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Selection indices for enhancing fruit quality characters in tomato (*Solanum lycopersicum* L.)

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Abstract

Association of 12 fruit characters viz., fruit weight, polar diameter of fruit, equatorial diameter of fruit, locule number per fruit, pericarp thickness, TSS, lycopene, â carotene, total sugar, reducing sugar, titrable acidity and ascorbic acid contents of the fruit have been studied utilizing average data over two years on 12 widely divergent genotypes of tomato to determine important selection indices for enhancing fruit quality characters in tomato. Correlation and path coefficient analyses confirmed that medium sized fruits, fewer locules, thick pericarp, high total soluble solids and medium titrable acidity level in the fruits should be considered as the most important selection indices for enhancing lycopene, â carotene and ascorbic acid contents in the fruit.

Keywords: Tomato, Fruit quality, Post-harvest, TSS, Lycopene

Introduction

The cultivated tomato (*Solanum lycopersicum* L.) is widely grown around the world and constitutes a major agricultural industry and it is the second most consumed vegetable after potato. It is one of the most important vegetable crops grown in both temperate and tropical regions of the world. Ripe tomatoes contain high concentrations of several nutritive quality compounds particularly carotenoids such as lycopene and â carotene (provitamin A) and vitamin C (Beecher, 1998). The compositional fruit quality of tomato is receiving increasing interest, particularly given the results of recent studies highlighting the nutritional importance of lycopene, flavonoids, and chlorogenic acid in the human diet (Devaux et al., 2005; Dixon, 2005; Niggeweget al., 2006; Rein et al., 2006). Lycopene makes up approximately 80-90 % of the total carotenoids in common cultivars of tomatoes (Shi and Le Maguer, 2000), the pigment that gives tomato its red color. There is considerable interest in the dietary role of lycopene in inhibition of heart disease (Rissanen et al., 2003) and reducing the risk of certain cancers, including prostate cancer (Clinton, 1998; Ansari and Gupta, 2003; Giovannucci, 2002; Wu et al., 2004; Stacewicz-Sapuntzakis and Bowen, 2005) and breast cancer (Sesso et al., 2005). Other carotenoids present in ripe tomato fruits include â carotene and small amounts of phytoene, phytofluene, dcarotene, z-carotene, neorosporene, and lutein (Khachiket al., 2002). 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). Today, fruit quality is a major focus of most tomato breeding programs, the major fruit quality traits of interest to both fresh market and processing tomato industries being fruit size, shape, total solids, lycopene, â carotene, firmness, nutritional quality and flavour and other important fruit quality characteristics include pH, titratable acidity and vitamin contents (Foolad, 2007). Hence, the present investigation was outlined to study the association of 12 fruit characters including 7 quality characters utilizing the pooled data over two years on 12 widely divergent genotypes to frame selection indices for enhancing fruit quality characters in tomato.

Materials and Methods

The field experiments were conducted in two consecutive years (2009-2010 to 2010-2011) at the Central Research Farm, Gayeshpur, Bidhan Chandra KrishiViswavidyalaya, West Bengal, India situated at 22°57'N lat and 88°20'E long with an average altitude of 9.75 m above the mean sea level employing 12 varieties and breeding lines viz., Berika , FEB-2, BCT-115, CLN B , CLN R, Patharkutchi, BCT-53, BCT-119, BCT-111*rin*, Alisa Craig, Alisa Craig *hp* and Alisa Craig *og*^{c} (Table 1).

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These genotypes were grown during autumn–winter season 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 x 60 cm spacing.

Five random plants per replication were selected to record the observations on different fruit characters. Three ripe fruits from the 5 randomly selected plants per plot were harvested 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. These 15 cut fruits per replication were utilized to make composite sample per replication for estimation of 7 fruit quality traits viz., TSS, lycopene, â carotene, total sugar, reducing sugar, titrable acidity and ascorbic acid contents of fruits following standard biochemical methods (Sadasivam and Manickam, 1996) in the Department of Vegetable crops, Bidhan Chandra Krishi Viswavidyalaya.

Data recorded for 12 fruit characters in two years were averaged and used for analysis of variance. Phenotypic and genotypic correlation coefficients were calculated following Al-Jibouri et al (1958) and path analyses were done as per Dewey and Lu (1959).

Results and Discussion

Correlation coefficient

The intensity and direction of association among the characters can conveniently be measured by genotypic and phenotypic correlation coefficient. In fact, knowledge of genotypic interrelationship between characters is also of theoretical interest because genotypic correlation may be derived from genetic linkage, pleiotropy or developmentally induced relationship between components, which are only indirectly the consequence of gene action (Adams, 1967). The phenotypic and genotypic correlation coefficients for most of the pair of characters corresponded closely indicating little influence of environment on the correlated response on most of the pair of fruit and fruit quality characters (Table 2). It appeared that fruit weight, fruit diameters (polar and equatorial) and pericarp thickness are linearly correlated characters because of significant and positive correlations among themselves which has found ample support from the earlier report of Padma et al. (2002). Locule number was found uncorrelated with pericarp thickness ($rP = 0.22$) while, significant negative correlations between locule number and pericarp thickness was recorded in other study (Kumar and Tewari, 1999). Significant and positive correlations between locule number and fruit weight and diameters in the present investigation did not find support from the earlier findings of Kurian and Peter (1997). These discrepancies in character association in the present investigation with regard to some such earlier studies arose due to different set of genotypes under study.

No fruit morphological characters viz., fruit weight, diameters, locule number and pericarp thickness did register any significant correlations with any of the seven fruit quality characters suggesting different physiological mechanisms and genetic control for fruit morphological and fruit quality characters. On the other hand, canonic correlation estimated by do Amaral Junior et al. (1997) showed that fruit weight was positively correlated with soluble solids, ascorbic acid and â carotene contents. Correlations between locule number and TSS, lycopene, â carotene and total sugar content was negative but non-

Table1. Genotypes of tomato employed in the investigation

Genotype (Variety/line)	Specific character or gene in it	Source
Berika	High lycopene containing variety	Institute of Physiology and Genetics, Bulgarian academy of Science, Sofia, Bulgaria
FEB-2	Early blight resistant variety	I.A.R.I., New Delhi
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 low in carotenoid pigments	AVRDC, Taiwan
CLN R	Heat tolerant line low in carotenoid pigments	AVRDC, Taiwan
BCT-53	High yielding line developed by selection from a material collected from Assam	Dept. of Vegetable crops, B.C.K.V., Mohanpur, West Bengal
Patharkutchi	Old, popular and adaptable cultivar of West bengal	Dept. of Vegetable crops, B.C.K.V., Mohanpur, West Bengal
BCT-111*rin*	Very slow ripening genotype containing *rin* gene	M. K. Banerjee, former Professor, Dept. of Vegetable Science, HAU, Hisar
Alisa Craig	Old variety	Institute of Physiology and Genetics, Bulgarian academy of Science, Sofia, Bulgaria
Alisa Craig *hp*	An isogenic line of Alisa Craig with *hp* gene	Institute of Physiology and Genetics, Bulgarian academy of Science, Sofia, Bulgaria
Alisa Craig og^c	An isogenic line of Alisa Craig with og^c gene	Institute of Physiology and Genetics, Bulgarian academy of Science, Sofia, Bulgaria

significant and between locule number and reducing sugar, titrable acidity and ascorbic acid content was positive but non-significant. Number of fruit locules was inversely correlated to lycopene, soluble solids, â carotene and ascorbic acid contents as recorded by do Amaral Junior et al. (1997) somewhat supported the present findings.

Total soluble solids content of the fruit emerged as the most important fruit quality character which influenced other important quality traits because of its highly significant and positive correlations with lycopene content (rP = 0.63), â carotene content (rP = 0.52), reducing sugar content (rP = 0.81) and titrable acidity (rP = 0.59). Reducing sugar content also registered significant and positive correlation with lycopene content (rP = 0.52) and titrable acidity (rP = 0.51). Macua et al. (2007) reported that there was a link between higher degrees Brix values (high TSS content) and higher lycopene content. According to Stommel et al., (2005) â carotene and lycopene are the principal carotenoids in tomato fruit that impart colour. High â carotene genotypes contained higher levels of sugars and soluble solids and equal or higher titrable acidity than the red-pigmented cultivars. These two earlier reports highly supported the present findings.

To address the question of the role of sugars in controlling carotenoid accumulation, Telef et al. (2006) cultured fruit pericarp discs (mature green fruits) in vitro in the presence of various sucrose concentrations. A significant difference in soluble sugar content was achieved depending on external sucrose availability. Sucrose limitation delayed and reduced lycopene and phytoene accumulation, with no significant effect on other carotenoids. Chlorophyll degradation and starch catabolism were not affected by variations of sucrose availability. The reduction of lycopene synthesis observed in sucrose-limited conditions was mediated through metabolic changes illustrated by reduced hexose accumulation levels. He suggested that the modulation of carotenoid accumulation by sucrose availability occurs at the metabolic level and involves the differential regulation of genes involved in carotenoid biosynthesis. The findings of do Amaral Junior et al. (1997) that multilocular fruits had higher ascorbic acid contents than bilocular fruits , which in turn tended to have more lycopene amply supported significant and positive correlation between lycopene and ascorbic acid contents (rP = 0.52) emerged in the present investigation.Very high, significant and positive correlation (rP = 0.95) between lycopene and â carotene contents in the present investigation amply suggested that high lycopene precursor might have increased the accumulation of â carotene in tomato fruit because â carotene is found downstream of lycopene in the carotenoid biosynthetic pathway. Results of the experiment conducted by Obasi and Okoh (2006) showed that total carotenoids and lycopene contents were positively correlated with each other at all stages of fruit ripening in all cultivars which corroborated to the present findings.

Path coefficient

Linear correlation between any two characters may

Table 2. Phenotypic (P) and genotypic (G) correlation coefficients over two years

	Polar diameter	Equatorial diameter	Locule no.	Pericarp thickness	TSS	Lycopene content	β carotene content	Total sugar content	Reducing sugar	Acidity	Ascorbic acid
Fruit weight	P 0.896*	P 0.858*	P 0.637*	P 0.665*	P -0.080	P 0.223	P 0.144	P -0.227	P 0.044	P -0.056	P -0.260
	G 0.868	G 0.839	G 0.624	G 0.642	G -0.071	G 0.203	G 0.134	G -0.218	G 0.014	G -0.051	G -0.161
Polar diameter	P 1.000	P 0.773*	P 0.519*	P 0.665*	P -0.252	P -0.028	P -0.124	P -0.222	P -0.200	P -0.326	P -0.373
	G 1.000	G 0.733	G 0.509	G 0.627	G -0.215	G -0.015	G -0.121	G -0.179	G -0.199	G -0.312	G -0.333
Equatorial diameter		P 1.000	P 0.768*	P 0.622*	P -0.220	P -0.075	P -0.082	P -0.204	P -0.036	P 0.096	P -0.323
		G 1.000	G 0.728	G 0.574	G -0.215	G -0.042	G -0.081	G -0.179	G -0.035	G 0.091	G -0.312
Locule no.			P 1.000	P 0.224	P -0.144	P -0.244	P -0.264	P -0.173	P 0.118	P 0.137	P -0.369
			G 1.000	G 0.207	G -0.137	G -0.229	G -0.259	G -0.130	G 0.112	G 0.133	G -0.323
Pericarp thickness				P 1.000	P 0.196	P 0.265	P 0.210	P -0.227	P 0.096	P -0.047	P -0.201
				G 1.000	G 0.193	G 0.247	G 0.209	G -0.256	G 0.091	G -0.026	G -0.186
TSS					P 1.000	P 0.637*	P 0.523*	P 0.055	P 0.816*	P 0.593*	P 0.381
					G 1.000	G 0.623	G 0.508	G 0.520	G 0.764	G 0.572	G 0.366
Lycopene						P 1.000	P 0.956*	P 0.092	P 0.521	P 0.364	P 0.520*
						G 1.000	G 0.949	G .082	G 0.422	G 0.328	G 0.515
β carotene							P 1.000	P 0.090	P 0.439	P 0.391	P 0.495
							G 1.000	G .077	G 0.341	G 0.297	G 0.488
Total sugar								P 1.000	P 0.201	P -0.029	P 0.515
								G 1.000	G 0.138	G -0.014	G 0.340
Reducing sugar									P 1.000	P 0.541	P 0.569
									G 1.000	G 0.536	G 0.556
Acidity										P 1.000	P 0.206
										G 1.000	G 0.201

*= Significant at 5% level of significance

Table 3. Phenotypic path analysis over two years

Character	Fruit weight	Polar diameter	Equatorial diameter	Locule no.	Pericarp thickness	TSS	β carotene	Total sugar	Reducing sugar	Acidity	Ascorbic acid	Phenotypic correlation with lycopene content
Fruit weight	**0.592**	-0.132	-0.190	-0.016	-0.025	-0.034	0.092	0.000	-0.012	0.001	-0.055	0.223
Polar diameter	0.531	**-0.147**	-0.171	-0.013	-0.025	-0.105	-0.079	0.000	0.053	0.008	-0.079	-0.028
Equatorial diameter	0.508	-0.114	**-0.222**	-0.019	-0.023	-0.092	-0.052	0.000	0.010	-0.002	-0.069	-0.075
Locule no.	0.377	-0.077	-0.170	**-0.025**	-0.008	-0.060	-0.168	0.000	-0.031	-0.003	-0.078	-0.244
Pericarp thickness	0.394	-0.098	-0.138	-0.006	**-0.037**	0.082	0.134	0.000	-0.025	0.001	-0.043	0.265
TSS	-0.048	0.037	0.049	0.004	-0.007	**0.418**	0.333	0.000	-0.215	-0.015	0.081	0.637
β carotene	0.085	0.018	0.018	0.007	-0.008	0.219	**0.637**	0.000	-0.116	-0.010	0.105	0.956
Total sugar	-0.135	0.033	0.045	0.004	0.008	0.023	0.057	**-0.001**	-0.053	0.001	0.109	0.092
Reducing sugar	0.026	0.029	0.008	-0.003	-0.004	0.341	0.280	0.000	**-0.264**	-0.014	0.121	0.521
Acidity	-0.033	0.048	-0.021	-0.003	0.002	0.248	0.249	0.000	-0.143	**-0.026**	0.044	0.364
Ascorbic acid	-0.154	0.055	0.072	0.009	0.007	0.159	0.316	-0.001	-0.150	-0.005	**0.212**	0.520

Residual effect= 0.0123

present a confusing picture because any character may exert simultaneous influence on many characters of the plant. Path coefficient analysis is more useful in establishing direct and indirect relationship among any characters, which is more realistic interpretation regarding influence of a character on a particular trait. The path coefficient analysis using phenotypic correlation coefficient among pair of characters depicting direct and indirect effect on lycopene content has been presented in Table 3. Mean residual effect was 0.012 suggesting the inclusion of 98% lycopene content determining characters in this study which justified the reliability of this study with the inclusion of these characters.

The character which exerted the highest and positive direct effect on lycopene content of fruit was â carotene content (0.637) followed by fruit weight (0.592), total soluble solids (0.418), and ascorbic acid content (0.212) indicating high importance of these characters for developing the genotype with fruits containing high lycopene content. Anitha *et al.* (2007) from path analysis revealed that oxalates, acidity, ascorbic acid and TSS had positive and high direct effects on lycopene which was agreed well to the findings of the present investigation.

Both polar and equatorial diameter registered appreciably high negative direct effect on lycopene content which imposed restriction on realizing high lycopene content in big sized fruits. Direct effect of both locule number (- 0.02) and pericarp thickness (- 0.03) on lycopene content was very low although negative in direction however, their indirect effect *via* fruit weight was appreciably high and positive.

The present analyses confirmed that medium sized fruits, fewer locules, thick pericarp, high total soluble solids and medium titratable acidity content should be considered as the most important selection indices for enhancing lycopene, â carotene and ascorbic acid contents in the fruit.

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सारांश

टमाटर में 12 फल घटकों यानी फल भार, फल का ध्रुवीय व्यास, फल का भूमध्य व्यास, प्रतिफल प्रकोष्ठ की संख्या, फल भित्ति की मोटाई, फुल विलेय ठोस, लाइकोपीन, बीटा कैरोटिन, कुल शर्करा, घटाव शर्करा, विश्लेषणीय अम्लता एवं फल एस्कार्बिक अम्लता की मात्रा का मापन लगातार 2 वर्षों तक कुल 12 विविध जननद्रव्यों को समाहित कर किया गया। जिससे महत्वपूर्ण चयन सूचकांक का निर्धारण फल गुणों के वृद्धि हेतु किया जा सके। सह सम्बन्ध एवं पथ गुणांक विश्लेषण से पता चला कि मध्यम फल आकार, कम प्रकोष्ठ, फल भित्ती मोटाई, उच्च कुल विलेय ठोस, एवं फल में मध्यम विश्लेषणीय अम्लता को लाइकोपीन, बिटा–कैरोटिन तथा एस्कार्बिक अम्लता के उन्नयन हेतु सबसे महत्वपूर्ण चयन सूचकांक को समाहित करना चाहिए।

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