Vegetable Science (2012) 39 (2) : 203-206

Genetic analysis for quality and nutritional traits in tomato under low temperature regime

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Received : October, 2011 / Accepted : July, 2012

Tomato has become a popular vegetable during recent years due to its high nutritional value, processing traits and scope for value added products. In developed countries it is commonly consumed fresh; over 80% of the tomato consumption comes from processed products such as juice, paste, puree, ketchup and sauce. It contributes significantly to the dietary intake of vitamins A and C as well as essential minerals and other nutrients. Tomato is an important source of lipid-soluble antioxidants in the human diet because of their relatively high content of carotenoids. The presence of lycopene in plasma has been related to a reduction in the risk of prostate cancer. Other carotenoids present in ripe tomato fruits include β-carotene and small amounts of phytoene, phytofluene, ζ-carotene, γ-carotene, neorosporene and lutein (Khachik *et al*., 2002).The knowledge of the nature and magnitude of gene effects controlling inheritance of characters related to productivity would aid in the choice of efficient breeding methods and thus accelerate the pace of its genetic improvement and also breaking the yield barriers. Breeding methods selected in the absence of such knowledge may not result in appreciable improvement. Considering the importance of such information, an experiment was conducted to understand the predominant gene effects governing various fruit quality and nutritional traits in tomato.

Six parental lines comprising of two cold set (Pusa Sheetal and Pusa Sadabahar) and four normal set (Booster, Pusa Rohini, Pusa Uphar and Chiku) were crossed to produce nine hybrids F_1 subsequently F_2, B_1 and B_2 populations were developed. All the six generations *viz*., P_1, P_2, F_1, F_2, B_1 and B_2 were evaluated at Research Farm, Division of Vegetable Science, Indian Agricultural Research Institute, New Delhi. The experiment was laid out in a randomized block design (RBD) using three replications. Each genotypes were transplanted on raised beds, spaced at 60cm in experimental field with spacing of 45 cm between plants. Data were recorded on five plants in parents and F_1s, 10 plants in B_1 and B_2 and 20 plants in F_2s for average fruit weight, fruit length, fruit diameter, total soluble solids, vitamin C, lycopene content and β-carotene content. The mean data were subjected to generation mean analysis (Hayman, 1958) to obtain information on additive, dominance and digenic epistatic interactions.

The traits means for six generations of each the nine crosses are presented in Table 1 for various quality and nutritional traits. Duplicate type of epistasis was observed in crosses Pusa Sheetal x Booster, Pusa Sheetal x DT-39, Pusa Sheetal x Chiku, Pusa Sadabahar x Booster, Pusa Sadabahar x DT-39, Pusa Sadabahar x Pusa Uphar and Pusa Sadabahar x Chiku. Hence, it showed the importance of heterosis breeding followed by selection method. In cross Pusa Sheetal x Pusa Sadabahar and Pusa Sheetal x Pusa Uphar additive and complementary type of epistasis were found to be significant indicating improvement of this character through selection. Cross, Pusa Sheetal x Chiku expressed dominance gene action for fruit length indicating importance of heterosis for improvement of this trait. While examining the type of epistasis it was found that three crosses, *i.e.* Pusa Sheetal x DT-39, Pusa Sheetal x Pusa Uphar and Pusa Sadabahar x Chiku out of nine crosses had shown duplicate epistasis. Therefore, dominance genetic component was important for the inheritance of this trait. Complementary type of interaction was found in crosses Pusa Sheetal x Booster, Pusa Sadabahar x Booster, Pusa Sadabahar x DT-39 and Pusa Sadabahar x Pusa Uphar indicating the importance of selection for this trait in these crosses. Crosses, Pusa Sheetal x Pusa Sadabahar, Pusa Sheetal x DT-39, Pusa Sheetal x Pusa Uphar, Pusa Sadabahar x Pusa Uphar and Pusa Sadabahar x Chiku showed the presence of epistasis for fruit diameter. Duplicate type of epistasis was predominant in all the crosses except

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Table 1: Generation mean, gene effect and their standard error for various traits.

Traits	Crosses								
	PSH X PS	PSH x B	PSH x DT-39	PSH x PU	PSH x CH	PS x B	PS x DT-39	PS x PU	PS x CH
Fruit weight									
m	45.09**	58.13**	67.46**	66.33**	70.78**	65.17**	51.20**	62.10**	71.94**
	(0.50)	(1.11)	(1.26)	(0.68)	(0.70)	(0.73)	(0.63)	(1.16)	(0.78)
d	-1.00	5.84**	5.10**	2.60**	5.47**	-12.08**	15.53**	-1.62**	14.57**
	(0.74)	(1.31)	(1.45)	(0.84)	(0.74)	(1.16)	(0.70)	(0.29)	(1.68)
h	4.41	-0.76	-0.40	27.42**	9.22**	-13.62**	28.16**	16.70**	-8.58
	(2.69)	(1.52)	(5.93)	(3.30)	(3.45)	(4.00)	(3.00)	(4.77)	(4.72)
i	10.95**	-3.11**	14.04**	7.70*	-8.83*	-18.37**	28.15**	4.83	-28.89
	(2.49)	(5.17)	(5.82)	(3.17)	(3.18)	(3.71)	(2.90)	(4.67)	(4.59)
j	2.75**	9.01	3.85**	-0.32	3.43**	12.67**	10.51**	-8.31**	8.78**
	(1.05)	(1.57)	(1.63)	(1.05)	(0.99)	(1.39)	(0.95)	(0.60)	(1.77)
l	6.53	11.43**	-2.20	-35.61**	-20.11**	30.58**	-33.78**	-13.79**	34.88**
	(4.14)	(7.25)	(8.03)	(4.63)	(4.30)	(6.22)	(4.09)	(5.19)	(7.78)
Ep.	C	D	C	D	D	D	D	D	D
Fruit length									
m	3.700**	3.20**	3.20**	3.85**	3.92**	3.40**	3.85**	3.37**	5.10**
	(0.15)	(0.06)	(0.06)	(0.03)	(0.06)	(0.06)	(0.03)	(0.09)	(0.06)
d	-0.26**	-0.19	-0.30**	0.46**	-0.36**	0.50**	0.48**	-0.90**	1.33**
	(0.16)	(0.14)	(0.40)	(0.10)	(0.06)	(0.11)	(0.07)	(0.12)	(0.14)
h	0.53	-1.33**	-0.68**	-0.23	0.88**	3.25**	2.27**	0.73	-2.16**
	(0.70)	(0.42)	(0.27)	(0.25)	(0.28)	(0.34)	(0.23)	(0.44)	(0.40)
i	0.13	1.33**	0.79**	0.06	0.66	2.86**	1.77**	-0.53	-3.20**
	(0.69)	(0.37)	(0.24)	(0.24)	(0.4)	(0.31)	(0.19)	(065)	(0.37)
j	0.03	-0.04	0.11	1.46**	0.16	0.35**	0.63**	-0.20	1.56**
	(0.18)	(0.15)	(0.11)	(0.11)	(0.10)	(0.13)	(0.14)	(0.15)	(0.18)
l	0.93	-0.86	1.16**	1.86**	-0.43	2.76**	1.01**	1.93*	5.40**
	(0.92)	(0.72)	(0.36)	(0.45)	(0.39)	(0.55)	(0.41)	(0.43)	(0.69)
Ep.	-	C	D	D	-	C	C	C	D
Vitamin C									
P_1	16.40	16.40	16.40	16.40	16.40	16.55	16.55	16.55	16.55
	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.15)	(0.15)	(0.15)	(0.15)
P_2	16.55	15.12	14.67	15.67	13.84	15.12	14.67	15.67	13.84
	(0.15)	(0.36)	(0.33)	(0.33)	(0.31)	(0.36)	(0.33)	(0.33)	(0.31)
F_1	15.50	14.50	15.93	18.13	16.33	14.67	15.00	16.33	15.33
	(0.29)	(0.29)	(0.43)	(0.13)	(0.33)	(0.33)	(0.58)	(0.33)	(0.67)

Traits	Crosses								
	PSH x PS	PSH x B	PSH x DT-39	PSH x PU	PSH x CH	PS x B	PS x DT-39	PS x PU	PS x CH
Fruit diameter									
m	4.53**	4.12**	3.37**	4.90**	4.08**	3.50**	3.88**	4.30**	3.78**
	(0.09)	(0.06)	(0.09)	(0.06)	(0.04)	(0.06)	(0.04)	(0.06)	(0.06)
d	0.13	-0.10**	-0.13**	0.9**	0.30**	-0.74**	0.56**	-0.53**	0.00
	(0.10)	(0.04)	(0.06)	(0.08)	(0.08)	(0.05)	(0.09)	(0.12)	(0.04)
h	-0.78	-0.35	1.53**	0.60**	1.43**	0.51	0.03	-1.87**	1.34**
	(0.41)	(0.26)	(0.38)	(0.28)	(0.24)	(0.26)	(0.26)	(0.34)	(0.26)
i	-1.06**	-0.40	1.86**	0.001	0.36	0.23	0.13	-1.60**	1.53**
	(0.41)	(0.25)	(0.37)	(0.28)	(0.24)	(0.25)	(0.26)	(0.33)	(0.25)
j	0.45**	-0.09	-0.09	0.92**	0.13**	-0.06	0.18	-0.32**	-0.48**
	(0.11)	(0.05)	(0.06)	(0.08)	(0.08)	(0.07)	(0.10)	(0.13)	(0.07)
l	2.76**	0.36	0.80	-0.65	0.13	0.31	0.23	5.75**	1.03**
	(0.57)	(0.33)	(0.47)	(0.41)	(0.38)	(0.34)	(0.43)	(0.55)	(0.34)
Ep.	D	-	C	D	C	-	-	D	C
TSS (°Brix)									
m	3.10**	4.37**	4.27**	4.60**	4.10**	3.50**	4.90**	4.33**	3.80**
	(1.45)	(0.22)	(0.32)	(0.06)	(0.06)	(0.06)	(0.06)	(0.04)	(0.06)
d	0.59**	0.13	0.31**	0.23**	0.30**	0.39**	0.33**	0.16**	0.21**
	(0.08)	(0.17)	(0.05)	(0.10)	(0.08)	(0.04)	(0.06)	(0.06)	(0.08)
h	6.25	1.58	0.13	1.51**	-0.59**	0.19	0.43	-0.25	0.74**
	(5.81)	(0.94)	(1.27)	(0.31)	(0.28)	(0.25)	(0.27)	(0.21)	(0.28)
i	6.40	1.47	0.63	0.86	0.60**	0.59	-0.13	-0.57	0.83**
	(5.81)	(0.94)	(1.28)	(0.31)	(0.28)	(0.24)	(0.26)	(0.19)	(0.28)
j	0.21**	-0.65**	0.01	-0.56**	-0.32**	-0.00	0.38	-0.24	-0.02
	(0.09)	(0.18)	(0.07)	(0.11)	(0.09)	(0.57)	(0.27)	(0.07)	(0.09)
l	-5.56	-1.83	0.26	-0.57	1.34**	0.80**	0.39	0.20	0.38
	(5.83)	(1.13)	(1.29)	(0.49)	(0.41)	(0.31)	(0.37)	(0.33)	(0.41)
Ep.	D	D	-	D	D	C	-	-	C
Lycopene content									
P_1	1.28	1.28	1.28	1.28	1.28	1.64	1.64	1.64	1.64
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)	(0.04)	(0.04)	(0.04)
P_2	1.64	1.43	1.56	1.00	1.29	1.43	1.56	1.00	1.29
	(0.04)	(0.02)	(0.01)	(0.01)	(0.04)	(0.02)	(0.01)	(0.01)	(0.04)
F_1	1.77	1.38	1.15	1.64	1.50	1.02	1.20	1.44	1.75
	(0.04)	(0.03)	(0.08)	(0.02)	(0.04)	(0.03)	(0.12)	(0.08)	(0.05)

F_2	14.33	14.50	15.50	17.17	16.30	15.27	15.37	16.33	16.17
	(0.33)	(0.17)	(0.29)	(0.44)	(0.13)	(0.12)	(0.13)	(0.23)	(0.38)
B_1	14.70	16.20	14.93	17.13	16.55	14.67	14.67	16.43	14.67
	(0.35)	(0.15)	(0.47)	(0.29)	(0.08)	(0.33)	(0.33)	(0.23)	(0.33)
B_2	15.60	16.25	16.60	16.67	15.79	16.07	15.70	16.67	15.50
	(0.42)	(0.14)	(0.15)	(0.88)	(0.29)	(0.52)	(0.15)	(0.88)	(0.29)
m	14.33**	14.50**	15.50**	17.17**	16.30**	15.27**	15.37**	16.33**	16.17**
	(0.33)	(0.17)	(0.29)	(0.44)	(0.13)	(0.12)	(0.13)	(0.23)	(0.38)
d	-0.89	-0.05	-1.67**	0.36	0.76**	-1.40**	-1.03**	-0.23**	-0.83
	(0.54)	(0.21)	(0.49)	(0.90)	(0.29)	(0.61)	(0.36)	(0.91)	(0.44)
h	2.29	5.64**	1.47	2.57**	0.68	-0.76	-1.34	0.69	-4.19**
	(1.74)	(0.87)	(1.58)	(0.83)	(0.83)	(1.38)	(1.06)	(2.08)	(1.87)
i	3.27**	6.89**	1.06	-1.27	-0.52	0.39	-0.73	0.46	-4.33**
	(1.72)	(0.81)	(1.52)	(2.56)	(0.74)	(1.32)	(0.87)	(2.04)	(1.74)
j	-0.82	-0.69**	-2.53**	0.00	-0.51	0.11	-1.97**	-0.64	-2.18**
	(0.55)	(0.27)	(0.53)	(0.94)	(0.33)	(0.64)	(0.47)	(0.93)	(0.47)
l	0.08	-11.28**	-1.20	2.20	-1.23	-0.86	1.29	-1.78	5.05**
	(2.62)	(1.28)	(2.46)	(4.13)	(1.47)	(2.63)	(1.96)	(3.84)	(2.69)
Ep.	C	D	D	-	-	-	D	-	D
β-Carotene content									
m	3.09**	3.74**	4.20**	3.93**	4.50**	3.25**	4.10**	6.25**	4.72**
	(0.93)	(0.94)	(0.06)	(0.94)	(0.28)	(0.08)	(0.06)	(0.04)	(0.06)
d	1.28**	0.58**	0.43	0.38**	0.58**	0.16	0.51**	0.39**	0.23
	(0.21)	(0.08)	(0.45)	(0.08)	(0.21)	(0.26)	(0.12)	(0.04)	(0.32)
h	2.38**	0.59**	-0.63**	0.78**	1.85**	0.43**	1.23**	1.54**	0.56**
	(0.51)	(0.24)	(0.08)	(0.18)	(0.21)	(0.08)	(0.56)	(0.12)	(0.12)
i	3.12	-1.48**	0.28	4.12**	0.82	2.12	0.65	3.21	4.26**
	(2.18)	(0.13)	(0.48)	(1.34)	(0.64)	(2.67)	(0.43)	(2.25)	(0.95)
j	0.05	1.87	1.90	0.34	0.08	2.45	0.656	1.43	-3.23**
	(0.08)	(1.23)	(1.09)	(0.23)	(0.09)	(1.42)	(1.13)	(2.34)	(1.05)
l	6.65	1.87**	0.12	-0.87**	1.56	0.07	0.02	1.86	-2.25**
	(5.32)	(0.28)	(1.19)	(0.08)	(2.13)	(0.08)	(0.09)	(2.59)	(0.52)
Ep.	-	C	-	D	-	-	-	-	D

F_2	1.45	1.30	1.20	1.37	1.63	0.99	0.99	1.42	1.59
	(0.05)	(0.02)	(0.05)	(0.07)	(0.27)	(0.01)	(0.01)	(0.08)	(0.29)
B_1	1.68	1.44	0.99	1.42	1.48	0.98	1.38	0.99	1.30
	(0.00)	(0.01)	(0.01)	(0.01)	(0.26)	(0.01)	(0.02)	(0.01)	(0.11)
B_2	1.33	1.25	1.95	1.22	1.67	1.37	1.42	1.33	1.60
	(0.03)	(0.02)	(0.02)	(0.01)	(0.10)	(0.07)	(0.01)	(0.02)	(0.05)
m	1.45**	1.30**	1.20**	1.37**	1.63**	0.99**	0.09	1.42**	1.59**
	(0.05)	(0.02)	(0.05)	(0.07)	(0.27)	(0.01)	(0.01)	(0.08)	(0.29)
d	0.34**	0.18**	-0.95**	0.19**	-0.18**	-0.38**	-0.03	-0.34**	-0.30**
	(0.02)	(0.01)	(0.01)	(0.01)	(0.08)	(0.06)	(0.02)	(0.02)	(0.12)
h	0.52**	0.20	0.82**	0.34	-0.02	0.21	1.24**	-0.90	-0.25
	(0.21)	(0.13)	(0.23)	(0.29)	(1.23)	(0.14)	(0.13)	(0.34)	(0.89)
i	0.21	0.18	1.09**	-0.18	-0.23	0.23	1.64**	-1.02**	-0.54
	(0.20)	(0.10)	(0.22)	(0.29)	(1.22)	(0.13)	(0.05)	(0.33)	(0.86)
j	0.02	0.26	-0.82**	0.05	-0.17	-0.08	-0.07	-0.66**	-0.47**
	(0.03)	(0.22)	(0.02)	(0.02)	(0.27)	(0.07)	(0.03)	(0.03)	(0.12)
l	0.22	-0.08	-1.83**	0.47	-0.48	-0.31	-1.65**	1.89**	1.18
	(0.24)	(0.13)	(0.27)	(0.30)	(1.58)	(0.28)	(0.25)	(0.38)	(1.08)
Ep.	-	-	D	-	-	-	D	D	D

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Pusa Sheetal x Pusa Sadabahar, Pusa Sheetal x Pusa Uphar and Pusa Sadabahar x Pusa Uphar. Hence, it showed the importance of heterosis breeding. In the crosses, Pusa Sheetal x DT-39, Pusa Sheetal x Chiku and Pusa Sadabahar x Chiku complementary epistasis was observed which indicated the importance of selection for improvement of this trait. In cross Pusa Sadabahar x Booster additive component was significant indicating the importance of selection in improving this trait. Similar result for fruit length were reported by Sheif and Hussain (1992) *i.e.* dominance genetic components was important for the inheritance of fruit length under high temperature regime. Fruit diameter was agreement with results of Rai *et al.* (2005) observed importance of both dominance and duplicate epistasis for fruit diameter. Whereas, Ghosh *et al.* (1996) reported partial dominance for this trait.

Additive effects were of greatest importance in crosses Pusa Sheetal x DT-39, Pusa Sadabahar x DT-39 and Pusa Sadabahar x Pusa Uphar for TSS. Whereas, additive and complementary type of epistasis were predominant in cross Pusa Sadabahar x Booster indicating improvement of this trait through single seed descent method till high level of gene fixation is attained followed by reciprocal selection in subsequent generations. Dominance effects played predominant role in cross Pusa Sheetal x Pusa Uphar for TSS. The estimates of additive effects were found in favourable direction in cross Pusa Sheetal x Chiku for Vit. C indicating importance of selection for improvement of this trait. Two crosses Pusa Sheetal x Booster and Pusa Sadabahar x Chiku expressed duplicate epistasis for this trait. Hence, it showed the importance of heterosis breeding followed by selection procedure. Dominance type of gene effects were observed in cross Pusa Sheetal x Pusa Uphar for Vit. C content. Dominance and duplicate type of epistasis were of greatest importance in crosses Pusa Sheetal x Pusa Sadabahar, Pusa Sheetal x DT-39, Pusa Sadabahar x DT-39 and Pusa Sadabahar x Pusa Uphar for lycopene content. Hence, it showed the importance of heterosis breeding. Additive type of gene effects were expressed by cross Pusa Sheetal x Booster indicating the importance of selection. The cross Pusa Sadabahar x Chiku showed presence of duplicate type of epistasis for b-carotene content indicating importance of heterosis for improvement of this trait. In the crosses Pusa Sheetal x Pusa Sadabahar, Pusa Sheetal x Chiku and Pusa Sadabahar x Pusa Uphar both dominance and additive gene effects were of greatest importance. Similar result for these traits were earlier reported by Tikkoo (1987) and Kanthaswamy *et al.* (1995) for TSS, Khattra *et al.* (1990) for Vit. C content and Roopa *et al.* (2001) for lycopene content in tomato.

The knowledge of nature and magnitude of gene effects controlling inheritance of traits related to quality and nutritional would aid to choice of efficient breeding methods and thus accelerate the pace of its genetic improvement. In general dominance and epistasis effects were significant for most of the characters. It is suggested that the heterosis breeding may be useful in the crosses which exhibited duplicate epistasis along with pronounced dominance gene effects. Whereas, the crosses, which showed, pronounced additive gene effects along with complementary epistasis, suggested the possibility of fixing the particular character through selection methods.

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