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Detection and estimation of components of genetic variation for some metric traits in tomato (*Lycopersicon esculentum* Mill)

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Summary. Sixty families from two tomato triple test crosses (S120 × EC61747 and EC31513 × 'Pusa Ruby') were raised in complete randomized blocks in two replications and two environments (two fertilizer levels). Jinks and Perkins' (1970) analysis was used to detect and estimate the additive, dominance and epistatic components of genetic variation for flowering time, maturity period, number of branches per plant, final height, shape index of fruit, locule number, number of fruits per plant, yield per plant and weight per fruit. The j & l type epistasis was more important than the i type epistasis in the first cross, while in the second cross the two components of epistasis played almost equal roles in the control of characters studied. Both the D (additive) and H (dominance) components were significant for most of the characters in both crosses and in both the environments. The D component was relatively more important than the H component in the first cross, while the situation was just the reverse in the second cross. Dominance was directional in 8 out of 36 cases. Ambidirectional dominance was observed in 27 cases. A real absence of dominance was observed in one case only.

Key words: Genetic variation – Metric trait – Tomato – Triple test cross

Introduction

The triple test cross method, which is a simple extension of the Design III of Comstock and Robinson (1952), was first described by Kearsey and Jinks (1968). A number of modifications/extensions have since been proposed in the design and analysis of this method. Jinks and Perkins (1970) suggested an important modification in the analysis of this design by partitioning the epistasis into i type (homozygote × homozygote) and j & l type (homozygote × heterozygote and heterozygote × heterozygote). They also obtained a more reliable estimate of additive component by including L_{3i} families ($F_2 \times F_1$) in the analysis of sums (measuring additive component).

The triple test cross method is, in several respects, superior to other biometrical procedures, particularly those based on second degree statistics: (1) the method provides an unambiguous test for epistasis and unbiased estimates of additive and dominance components of genetic variation if epistasis is absent, (2) it allows for detection of interaction between environment and the additive and dominance effects of genes both at micro-environmental and macro-environmental levels, and (3) the approach is independent of the allelic frequency, gene correlation and degree of inbreeding.

Materials and methods

Experimental design

Twenty plants were randomly selected from each of the two tamato F_2s (S120 × EC61747 and EC31513 × 'Pusa Ruby'). Each of these plants was crossed, as male, to both its parents (P_1 and P_2) and the F_1 ($P_1 \times P_2$) to produce L_{1i}, L_{2i} and L_{3i} families, respectively. Sixty families of each of the two crosses thus produced were raised in complete randomized blocks in two replications with two fertilizer levels (50 N: 30 P: 30 K and 100 N: 60 P: 60 K kg/h) in the spring of 1980. Observations were recorded on five competitive plants from each family for flowering time, maturity period, number of branches per plant, final height (cm), shape index of fruit, number of locules per fruit, number of fruits per plant, yield per plant (g) and weight per fruit (g).

Statistical analysis

The detection and estimation of additive (D), dominance (H) and epistatic components of genetic variation were carried out according to Jinks and Perkins (1970).

Test for epistasis. The mean squares due to the $(\bar{L}_{1i} + \bar{L}_{2i} - 2\bar{L}_{3i})$ item were obtained for 20 d.f. This item was tested, as χ^2, against within families mean squares calculated for 480 d.f. except where replicate error (20 d.f.) was significant. If the replicate error was signifcant, this error was used to test the significance of the item epistasis as variance ratio. The item epistasis was partitioned into i type and j & l type subcomponents for 1 and 19 d.f., respectively. The significance of this item was tested against i type epistasis × replicates and j & l type epistasis × replicates' items calculated for 1 and 19 d.f., respectively, if the latter two items were significant when tested against within families error.

Detection and estimation of D, H and F components. The mean squares due to sums $(\bar{L}_{1i} + \bar{L}_{2i} + \bar{L}_{3i})$ and due to differences $(\bar{L}_{1i} - \bar{L}_{2i})$ were each computed for 19 d.f. The significance of these items was tested, as X^2, against their respective within families error except where corresponding replicate interaction (sums × replicates/differences × replicates) for 19 d.f. was significant. In such cases, the sums and differences items were tested against their corresponding interactions, as variance ratio. The estimates of D, H and F components were obtained according to Jinks and Perkins (1970), assuming no linkage.

Results and discussion

Epistasis

The mean squares due to epistasis and their significance levels for nine characters are presented in Table 1. The epistasis was found significant for all nine characters except maturity period in the first environment in cross 1 (S120 × EC61747), indicating thereby a significant role played by epistasis in the control of characters in this cross. In cross 1, i type epistasis was significant for number of branches, number of fruit and yield per plant in the first environment, for shape index in the second environment and for final height in both environments. The j & l type epistasis was significant for all characters in both environments except maturity period in the first environment. In cross 2 (EC31513 × 'Pusa Ruby'), i type epistasis was significant for all the characters in both the environments except for final height in the second environment. The item j & l type epistasis also showed significant mean squares for all nine characters in each of the two environments for this cross. These results indicated that j & l type epistasis was relatively more important than i type epistasis in this tomato material. Singh and Singh (1976) have also observed similar results. They have reported that j & l type epistasis was relatively more important than i type epistasis in two wheat crosses.

D, H and F components and degree of dominance

The estimates of D, H and F components and degree of dominance for nine characters for two triple test crosses grown in two environments are presented in Table 2. D and H components were highly significant for all characters in each environment in both the crosses except that D was non-significant for maturity period and H was non-significant for locule number in the first environment for first cross. The presence of epistasis for all nine characters except maturity period in the first environment in cross 1 indicates that the estimates of D and H components were biased to an unknown extent because of the presence of epistasis in all these cases. However, highly significant values of the D and H components for almost all characters strongly suggest that these characters were controlled by all three kinds (additive, dominance and epistasis) of gene effects.

The additive component was relatively more important than the dominance component in the first cross, while in the second cross the dominance component was more important than the additive one. The H and F components were significant for 9 out of 36 cases indicating the presence of a directional dominance element for these cases. The values of F were positive for flowering time and shape index in the second environment, for maturity period in the first environment in the first cross and for number of fruit in the second environment in the second cross. This shows that dominant increasers were more frequent than dominant decreasers for these traits. On the other hand, the negative values of F were found for final height in the first environment in first cross and for number of branches and locule number in the first environment and for final height in both the environments in the second cross. This indicated that for these cases the dominant decreasing alleles were more frequent than dominant increasing alleles. The significant values of H and non-significant values F for 26 out of 36 cases indicated an equal role played by dominant increasing and dominant decreasing alleles in the control of characters in these 26 cases, that is, a case of ambidirectional dominance. Non-significant values of both H and F for locule number in the first environment in the first cross indicated the real absence of the dominance component for this character. As regards the degree of dominance, the ratio $(H/D)^{1/2}$ did not vary very much between the two environments. However, the degree of dominance varied from character to character and from cross to cross for the same character.

Table 1. Mean squares from the analysis of variance for epistasis for nine characters in two tomato triple test crosses, 1 (S120 × EC61747) and 2 (EC31513 × 'Pusa Ruby'), grown in two environments

Item	TTC	Environment	d.f.	Flowering time	Maturity period	No. of branches	Final height (cm)	Shape index
Epistasis ($\bar{L}_{1i} + \bar{L}_{2i} - 2\bar{L}_{3i}$)	1	1	20	11.162**	5.669	5.110**	137.376**	0.015**
		2	20	10.442**	11.146**	5.233**	207.456**	0.016**
	2	1	20	54.505**	37.796**	4.409**	692.527**	0.013**
		2	20	35.837**	26.885**	5.952**	629.685**	0.012**
i type epistasis	1	1	1	0.450	2.730	12.512**	904.809**	0.006
		2	1	3.800	1.944	48.420	2,461.440**	0.013*
	2	1	1	501.704**	319.704**	5.766**	227.370**	0.048**
		2	1	317.400**	184.804**	37.921**	14.701	0.046**
j & l type epistasis	1	1	19	11.726**	5.834	4.720**	96.984**	0.016**
		2	19	10.792**	11.630**	2.960**	88.825**	0.016**
	2	1	19	30.968**	22.959**	4.337**	717.008**	0.011**
		2	19	21.018**	18.571**	4.270**	662.052**	0.011**
Replicate error	1	1	20	0.939	2.761*	0.624	12.129	0.001
		2	20	2.139*	3.389**	0.763	9.107	0.001
	2	1	20	1.440	1.693	1.076	30.735	0.001
		2	20	0.978	3.223**	0.269	23.521	0.001
i type epistasis × replicates	1	1	1	0.024	0.681	0.080	13.258	0.000
		2	1	6.600*	6.016	6.080*	0.005	0.000
	2	1	1	3.128	0.013	0.240	0.522	0.000
		2	1	1.176	2.685	0.001	120.133	0.001
j & l type epistasis × replicates	1	1	19	0.988	2.871*	0.653	12.070	0.001
		2	19	1.904	3.251**	0.483	9.586	0.001
	2	1	19	1.351	1.782	1.119	32.325	0.001
		2	19	0.957	3.252**	0.283	18.436	0.001
Within families error	1	1	480	1.398	1.698	1.339	15.419	0.003
		2	480	1.250	1.610	1.062	19.717	0.003
	2	1	480	1.395	1.269	1.310	29.596	0.002
		2	480	1.470	1.289	1.130	32.576	0.002

Table 2. Estimates of D, H and F components and degree of dominance for nine characters in two tomato triple test crosses, 1 (S120 × EC61747) and 2 (EC31513 × 'Pusa Ruby') grown in two environments

Component	TTC	Environment	Flowering time	Maturity period	No. of branches	Final height	Shape index
D	1	1	47.245**	26.437	3.130**	115.236**	0.088**
		2	25.379**	32.042**	1.125**	285.562**	0.076**
	2	1	26.849**	41.202**	7.786**	1,220.912**	0.007**
		2	19.039**	26.122**	6.599**	1,166.688**	0.155**
H	1	1	21.110**	11.664**	9.973**	355.713**	0.021**
		2	15.396**	12.806**	4.385**	400.310**	0.030**
	2	1	15.796**	31.682**	10.369**	1,436.630**	0.008**
		2	19.403**	32.632**	9.509**	1,179.540**	0.004**
F	1	1	0.645	400.280**	−8.491	−1,073.030**	0.013
		2	63.400*	43.670	−1.725	−485.189	0.183**
	2	1	4.129	−46.36	−42.846**	−5,778.700**	0.003
		2	25.505	17.633	−16.775	−6,600.240**	0.016
$(H/D)^{1/2}$	1	1	0.668	0.664	1.785	1.756	0.488
		2	0.778	0.632	1.974	1.183	0.628
	2	1	0.767	0.876	1.154	1.084	1.101
		2	1.009	1.117	1.200	1.005	0.555

Table 1 (continued)

Item	TTC	Environment	d.f.	Locule no.	No. of fruit/ plant	Yield/plant (g)	Weight/ fruit (g)
Epistasis ($\bar{L}_{1i} + \bar{L}_{2i} - 2\bar{L}_{3i}$)	1	1	20	0.861**	146.340**	77,814.660**	53.172**
		2	20	1.033**	396.250**	252,185.130**	126.362**
	2	1	20	0.946**	85.739**	140,368.260**	121.758**
		2	20	0.704**	111.146**	189,999.130**	26.634**
i type epistasis	1	1	1	0.060	611.848**	683,431.000**	1.027
		2	1	0.020	3,313.780	1,509,326.000	257.300
	2	1	1	1.666**	122.694**	152,958.000**	21.223**
		2	1	0.888*	154.240**	245,847.400**	45.170**
j & l type epistasis	1	1	19	0.903**	121.840**	45,940.120**	55.917**
		2	19	1.086**	242.706**	186,019.770**	119.471**
	2	1	19	0.908**	83.794**	139,737.200**	127.049**
		2	19	0.694**	108.878**	187,059.700**	25.658**
Replicate error	1	1	20	0.118	6.269	4,788.810	4.868**
		2	20	0.230	10.935	8,380.920	3.792*
	2	1	20	0.046	4.914	4,143.875	0.492
		2	20	0.070	15.341**	6,781.630	1.042
i type epistasis × replicates	1	1	1	0.086	1.944	12,442.000	18.984**
		2	1	0.004	76.840**	45,006.300**	10.128*
	2	1	1	0.016	2.730	11,758.090	2.853
		2	1	0.060	9.440	604.320	2.453
j & l type epistasis × replicates	1	1	19	0.120	6.497	4,386.000	4.125*
		2	19	0.093	7.467	6,453.260	3.458*
	2	1	19	0.048	5.028	3,743.120	0.368
		2	19	0.070	15.652	7,106.700	0.967
Within families error	1	1	480	0.273	6.791	4,778.630	2.337
		2	480	0.230	7.142	5,791.500	2.057
	2	1	480	0.207	5.204	3,692.915	0.789
		2	480	0.205	4.750	4,510.232	0.709

* Significant at 5% level; ** Significant at 1% level

Table 2 (continued)

Component	TTC	Environment	Locule no.	No. of fruit/ plant	Yield/plant (g)	Weight/fruit (g)
D	1	1	2.501**	281.124**	202,606.500**	295.589**
		2	3.566**	531.178**	403,021.370**	333.072**
	2	1	0.625**	213.273**	178,276.300**	139.478**
		2	0.494**	532.520**	26,228.565**	113.370**
H	1	1	0.247	498.446**	367,984.000**	144.581**
		2	0.661**	977.180**	791,260.000**	64.648**
	2	1	0.871**	258.472**	235,876.580**	109.995**
		2	0.701**	645.406**	342,174.940**	48.138**
F	1	1	0.012	300.326	−286,339.360	20.771
		2	−1.425	663.684	−1,351,610.700	277.496
	2	1	−3.482*	160.594	−303,558.730	162.88
		2	1.657	651.920**	−275,708.630	−175.977
$(H/D)^{1/2}$	1	1	0.314	1.331	1.347	0.699
		2	0.430	1.356	1.401	0.440
	2	1	1.180	1.100	1.149	0.888
		2	1.191	1.100	3.611	0.651

* Significant at 5% level; ** Significant at 1% level

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