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Genetic analysis for yield and its contributing traits in tomato under low temperature regime

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Abstract: The estimates of six parameters (m,d,h,i,j and l) for nine cross combinations were calculated for yield and yield related traits. Interacting and non-interacting crosses were classified by scaling test. The scaling test was found significant for most of the traits in all the crosses. Duplicate epistasis was most commonly observed for all traits in majority of the crosses, whereas for number of branches, days to first fruit harvest, number of fruit/cluster and yield/plant all crosses exhibited duplicate epistasis. Complementary epistasis was observed in crosses Pusa Sheetal x Booster and Pusa Sheetal x DT-39 for days to 50% flowering, Pusa Sheetal x Booster for days to first fruit set, Pusa Sheetal x Pusa Uphar , Pusa Sheetal x Chiku and Pusa Sadabahar x Booster for number cluster/plant, Pusa Sheetal x Pusa Sadabahar for number fruits/plant, Pusa Sadabahar x Chiku for shoot length, Pusa Sheetal x Chiku and Pusa Sadabahar x Chiku for plant height.

Keywords: Genetic analysis, scalling test, tomato

Introduction

The tomato (*Solanum lycopersicum*) is a worldwide cultivated vegetable crop, which is used both as a fresh market and processed product, such as paste, juice, sauce, powder or whole. It is a good source of potassium, folate, and vitamin E, soluble and insoluble dietary fibers. It has high levels of lycopene (71.6%) and ascorbic acid (12%) (Kaur and Kapoor, 2008). It contributes significantly to the dietary intake of vitamins A and C as well as essential minerals and other nutrients. 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 yield and yield related traits in tomato.

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Material and Method

Six parental lines comprising of two cold set (Pusa Sheetal and Pusa Sadabahar) and four non cold set (Booster, Pusa Rohini, Pusa Uphar and Chiku) were crossed to produce nine hybrids *i.e* . Pusa Sheetal x Pusa Sadabahar, Pusa Sheetal x Booster, Pusa Sheetal x DT-39, Pusa Sheetal x Pusa Uphar, Pusa Sheetal x Chiku, Pusa Sadabahar x Booster, Pusa Sadabahar x DT-39, Pusa Sadabahar x Pusa Uphar and Pusa Sadabahar x Chiku, subsequently F_2, B_1 and B_2 population developed. All the six generations viz., P_1, P_2, F_1, F_2, B_1 and B_2 were evaluated during winter 2004 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. The crop transplanted on raised beds, spaced at 60cm in the field with spacing of 45 cm between plants. Data was recorded on five plants in parents and F_1s, 10 plants in B_1 and B_2 and 20 plants in F_2s per replication for shoot length of seedling at transplanting stage, plant height, number of primary branches/plant, days taken to 50% flowering, days taken to first fruit set, number of cluster/ plant, number of fruits/cluster, days taken to first fruit harvest, number of fruits/plant and yield/plant. The data were subjected to generation mean analysis (Hayman, 1958) to obtain information on additive, dominance and digenic epistatic interactions.

Result and Discussion

The traits means for six generations of each the nine crosses are presented in Table 1 for various yield and yield related traits. Additive effects were important in crosses Pusa Sheetal x Pusa Sadabahar, Pusa Sheetal x DT-39 and Pusa Sadabahar x Pusa Uphar for shoot length. Hence, pedigree or recurrent selection method would be appropriate for this trait. In crosses Pusa Sheetal x Booster, Pusa Sheetal x Pusa Uphar, Pusa Sheetal x Chiku, and Pusa Sadabahar x Booster additive and non-additive effects were equally important and epistasis was of duplicate in nature. Hence, a breeding procedure which can exploit both kinds of gene action would be appropriate. In cross Pusa Sadabahar x Chiku epistasis was of complementary type and selection method will be effective in this cross for shoot length. In crosses Pusa Sheetal x Pusa Sadabahar additive gene component was significant and in positive direction for number of primary branches. Hence, these positive additive loci can be exploited through pedigree and recurrent selection method which would result in progress for this trait. Additive and dominance effects with duplicate epistasis were predominant in cross Pusa Sadabahar x Chiku whereas, additive and duplicate components were recorded in crosses Pusa Sheetal x Booster and Pusa Sheetal x Pusa Uphar. A breeding method based on single seed descent till high level of gene fixation is attained and subsequent selection would be appropriate. Dominance gene effects were significant in cross Pusa Sheetal x Chiku but in undesirable direction. Duplicate type of epistasis was found in crosses Pusa Sheetal x DT-39, Pusa Sadabahar x DT-39 and Pusa Sadabahar x Pusa Uphar. Heterosis breeding would be effective in exploitation of this trait. Duplicate type of epistasis was observed in three out of nine crosses *i.e.* Pusa Sadabahar x Booster, Pusa Sadabahar x DT-39 and Pusa Sadabahar x Pusa Uphar for days to 50% flowering. Hence, heterosis breeding followed by selection procedure will be important. Importance of additive gene action for days to flowering was also reported by Sonone *et al.,* (1981). Whereas, Brrooah and Talukdar (2001) observed importance of duplicate epistasis for this trait. Complimentary type of epistasis expressed by cross Pusa Sheetal x Booster showed importance of selection for improvement of this trait. Dominance gene effects and duplicate type of epistasis were observed in cross Pusa Sheetal x Pusa Sadabahar. Megha *et al.,* (2005) reported non-additive type of gene action for days to flowering. These results are in conformity to above finding. The major contributor of fruit set was observed to be additive and duplicate component of genetic variance in crosses Pusa Sheetal x DT-39, Pusa Sheetal x Pusa Uphar, Pusa Sheetal x Chiku and Pusa Sadabahar x Booster. These results point out towards the possibility of heterosis breeding for increased fruit set followed by proper selection procedure. The estimates of additive effects was found to be in favourable direction in cross Pusa Sheetal x Booster. In two crosses (Pusa Sadabahar x DT-39 and Pusa Sadabahar x Chiku) duplicate type of epistasis was found to be significant. The estimates of dominance x dominance effects were found to be in favourable negative direction for days to first fruit harvest in crosses Pusa Sheetal x Pusa Sadabahar, Pusa Sheetal x Booster, Pusa Sheetal x DT-39, Pusa Sheetal x Pusa Uphar, Pusa Sadabahar x Booster, Pusa Sadabahar x DT-39 and Pusa Sadabahar x Chiku. This indicates the possibility of obtaining early fruit harvest by heterosis breeding. Both additive and duplicate type of epistasis was observed in cross Pusa Sheetal x Booster, Pusa Sheetal x DT-39, Pusa Sheetal x Pusa Uphar and Pusa Sadabahar x DT-39. The improvement of this character may be achieved by proper selection procedure. Similar result for these traits were earlier reported by Dhoke (1995) for fruit set and Katoch and Vidyasagar (2004) days to first fruit harvest in tomato.

Additive type of gene effects possessed significant value in positive direction in seven out of nine crosses for number of cluster per plant. Duplicate epistasis was observed in four crosses. The improvement of this character may be achieved by heterosis breeding followed by proper selection procedure. Three crosses (Pusa Sheetal x Pusa Uphar, Pusa Sheetal x Chiku and Pusa Sadabahar x Booster) showed complementary type of epistasis and additive gene effects. These results indicate the possibility of selection for increased number of clusters per plant. Dominance effects and duplicate type of epistasis were observed in the crosses Pusa Sheetal x Pusa Sadabahar, Pusa Sheetal x Booster, Pusa Sheetal x Pusa Uphar and Pusa Sadabahar x Chiku for fruit per cluster. Hence, a breeding method based on single seed descent till high level of gene fixation is attained and subsequent selection would be appropriate for this trait. In cross Pusa Sheetal x DT-39, Pusa Sadabahar x Booster and Pusa Sadabahar x Pusa Uphar duplicate type of epistasis was found to be significant. It showed the importance of heterosis breeding for improvement of this trait. In crosses, Pusa Sheetal x Booster, Pusa Sadabahar x DT-39 and Pusa Sadabahar x Pusa Uphar duplicate type of epistasis were found to be significant for number of fruits per plant. It showed the importance of heterosis breeding for improvement of this trait. In the cross Pusa Sheetal x Pusa Sadabahar additive and complementary type epistasis were found to be significant. Hence, a breeding procedure based on selection would improve this trait. In the crosses Pusa Sheetal x DT-39, Pusa Sheetal x Chiku and Pusa Sadabahar x Booster, additive effects and duplicate epistasis were of higher magnitude hence, it can be exploited by initial single seed descent method till high level of gene fixation is attained followed by reciprocal recurrent selection in subsequent generations would

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
50% flowering									
P_1	94.47	94.47	94.47	94.47	94.47	91.13	91.13	91.13	91.13
	(0.95)	(0.95)	(0.95)	(0.95)	(0.95)	(0.55)	(0.55)	(0.55)	(0.55)
P_2	91.13	112.15	101.70	11.65	101.00	112.15	101.70	111.65	101.00
	(0.55)	(3.33)	(1.33)	(1.81)	(0.84)	(3.33)	(1.33)	(1.81)	(0.84)
F_1	88.27	105.78	99.07	103.33	109.00	101.83	105.00	110.00	103.00
	(0.59)	(1.44)	(0.55)	(0.88)	(0.58)	(3.83)	(0.58)	(1.50)	(0.58)
F_2	97.67	112.00	101.00	103.43	112.67	104.67	103.67	108.00	105.33
	(0.88)	(1.15)	(0.58)	(0.74)	(0.67)	(2.40)	(0.88)	(1.15)	(0.33)
B_1	91.67	107.33	99.17	102.97	110.00	107.50	111.50	105.30	115.00
	(0.88)	(1.20)	(0.60)	(1.05)	(1.15)	(0.76)	(0.76)	(0.57)	(0.58)
B_2	94.67	110.00	103.33	106.00	118.67	111.17	115.00	117.33	111.67
	(0.33)	(1.15)	(0.88)	(1.15)	(0.67)	(0.60)	(0.58)	(1.33)	(0.83)
m	97.67**	112.00**	101.00**	103.43** (0.74)	112.67**	104.67**	103.67**	108.00**	105.33**
	(0.88)	(1.15)	(0.58)		(0.67)	(2.40)	(0.88)	(1.15)	(0.33)
d	-1.30	-1.26	-1.41	-1.30	-1.86	-3.66**	-3.50**	-12.03**	3.33**
	(0.94)	(1.16)	(1.10)	(1.15)	(1.13)	(0.97)	(0.95)	(1.44)	(1.01)
h	-22.52**	-10.86**	1.19	2.44**	17.93**	18.86*	46.92**	21.87**	38.93**
	(1.40)	(1.61)	(1.32)	(1.45)	(1.38)	(9.96)	(4.11)	(5.65)	(2.54)
i	-18.00**	-13.33**	1.10	1.42	1.66	18.66*	38.33**	13.26*	21.42
	(1.40)	(1.56)	(1.31)	(1.43)	(1.37)	(9.80)	(4.01)	(5.45)	(2.42)
j	-1.46	1.61	-0.55	1.55	-1.54	6.84**	1.78	-1.77	8.27**
	(1.10)	(1.24)	(1.13)	(1.18)	(1.14)	(1.94)	(1.19)	(1.72)	(1.13)
l	1.74	-1.31	11.68**	-1.93	-50.53**	-49.05**	-88.50**	-35.75**	-87.20**
	(1.54)	(1.92)	(1.52)	(1.74)	(1.62)	(10.94)	(5.52)	(7.99)	(4.20)
Ep.	D	C	C	-	D	D	D	D	D
First fruit set									
P_1	96.60	96.60	96.60	96.60	96.60	92.55	92.55	92.55	92.55
	(1.01)	(1.01)	(1.01)	(1.01)	(1.01)	(0.86)	(0.86)	(0.86)	(0.86)
P_2	92.55	119.68	110.33	116.09	108.81	119.68	11.33	116.09	108.81
	(0.86)	(1.76)	(1.19)	(1.15)	(1.01)	(1.76)	(1.19)	(1.15)	(1.01)
F_1	91.58	111.33	102.00	109.30	115.74	111.67	113.00	118.00	107.33
	(0.79)	(0.67)	(0.58)	(0.55)	(1.70)	(0.88)	(0.58)	(1.15)	(1.20)
F_2	103.67	113.87	105.15	110.04	116.33	113.53	109.00	115.50	105.50
	(0.88)	(0.88)	(0.41)	(0.22)	(1.17)	(0.58)	(0.58)	(0.58)	(0.29)
B_1	96.63	110.83	104.33	108.03	111.83	105.83	115.17	110.00	119.00
	(0.41)	(0.60)	(0.60)	(1.39)	(1.01)	(0.44)	(0.60)	(0.76)	(0.58)
B_2	98.33	115.00	110.00	113.67	122.00	116.00	111.33	118.33	112.67
	(0.33)	(0.58)	(1.15)	(0.88)	(1.15)	(1.15)	(1.76)	(0.88)	(0.67)
m	103.67**	113.87**	105.15**	110.04**	116.33**	113.53**	109.00	115.50**	105.50**
	(0.88)	(0.88)	(0.41)	(0.22)	(1.17)	(0.58)	(0.58)	(0.58)	(0.29)
d	-1.70**	-4.16**	-5.66**	-5.23**	-10.16**	-10.16**	3.83**	-8.33**	6.33**
	(0.52)	(0.83)	(1.30)	(1.64)	(1.53)	(1.23)	(1.86)	(1.16)	(0.88)
h	-27.72**	-0.60	6.60	6.98	15.36**	-4.91	28.56**	8.35**	47.98**
	(3.82)	(4.06)	(3.78)	(3.53)	(5.88)	(3.63)	(4.48)	(3.55)	(2.51)
i	-24.74**	-3.80	8.06**	4.02	2.33	-10.46**	17.00**	-5.33	41.33**
	(3.68)	(3.88)	(3.07)	(3.40)	(5.58)	(3.38)	(4.38)	(3.28)	(2.10)
j	-3.72**	7.37**	1.19	4.51**	-4.05**	3.39**	2.72**	3.43**	14.46**
	(0.84)	(1.31)	(1.51)	(1.81)	(1.69)	(1.57)	(1.20)	(1.36)	(1.10)
l	7.49	-8.92	-255.80**	-16.94**	-33.11**	2.35	-41.1**	-6.70	-88.63**
	(4.60)	(5.41)	(5.79)	(1.68)	(8.55)	(6.05)	(8.02)	(5.87)	(4.61)
Ep.	D	C	D	D	D	D	D	D	D

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
Shoot length									
P_1	20.40	20.40	20.40	20.40	20.40	15.10	15.10	15.10	15.10
	(0.31)	(0.31)	(0.31)	(0.31)	(0.31)	(0.35)	(0.35)	(0.35)	(0.35)
P_2	15.10	16.64	17.37	19.27	15.87	16.64	17.37	19.27	15.87
	(0.35)	(0.09)	(0.59)	(0.13)	(0.24)	(0.09)	(0.59)	(0.13)	(0.24)
F_1	18.67	15.97	19.23	19.47	17.45	15.47	16.60	17.44	14.87
	(0.81)	(0.19)	(0.54)	(0.18)	(0.18)	(0.15)	(0.10)	(0.10)	(0.20)
F_2	18.10	14.57	17.54	18.03	16.17	14.49	14.77	14.67	16.27
	(0.06)	(0.03)	(0.54)	(0.09)	(0.20)	(0.21)	(0.15)	(0.09)	(0.03)
B_1	17.33	14.90	18.10	20.27	14.67	15.47	14.40	15.77	17.27
	(0.27)	(0.21)	(0.06)	(0.12)	(0.08)	(0.09)	(0.06)	(0.09)	(0.03)
B_2	17.10	14.23	17.50	18.29	16.37	14.40	15.13	14.17	14.53
	(0.06)	(0.15)	(0.17)	(0.28)	(0.09)	(0.06)	(0.09)	(0.09)	(0.15)
m	18.10**	14.57**	17.54**	18.03**	16.17**	14.49**	14.77**	14.67**	16.27**
	(0.05)	(0.03)	(0.54)	(0.09)	(0.20)	(0.21)	(0.15)	(0.09)	(0.03)
d	063**	0.66**	0.60**	1.19**	-1.17**	0.33**	-0.73**	1.16**	1.27**
	(0.27)	(0.25)	(0.18)	(0.30)	(0.12)	(0.06)	(0.10)	(0.12)	(0.14)
h	-1.18	-1.25**	1.12	1.46**	-1.32	-1.41**	0.36	0.14	1.20**
	(1.10)	(0.57)	(1.22)	(0.75)	(0.88)	(0.38)	(0.71)	(0.48)	(0.43)
i	-1.27**	0.00	0.93	1.14**	-1.25	-1.38**	0.00	0.12	-1.14**
	(0.59)	(0.52)	(1.21)	(0.35)	(0.84)	(0.37)	(0.61)	(0.43)	(0.32)
j	-1.29**	-1.12**	-0.31	1.49**	-1.38**	0.55**	0.40	0.36	1.31**
	(0.35)	(0.30)	(0.37)	(0.71)	(0.23)	(0.07)	(0.35)	(0.22)	(0.25)
l	1.58	10.70**	1.41	-1.34	11.69**	1.85**	+	0.81	-1.14
	(1.20)	(1.11)	(1.25)	(1.13)	(1.10)	(0.46)		(0.74)	(0.84)
Ep.	D	D	-	D	D	D	-	-	C
Number of branches									
P_1	5.08	5.08	5.08	5.08	5.08	4.10	4.10	4.10	4.10
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)
P_2	4.10	6.80	7.00	9.23	6.00	6.80	7.00	9.23	6.00
	(0.05)	(0.06)	(0.10)	(0.28)	(0.06)	(0.06)	(0.10)	(0.28)	(0.06)
F_1	5.57	7.08	6.60	6.09	7.14	6.09	6.19	6.82	0.22
	(0.22)	(0.06)	(0.20)	(0.05)	(0.07)	(0.04)	(0.10)	(0.04)	(0.06)
F_2	5.50	6.73	6.17	5.80	7.23	6.27	5.63	5.50	4.73
	(0.17)	(0.12)	(0.03)	(0.12)	(0.15)	(0.12)	(0.09)	(0.17)	(0.12)
B_1	5.30	6.83	5.50	5.77	5.60	5.50	4.77	4.17	7.80
	(0.06)	(0.09)	(0.25)	(0.09)	(0.15)	(0.06)	(0.09)	(0.09)	(0.17)
B_2	5.10	6.30	5.37	5.23	5.80	6.37	5.90	6.47	5.20
	(0.06)	(0.06)	(0.13)	(0.09)	(0.12)	(0.09)	(0.06)	(0.03	(0.06)
m	5.50**	6.73**	6.17**	5.80**	7.23**	6.27**	5.63**	5.50**	4.73**
	(0.17)	(0.12)	(0.03)	(0.12)	(0.15)	(0.12)	(0.09)	(0.17)	(0.12)
d	0.19**	0.53**	0.13	0.53**	-0.19	-0.86**	-1.11**	-1.23**	1.26**
	(0.08)	(0.10)	(0.27)	(0.12)	(0.19)	(0.10)	(1.10)	(0.09)	(0.18)
h	-0.122	0.46	-1.23*	-1.22*	-1.45**	-0.69	-0.55	-0.58	1.72**
	(0.74)	(0.52)	(0.06)	(0.54)	(0.70)	(0.52)	(0.42)	(0.73)	(0.60)
i	-1.12	-0.66	-1.29	-1.11	-1.61**	-1.13**	-1.11	-0.73	1.70*
	(0.71)	(0.52)	(0.57)	(0.52)	(0.69)	(0.52)	(0.41)	(0.71)	(0.60)
j	-0.29**	1.13**	1.10**	1.26**	0.25	0.48	0.30*	0.26	1.35**
	(0.08)	(0.11)	(0.28)	(0.19)	(0.19)	(0.31)	(0.12)	(0.17)	(0.18)
l	0.72	-0.43	1.64	1.56	0.87	0.67	1.33*	1.64*	-12.51**
	(0.88)	(0.65)	(1.11)	(0.74)	(0.97)	(0.65)	(0.59)	(0.84)	(0.88)
Ep.	D	D	D	D	D	D	D	D	D

Contd...

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
Number of fruit/cluster									
P_1	3.01	3.01	3.01	3.01	3.01	3.79	3.79	3.79	3.79
	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.32)	(0.32)	(0.32)	(0.32)
P_2	3.79	1.53	3.78	3.00	1.28	1.53	3.78	3.00	1.28
	(0.32)	(0.28)	(0.31)	(0.03)	(0.16)	(0.28)	(0.31)	(0.03)	(0.16)
F_1	4.28	2.40	1.26	2.97	2.61	1.84	3.65	1.45	1.79
	(0.11)	(0.06)	(0.04)	(0.41)	(0.09)	(0.18)	(0.18)	(0.24)	(0.15)
F_2	3.42	2.00	1.17	1.98	2.82	2.28	3.31	1.18	1.25
	(0.16)	(0.06)	(0.17)	(0.35)	(0.10)	(0.12)	(0.10)	(0.09)	(0.14)
B_1	4.04	2.33	1.15	2.72	1.97	3.14	1.17	1.42	2.80
	(0.05)	(0.12)	(0.08)	(0.14)	(0.09)	(0.08)	(0.09)	(0.30)	(0.06)
B_2	3.38	2.10	1.93	3.19	1.87	2.30	3.57	2.33	1.23
	(0.09)	(0.06)	(0.23)	(0.05)	(0.07)	(0.12)	(0.12)	(0.17)	(0.15)
m	3.42**	2.00**	1.17**	1.98**	2.82**	2.28**	3.31**	1.18**	1.25**
	(0.16)	(0.06)	(0.17)	(0.35)	(0.10)	(0.12)	(0.10)	(0.09)	(0.14)
d	0.66**	0.23	-0.78**	-0.47**	9.99**	0.84**	-2.39*	-0.91**	1.56**
	(0.19)	(0.13)	(0.24)	(0.14)	(0.11)	(0.14)	(0.94)	(0.34)	(0.15)
h	2.03**	1.00**	-0.62	3.87**	-3.16**	0.93	-3.90**	0.85	2.31**
	(0.77)	(0.39)	(0.84)	(1.49)	(0.46)	(0.67)	(0.57)	(0.82)	(0.69)
i	1.15**	0.88**	1.50	3.91**	-3.62**	1.75**	-3.76**	2.79**	3.06**
	(0.74)	(0.36)	(0.82)	(1.43)	(0.42)	(0.54)	(0.54)	(0.77)	(0.65)
j	1.05**	-0.50**	-0.39	-0.48**	-0.76**	-0.28	-2.40**	-1.31**	0.31
	(0.25)	(0.19)	(0.29)	(0.15)	(0.14)	(0.25)	(0.26)	(0.37)	(0.23)
l	-0.62**	-0.40	1.63**	-3.78**	5.48**	-3.63**	9.16**	-0.59	-2.48*
	(0.08)	(0.60)	(1.23)	(1.74)	(0.64)	(0.91)	(0.19)	(1.53)	(0.97)
Ep.	D	D	D	D	D	D	D	D	D
Number of fruits/plant									
P_1	57.14	57.14	57.14	57.14	57.14	61.97	61.97	61.97	61.97
	(0.65)	(0.65)	(0.65)	(0.65)	(0.65)	(0.90)	(0.90)	(0.90)	(0.90)
P_2	61.97	32.12	37.90	47.30	20.77	32.12	37.90	47.30	20.77
	(0.90)	(1.12)	(0.55)	(2.13)	(0.19)	(1.12)	(0.55)	(2.13)	(0.19)
F_1	69.00	37.33	43.87	53.67	28.57	33.00	45.50	36.33	34.46
	(0.58)	(0.67)	(0.68)	(0.73)	(0.25)	(0.58)	(0.29)	(0.88)	(0.26)
F_2	55.00	33.00	37.57	50.47	27.83	31.93	40.63	35.15	29.09
	(0.58)	(0.58)	(0.55)	(1.07)	(1.30)	(0.77)	(0.50)	(0.58)	(0.58)
B_1	61.50	33.50	41.00	53.00	31.33	42.83	37.50	28.50	53.50
	(0.76)	(0.50)	(0.76)	(0.76)	(0.67)	(0.60)	(0.76)	(0.29)	(0.76)
B_2	55.67	30.70	36.43	47.67	21.67	26.67	38.00	32.94	24.49
	(1.45)	(0.44)	(0.92)	(0.88)	(0.88)	(1.01)	(1.15)	(0.60)	(0.26)
m	55.00**	33.00**	37.57**	50.47**	27.83**	31.93**	40.63**	35.15**	29.09**
	(0.58)	(0.58)	(0.55)	(1.07)	(1.30)	(0.77)	(0.50)	(0.58)	(0.58)
d	5.83**	2.80	4.57**	5.33**	9.67**	16.16**	-0.50	-4.43**	29.01**
	(1.64)	(1.66)	(1.19)	(1.17)	(1.11)	(1.17)	(1.38)	(0.66)	(0.80)
h	13.78**	-10.89**	-0.94	0.5	-15.72**	-2.77	-15.97**	-35.96**	32.80**
	(4.09)	(2.82)	(3.44)	(5.6)	(5.67)	(3.98)	(3.52)	(3.04)	(2.89)
i	14.33**	-3.60	4.60	-0.53	-5.33	11.26**	-11.53**	-17.66**	39.70**
	(4.01)	(2.66)	(3.25)	(4.88)	(5.66)	(3.87)	(3.41)	(2.68)	(2.82)
j	8.24**	-9.70**	-5.05**	0.41	-8.52**	1.24	-12.53**	-11.78**	84.13**
	(1.73)	(0.92)	(1.51)	(1.61)	(1.16)	(1.38)	(1.60)	(1.33)	(0.92)
l	8.43**	39.12**	23.31**	10.7	34.38**	9.82	51.40**	76.72**	-44.01**
	(1.15)	(3.97)	(5.64)	(6.87)	(6.88)	(5.92)	(6.13)	(4.57)	(4.11)
Ep.	C	D	D	-	D	D	D	D	D

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
Days to first fruit harvest									
P_1	124.17	124.17	124.17	124.17	124.17	115.60	115.60	115.60	115.60
	(1.82)	(1.82)	(1.82)	(1.82)	(1.82)	(1.70)	(1.70)	(1.70)	(1.70)
P_2	115.60	136.35	133.43	136.08	131.75	136.35	133.433	139.08	131.75
	(1.70)	(0.67)	(0.89)	(0.69)	(0.75)	(0.67)	(0.89)	(0.69)	(0.75)
F_1	117.67	131.00	126.33	136.33	133.00	121.67	128.33	136.00	131.33
	(1.45)	(0.58)	(0.88)	(0.88)	(0.58)	(0.88)	(0.88)	(0.58)	(0.67)
F_2	123.33	131.67	129.00	140.67	138.00	125.00	133.33	141.00	125.00
	(0.67)	(1.86)	(0.58)	(1.76)	(1.15)	(0.58)	(0.67)	(0.58)	(0.58)
B_1	123.00	132.67	129.67	141.00	123.50	129.83	138.50	122.00	137.83
	(1.53)	(0.67)	(0.99)	(0.58)	(0.76)	(0.44)	(0.29)	(1.15)	(0.60)
B_2	125.00	136.33	132.67	145.00	143.00	128.67	134.67	141.00	126.33
	(0.58)	(0.88)	(0.67)	(0.58)	(0.58)	(0.67)	(0.67)	(0.58)	(0.88)
m	123.33	131.67	129.00	140.67	138.00	125.00	133.33**	141.00	125.00
	(0.67)	(1.86)	(0.58)	(1.76)	(1.15)	(0.58)	(0.67)	(0.58)	(0.58)
d	-2.00	-3.66**	-3.00**	-4.00**	-19.50**	1.16	3.83**	-19.00**	11.49**
	(1.63)	(1.10)	(0.74)	(0.81)	(0.95)	(0.79)	(0.72)	(1.29)	(1.06)
h	0.44	12.07	6.15	14.04	-13.95**	12.69**	24.77**	-29.34**	35.99**
	(4.63)	(7.82)	(3.25)	(7.36)	(5.12)	(3.08)	(3.30)	(3.63)	(3.34)
i	2.66	11.33	8.66**	9.33	-19.00**	17.00**	21.00**	-38.00**	28.33**
	(4.21)	(7.74)	(2.74)	(7.24)	(5.00)	(2.80)	(3.03)	(3.46)	(3.14)
j	-6.28**	2.42	1.67	3.45**	-15.71**	11.54**	12.79**	-7.25**	19.57**
	(2.05)	(1.47)	(1.25)	(1.27)	(1.37)	(1.21)	(1.20)	(1.58)	(1.41)
l	-23.56**	-26.81**	-22.97**	-45.41**	7.91	-38.71**	-61.54**	38.68**	-46.65**
	(8.02)	(8.93)	(4.63)	(8.20)	(6.41)	(4.69)	(4.74)	(6.05)	(5.36)
Ep.	D	D	D	D	D	D	D	D	D
Number of cluster/plant									
P_1	33.89	33.89	33.89	33.89	33.89	32.00	32.00	32.00	32.00
	(1.82)	(1.82)	(1.82)	(1.82)	(1.82)	(0.33)	(0.33)	(0.33)	(0.33)
P_2	32.00	27.50	31.03	37.14	22.91	27.50	31.03	37.14	22.91
	(0.33)	(0.68)	(0.33)	(0.55)	(0.23)	(0.68)	(0.33)	(0.55)	(0.23)
F_1	33.32	30.17	32.05	36.07	25.15	28.73	32.29	29.19	27.61
	(0.49)	(1.01)	(0.29)	(1.23)	(0.64)	(0.79)	(0.48)	(0.63)	(0.31)
F_2	29.50	25.37	27.33	35.78	21.22	25.47	28.89	27.50	23.67
	(0.76)	(0.45)	(0.67)	(0.70)	(0.64)	(0.68)	(0.56)	(0.29)	(0.88)
B_1	31.50	27.10	28.83	35.33	27.83	29.50	25.63	25.09	28.87
	(0.76)	(0.46)	(0.60)	(0.60)	(0.67)	(0.76)	(0.38)	(0.66)	(0.63)
B_2	28.67	23.00	25.17	31.00	17.83	23.83	26.67	25.13	22.00
	(0.67)	(0.58)	(0.60)	(0.58)	(0.44)	(0.44)	(0.67)	(0.47)	(1.15)
m	29.50**	25.37**	27.23**	35.78**	21.22**	25.47**	28.89**	27.50**	23.67**
	(0.76)	(0.45)	(0.67)	(0.70)	(0.64)	(0.68)	(0.56)	(0.29)	(0.88)
d	2.83**	4.10**	3.66**	4.33**	10.00	56.66**	-1.30	-4.00**	6.86**
	(1.01)	(0.73)	(0.84)	(0.83)	(0.79)	(0.88)	(0.76)	(0.80)	(1.39)
h	2.71	-1.79	-1.34	2.09	3.22	3.77	-1019**	-14.93**	7.22
	(3.81)	(2.71)	(3.33)	(3.61)	(0.20)	(3.34)	(2.76)	(2.10)	(4.41)
i	2.33	-1.26	-0.93	1.54	6.46	4.79	-10.97**	-9.54**	7.06
	(3.66)	(2.32)	(3.18)	(3.26)	(3.00)	(3.33)	(2.71)	(1.91)	(4.40)
j	1.88	0.90	2.23	5.95**	4.50**	3.49**	-1.51**	2.53**	2.32
	(1.37)	(1.21)	(1.25)	(1.26)	(1.21)	(0.94)	(0.79)	(0.86)	(1.33)
l	9.87	22.79**	21.95**	8.95	9.30	5.50	43.96**	36.60**	1.33
	(5.49)	(4.44)	(4.75)	(5.35)	(4.90)	(4.77)	(3.90)	(3.71)	(6.38)
Ep.	-	D	D	C	C	C	D	D	-

Contd...

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
Yield /plant									
P_1	2.07	2.07	2.07	2.07	2.07	3.67	3.67	3.67	3.67
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.09)	(0.09)	(0.09)	(0.09)
P_2	3.67	1.51	2.17	1.55	1.28	1.51	2.17	1.55	1.28
	(0.09)	(0.04)	(0.19)	(0.03)	(0.04)	(0.04)	(0.19)	(0.03)	(0.04)
F_1	4.40	2.67	3.57	3.30	2.67	3.62	3.20	1.90	2.20
	(0.32)	(0.09)	(0.19)	(0.10)	(0.12)	(0.09)	(0.12)	(0.03)	(0.15)
F_2	3.73	2.18	2.70	3.08	2.28	3.15	3.07	2.37	2.07
	(0.12)	(0.06)	(0.25)	(0.04)	(0.07)	(0.03)	(0.09)	(0.09)	(0.05)
B_1	4.10	2.40	3.13	3.20	2.53	3.57	2.40	1.93	1.33
	(0.06)	(0.06)	(0.07)	(0.03)	(0.03)	(0.12)	(0.10)	(0.06)	(0.33)
B_2	3.36	2.17	2.63	3.10	2.23	2.60	3.37	2.17	1.54
	(0.09)	(0.17)	(0.09)	(0.10)	(0.15)	(0.12)	(0.09)	(0.07)	(0.04)
m	3.73**	2.18**	2.70**	3.08**	2.28**	3.15**	3.07**	2.37**	2.07**
	(0.12)	(0.06)	(0.25)	(0.04)	(0.07)	(0.02)	(0.09)	(0.09)	(0.05)
d	0.46**	0.23	0.50**	0.10**	0.30**	0.97**	-0.96**	-0.24**	-0.23
	(0.10)	(0.17)	(0.11)	(0.06)	(0.14)	(0.17)	(0.13)	(0.10)	(0.32)
h	2.06**	1.27**	0.21*	1.76**	1.39**	0.76**	-0.44	-1.98**	-2.83**
	(0.61)	(0.43)	(0.10)	(0.25)	(0.43)	(0.36)	(0.47)	(0.41)	(0.69)
i	0.53	0.40	0.73	0.27	0.40	-0.26	-0.73	-1.28**	-2.56**
	(0.52)	(0.42)	(1.03)	(0.22)	(0.41)	(0.35)	(0.44)	(0.41)	(0.67)
j	1.26**	-0.04	0.54	-0.16**	-0.09	-0.11	-1.71**	-1.30**	-1.43**
	(0.12)	(0.18)	(0.15)	(0.07)	(0.15)	(0.17)	(0.16)	(0.19)	(0.33)
l	-1.45**	-0.61	-2.19*	-2.66**	-1.45**	0.35	1.54*	2.11**	6.21**
	(0.91)	(0.77)	(0.81)	(0.38)	(0.71)	(0.70)	(0.71)	(0.57)	(1.36)
Ep.	2.07	2.07	2.07	2.07	2.07	3.67	3.67	3.67	3.67
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.09)	(0.09)	(0.09)	(0.09)

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
Plant height									
P_1	78.27	78.27	78.27	78.27	78.27	57.88	57.88	57.88	57.88
	(1.03)	(1.03)	(1.03)	(1.03)	(1.03)	(0.85)	(0.85)	(0.85)	(0.85)
P_2	57.88	74.83	77.55	81.55	63.12	74.83	77.55	81.55	63.12
	(0.85)	(0.86)	(1.45)	(0.51)	(2.65)	(0.86)	(1.45)	(0.51)	(2.65)
F_1	82.17	92.83	77.33	90.00	85.00	72.07	69.87	74.50	65.0
	(1.17)	(0.44)	(1.20)	(1.15)	(0.58)	(0.74)	(0.47)	(0.29)	(0.58)
F_2	71.17	78.00	73.00	72.00	66.33	55.67	54.00	61.00	54.00
	(0.73)	(1.53)	(1.00)	(0.58)	(1.20)	(0.88)	(2.08)	(0.58)	(0.58)
B_1	77.33	81.50	74.00	85.67	63.67	70.73	65.00	61.50	64.70
	(0.67)	(0.76)	(0.58)	(1.20)	(0.88)	(0.64)	(0.58)	(0.76)	(0.91)
B_2	74.67	78.50	72.83	82.00	74.00	66.83	73.00	69.20	65.01
	(0.33)	(0.29)	(0.17)	(1.15)	(0.58)	(0.44)	(0.58)	(0.56)	(0.42)
m	71.17**	78.00**	73.00**	72.00**	66.33**	55.67**	54.00**	61.00**	54.00**
	(0.73)	(1.53)	(1.00)	(0.58)	(1.20)	(0.88)	(2.08)	(0.58)	(0.58)
d	2.67**	3.00**	1.16**	3.67**	-10.22**	3.90**	-8.00**	-7.70**	-0.30
	(0.74)	(0.81)	(0.30)	(1.67)	(1.05)	(0.77)	(0.81)	(0.94)	(0.99)
h	33.42**	24.28**	-1.09	57.42**	24.30**	58.17**	62.15**	12.18**	47.91**
	(3.53)	(6.37)	(4.43)	(4.26)	(5.46)	(3.96)	(8.53)	(3.03)	(3.40)
i	9.33**	8.00	1.67	47.33**	-9.99**	52.46**	60.00**	17.40**	43.41**
	(3.26)	(6.32)	(4.18)	(4.06)	(5.24)	(3.85)	(8.48)	(2.98)	(3.05)
j	-7.52**	1.28	0.80	5.30**	-17.90**	12.38**	1.83**	4.13**	2.31
	(1.00)	(1.05)	(1.07)	(1.76)	(1.76)	(0.98)	(1.17)	(1.06)	(1.71)
l	-22.85**	10.77	15.14**	-42.85**	26.06**	-50.75**	-60.84**	9.62**	-51.82**
	(4.96)	(7.11)	(5.54)	(7.51)	(7.09)	(5.06)	(9.84)	(4.58)	(5.50)
Ep.	D	-	D	D	C	D	D	C	D

PSH-Pusa Sheetal, PS- Pusa Sadabahar, B-Booster, CH-Chiku, PU-Pusa Uphar improve this trait. Dominance and duplicate type of epistasis were of greatest importance in crosses *i.e.* Pusa Sheetal x Pusa Sadabahar, Pusa Sheetal x Pusa Uphar, Pusa Sadabahar x Booster, Pusa Sadabahar x DT-39 and Pusa Sadabahar x Chiku for plant height. Hence, heterosis breeding can be advocated for improvement of this trait. In the cross Pusa Sheetal x Booster both additive and dominance effects were predominant, indicating improvement of this character through heterosis breeding. In cross Pusa Sheetal x Chiku and Pusa Sadabahar x Pusa Uphar complementary type of epistasis was highly significant. In crosses Pusa Sheetal x Pusa Sadabahar and Pusa Sheetal x DT-39 additive, dominance and duplicate were important for yield per plant. Hence, a breeding procedure which can exploit both kinds of gene effects would be appropriate for improvement. Single seed descent method followed by reciprocal recurrent selection method would improve this trait. Dominance x dominance effects with duplicate epistasis was observed in crosses Pusa Sadabahar x DT-39, Pusa Sadabahar x Pusa Uphar and Pusa Sadabahar x Chiku. These results indicate that substantial gain can be achieved through heterosis breeding. In the crosses Pusa Sheetal x Booster, Pusa Sheetal x Pusa Uphar and Pusa Sheetal x Chiku dominance component was of greatest importance indicating importance of heterosis breeding for improvement of this trait. Similar result for these traits were earlier reported by Bhattacharjee (1999) for number of fruit/cluster and number of fruit/plant, Katoch and Vidyasagar (2004) for plant height and yield/plant and Dhankhar and Dhankhar (2002) and Dod *et al*., (1992) for fruit yield/ plant in tomato.

The results overall indicated the importance of heterosis breeding for most of the traits in various cross combinations. 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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