	67.56	48.85	48.73	3.08	5.56	4.56	1.08	3.61
2	67.24	48.39	47.83	3.09	5.27	4.57	1.17	3.37
CD (P = 0.05)	0.143	0.123	0.09	0.01	0.03	0.06	0.02	0.03

Table 4 Mean for fruit characters in 9 genotypes irrespective of the year, cluster and fruit position in the cluster

Genotype	Fruit weight (g)	Polar diameter (mm)	Equatorial diameter (mm)	Locule no.	Pericarp thickness (mm)	TSS (° Brix)	β carotene (mg/100g)	Lycopene (mg/100g)
Berika	86.49	59.34	50.33	2.00	7.47	4.84	1.60	5.64
FEB 2	90.27	53.58	53.59	3.54	5.53	3.95	1.03	3.52
BCT 115	95.47	57.12	57.61	3.62	5.93	4.01	1.83	5.06
CLN B	38.32	42.21	39.23	2.00	4.94	4.82	1.04	2.25
CLN R	19.27	35.33	30.84	2.00	3.68	4.27	0.91	2.78
Patharkutchi	68.85	45.30	53.67	4.03	5.55	5.57	1.47	5.07
BCT 53	57.05	49.27	44.05	2.63	5.32	5.04	1.08	3.60
BCT 119	77.03	45.15	53.05	3.56	5.51	4.67	0.97	3.12
BCT 111 *rin*	73.88	50.30	52.15	4.42	4.85	3.91	0.19	0.37
CD (P = 0.05)	0.33	0.26	0.29	0.02	0.05	0.03	0.05	0.07

genes for high pigmentation unlike BCT 115 having *dg* gene in it which suggested the presence of quantitative genes other than the major genes for enhancing the carotenoid content in the fruits. Involvement of quantitative genes for the control of different fruit quality characters was also established from several earlier studies (Potaczek and Michalik 1989, Sacks and Francis 2001, Li *et al.* 2006, Garg *et al*. 2008).

The means for 8 characters in first five sequential flower clusters on the main stem irrespective of year, genotype and fruit position (Table 5) indicated that fruit weight and diameter was highest in the first cluster which fell linearly up to fifth cluster. Locule number did not vary significantly in the fruits of different flower cluster. Pericarp thickness in the fruits of the first cluster was the highest which gradually declined up to fifth cluster. It was interesting to note that fruit weight, polar and equatorial diameter and pericarp thickness in the fruits harvested from third cluster represented almost the mean value for the respective characters over the five clusters. Mean fruit weight of the genotypes over the year and fruit position was 67.40 g and that of the fruits harvested from third cluster was 64.05 g similarly, mean pericarp thickness of the genotypes over the year and fruit position was 4.41 mm and that of the fruits harvested from third cluster was 5.40 mm (Table 5). TSS, β carotene and lycopene contents of the fruits did not vary markedly in the fruits of different flower clusters however, values of all the three fruit quality characters were highest in the fruits harvested from third cluster.

The means for 8 characters in two fruit position (first and last fruit in the cluster) irrespective of the sequential flower cluster on the main stem, year and genotype indicated that fruit weight and diameter and pericarp thickness was markedly higher in the first fruit of the cluster than the last fruit of the cluster (Table 6). The fruit quality characters, viz. TSS, β carotene and lycopene contents though did not vary much between the first and last fruit of the cluster yet the quantity of the three fruit quality related characters were the highest in the last fruit of the cluster. The present observation suggested that locule number per fruit and three fruit quality traits, viz. TSS, β carotene and lycopene contents of the fruits were highly genotype-dependent characters and did not vary markedly with the cluster and fruit position in the cluster, although the content of the fruit quality compositions were the highest in the fruits of the third cluster. Thapliyal and Singh (2009) recorded earlier that locules per fruit did not vary with the environments. Xian *et al*. (2007) also recorded that the ratio of sugar-acid of fruit could not be disturbed by environments, and the phenotypes could reflect the heredities of the lines which agreed well to the present findings.

Fruit quality characters did not vary markedly among the first and last fruits of the five clusters which was in agreement of the findings of Bertin *et al*. (2001) that fruit

Table 5 Mean for fruit characters in five sequential flower clusters on the main stem irrespective of year, genotype and fruit position in the cluster

Cluster no.	Fruit weight (g)	Polar diameter (mm)	Equatorial diameter (mm)	Locule no.	Pericarp thickness (mm)	TSS (° Brix)	β carotene (mg/100g)	Lycopene (mg/100g)
1	92.21	54.00	54.33	3.11	6.29	4.53	1.10	3.30
2	81.21	51.80	51.70	3.13	5.90	4.64	1.12	3.61
3	64.05	49.61	48.22	3.01	5.40	4.66	1.18	3.84
4	56.10	46.10	45.84	3.13	4.97	4.60	1.12	3.44
5	43.44	41.61	41.30	3.05	4.52	4.39	1.11	3.27
CD (P = 0.05)	0.26	0.19	0.15	0.02	0.03	0.02	0.05	0.02

Table 6 Mean for fruit characters in two fruit position (first and last fruit in the cluster) irrespective of the sequential flower cluster on the main stem, year and genotype

Fruit position in cluster	Fruit weight (g)	Polar diameter (mm)	Equatorial diameter (mm)	Locule no.	Pericarp thickness (mm)	TSS (° Brix)	β carotene (mg/100g)	Lycopene (mg/100g)
First	81.23	51.60	51.78	3.21	5.88	4.56	1.07	3.26
Last	53.58	45.65	44.78	2.97	4.96	4.57	1.18	3.72
SE M	0.073	0.063	0.050	0.005	0.011	0.003	0.006	0.002
CD (P = 0.05)	0.14	0.12	0.09	0.02	0.06	0.02	0.01	0.03

fresh weight significantly differed among fruits within the sixth truss however, fruit composition did not vary among basal and tip fruits of the cluster because competition only during the cell division period hardly influenced the fruit composition.

Genotype emerged as the most important determining factor for all the fruit characters however, cluster position and fruit position in the cluster had significant influence on the expression of the characters which amply justified the necessity of framing sampling technique for fruit characters. It was revealed that the fruits from the third cluster might show the representative average for fruit weight, polar and equatorial diameter and pericarp thickness and highest value for fruit quality related components, viz. TSS, β carotene and lycopene contents for the concerned genotype. So, sampling of the fruits from the third cluster will ensure the possibility of realizing high genetic advance for fruit quality characters during selection process. However, sampling of the only the first fruit from the third cluster may give exaggerated picture on genotypic worth for fruit weight, polar and equatorial diameter and pericarp thickness while, sampling of only last fruit of the third cluster may give high estimate about the genotype for the three fruit quality characters, viz. TSS, β carotene and lycopene contents.

Considering the variation in fruit characters with the year, genotypes, cluster position and fruit position in the cluster it may be suggested to repeat the evaluation of the genotypes and to sample the first and last fruit of the third cluster for recording fruit weight, polar and equatorial diameter and pericarp thickness and to use the composite sample from these fruits for estimation fruit quality compounds, viz. TSS, β carotene and lycopene contents following standard methods to ascertain the genotypic worth for different quantitative and quality characters of fruit in tomato.

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