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RELATIONSHIPS BETWEEN TOMATO EARLINESS INDEXES AND THEIR INTERACTION WITH CULTIVATION METHODS

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ABSTRACT

On the basis of a semidiallel experiment carried out among 11 parental lines, relationships between earliness production indexes (EPI) and earliness temporal indexes (ETI) based both on the yield (Y) and on the number of fruits (N), have been studied. Both earliness temporal indexes (ETI_Y and ETI_N) are correlated with Y, N and Y/N, the genotypic correlation between both indexes being very high. Genotypic and environmental correlations between ETI_Y and EPI_Y and between ETI_N and EPI_N are also high. Moreover, both under open-air cultivation and under plastic-house, temporal earliness ETI_Y (ETI_N) has a higher influence on early production EPI_Y (EPI_N) than the yield Y (N). Genotypic, environmental and phenotypic correlation between any pair of these characters, show a similar magnitude and are similar also under plastic-house and in the open-air. Neverthel ss, genotypic correlations between plastic-house and open-air cultivation were extraordinarily low for all the indexes, showing the existence of strong genotype-environment interactions r_g. (ETI)=0 072, r_g. (ETI_N)=0·102, r_g (EPI_Y)=0 277, r_g (EPI_N)=0 417. Variance analysis of the combining ability belonging to each one of the indexes, point out high significance both for GCA and SCA. The greater importance of SCA Compared to GCA is noteworthy, particularly under open-air cultivation.

THE economical importance of early production regarding cultivation of tomatoes for fresh consumption is doubtless, and has therefore been studied in many occasions (Williams and Gilbert, 1960; Baroncelli *et al* 1972). Nevertheless, earliness in the sense of period over which fruits reach their highest price at the beginning of each production period, contains many non-biological variables, such as cultivation period, fruits destination and market prices, that make the precocious period more or less long. To avoid these inconveniences, the use of indexes not bound to the mentioned variables, has been suggested (Longo, 1979). In this work two earliness indexes estimated by means of production and number of fruits are used to study precocity in two environments (plastic-house and open-air), by means of a semidiallel experiment, as reciprocal effects are not important (Trinklen and Lambeth, 1974).

MATERIALS AND METHODS

A diallel experiment has been carried out (Griffing's method 2, 1956) including varieties: (1) Valenciana, (2) Piervil, (3) Ace, (4) Marglobe, (5) Manalucie, (6) Early Pak, (7) Muchamiel, (8) Supersonic, (9) Floradel, (10) Harold and (11) Red Top. A design of randomized blocks with three repetitions and eight plants per plot has been used. The experiment was repeated entirely in two localities under different cultivation methods: Malaga, under polyethylene plastic-house without heating, and Valencia in the open-air. In the first locality sowing took place on January, 25th 1979 and in the second one, on February 28th 1979. Under plastic-house cultivation conditions, floral clusters were treated with β-napthoxyacetic acid and under open-air cultivation conditions no products to help setting were used. Data were noted regarding crop yield (Y), number of fruits (N) and average fruit weight (W) per plant, over a productive period that ended after harvesting the 5th cluster. With these data different precocity indexes were calculated. We shall call the production reached up to a harvesting established beforehand-precise y the one in which the genotypes average reached 30% of total production, early production index (EPI_Y). In a similar way, EPI_N index is defined based on the number of fruits, rather than on the yield crop. Additionally, the earliness temporal index ETI_Y was estimated as the number of days elapsed (harvestings) until the plant reached 30% of its total production. On the other hand, ETI_N index points out the number of harvestings elapsed until the plant produced 30% of fruits. Combining abilities have been analysed following G iffi ıg's methods. We shall call the mean squares of the corresponding effects–deduced from the expectations of Mg (MS_{GCA}) and Ms (MS_{SCA})–K^2_{GCA} and K^2_{SCA}.

Results and Discussion

The randomized blocks design has been analysed by using individual plant data. The analysis of variance belonging to the four precocity indexes point out that all the effects: varieties (v), blocks (b) and block × variety (bv) are highly significant, both under open-air and plastic-house cultivation conditions. With the variance-covariance analysis belonging to the total production (Y), total number of fruits (N), average fruit weight (W) and earliness indexes, the phenotypic (r_P), genotypic (r_G) and environmental (r_E) correlations among all these characters have been calculated (Table 1). The earliness temporal index

TABLE 1

Phenotypic (r_p), genotypic (r_G) and environmental (r_e) correlations among precocity indexes, total production (Y), number of fruits per plant (N), and average fruit weight (W)

	Y	EPI_Y	ETI_Y	N	EPI_N	ETI_N	W
	—	0.578	−0.023	0.697	0.399	−0.023	0.468
Y	—	0.664*	0.016	0.530*	0.326*	−0.043	0.552*
		0.548	−0.037	0.779	0.434	−0.017	0.419
	0.425		−0.719	0.328	0.829	−0.639	0.380
EPI_Y	0.501*	—	−0.702*	0.245	0.683*	−0.689*	0.498*
	0.408		−0.727	0.362	0.880	−0.630	0.338
	0.147	−0.672		0.070	−0 668	0.823	−0.127
ETI_Y	0.086	−0.744*	—	0.108	−0.631*	0.935*	−0.117
	0.159	−0.661		0.059	−0.685	0.800	−0.146
	0.512	0.264	−0.014		0.483	0.112	−0.274
N	−0.024	0.087	−0.195	—	0.634*	−0.054	−0.400*
	0.705	0.325	0.033		0.420	0.166	−0.194
	0.062	0.739	−0.705	0.456		−0.707	−0.039
EPI_N	−0.277	0.425*	−0.695*	0.736*	—	−0.770*	−0.246
	0.167	0.835	−0.723	0.336		−0.697	0.090
	0.155	−0.643	0.928	0.013	−0.736		−0.179
ETI_N	0.193	−0.666*	0.971*	−0.157	−0.716*	—	−0.024
	0.148	−0.639	0.922	0.063	−0.753		−0.272
	0.525	0.206	0.148	−0.400	−0.327	0.123	
W	0.630*	0.290*	0.162	−0.768*	−0.667*	0.175	—
	0.521	0.191	0.164	−0.147	−0.124	0.116	

*$0.05 > P > 0.01$; Plastic house: Upper half; Open air: Lower half.

for yield is uncorrelated with Y and N, and points out a very low non-significant, negative correlation with W. Its genotypic correlation with ETI_N is very high; moreover the environmental factors that modify yield temporal earliness, also modify the number of fruits temporal earliness in the same sense: r_E (ETI_Y, ETI_N) = 0·800 (plastic house), 0·922 (open-air). There is also a very high correlation with early production, slightly higher for the one estimated upon crop yield, than for the one estimated upon total number of fruits, particularly under plastic-house cultivation conditions. A similar behaviour is remarked for fruit number temporal earliness. It is correlated with Y, N and W, showing high correlations with early production, a little greater with EPI_N than with EPI_Y. Early production based on crop yield does show a significant genotypic correlation with production both under plastic-house (r_G=0·664) and in the open air (r_G=0·501). Nevertheless, correlations with N and W decrease remarkably, particularly under open-air cultivation conditions, coinciding with Cuartero & Cubero (in press). Correlations between EPI_Y and EPI_N, although significant, are inferior to those existing between ETI_Y and ETI_N. Relations among ETI_Y, EPI_Y and Y point out the very nature of these earliness indexes. ETI_Y shows the way in which production distributes within the plant production cycle, independently from its total production. On the contrary, EPI_Y measures the production obtained up to a certain date, depending both on the total production and on its distribution within the production cycle. The above mentioned results, show that both in the open-air and under plastic-house cultivation conditions, and for the set of genotypes studied by us, temporal earliness has a higher influence upon early production, than the production itself. Regression equations for typified values are,: Plastic-house: EPI_Y=0·052 Y–0·710 ETI_Y, R^2=0·99; Open-air: EPI_Y=0·554 Y–0·753 ETI_Y, R^2=0·99 the adjustment value R^2=(1–Vr)/var (EPI_Y), being very high. The highest partial regression coefficient for ETI_Y, with regard to Y's, points out the greater influence that temporal earliness has upon early production, with regard to production. These results agree with the ones obtained by Nuez and Tarrega (1981).

There is also significant correlation between EPI_N and number of fruits, which is clearly superior to the one existing between this earliness index and Y and W. The corresponding regression equations are: Plastic-house: EPI_N=0·592 N–0·740 ETI_N, R^2=0·96; Open-air: EPI_N=0·633 N–0·605 ETI_N, R^2=0·94.

The high correlations existing between ETI_Y and ETI_N point out that any of either indexes can be used to measure temporal earliness, but the strong reduction of genetic correlation between EPI_Y and EPI_N, advise using only EPI_Y as a measure of production earliness. Nevertheless, it is possible to obtain a highly satisfactory estimation of production earliness upon a conjunct basis of EPI_N and W as follows: Plastic-house: EPI_Y=0·849 EPI_N+0·673 W, R^2= 0·99; Open-air: EPI_Y=1·104 EPI_N+0·954 W, R^2=0·99.

Genotypic correlations are similar under plastic-house and in the open-air except for r_G (Y, N), that unexpectedly shows null value in the open-air.

Environmental and phenotypic correlations are generally higher or similar under plastic-house than in the open-air, except for the ones existing between ETI_Y–ETI_N and W–R, which are a little higher in the open air than under plastic-house, although the difference is not significant. The similar magnitude that the three correlations r_G, r_E and r_P show is also remarkable. The greater differences between r_G and r_E are to be noticed in the open-air for characters Y–N, N–EPI_N, EPI_Y–EPI_N. In short, genotypic correlations among characters are schematized in Fig. 1.

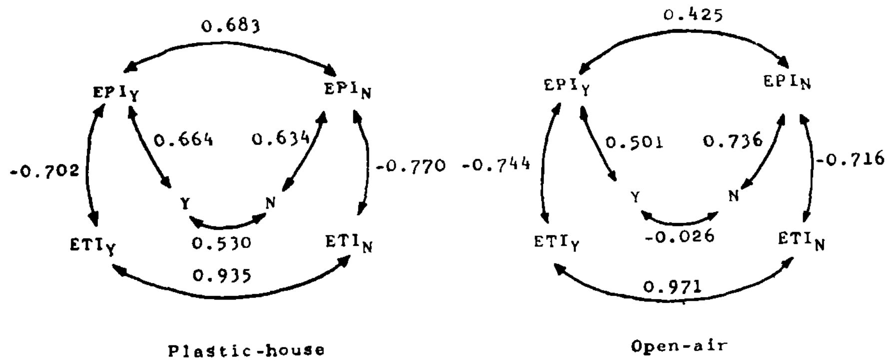

FIG. 1. Genotypic correlations between characters under plastic-house and in the open-air.

Heritabilities estimated with variance component among varieties (Table 2), although statistically significant, were lower than the ones obtained by Nuez and Tarrega (1981) for EPI_Y and ETI_Y.

TABLE 2

Broad sense heritability estimations

	EPI_Y	ETI_Y	EPI_N	ETI_N
Plastic-house	0.238	0.168	0.274	0.170
Open-air	0.164	0.128	0.279	0.148

Genotypic correlations between plastic-house and open-air cultivation conditions for temporal earliness are extraordinarily low: r_G $(ETI_Y)=0\cdot072$, r_G $(ETI_N)=0\cdot102$ and do not differ significantly from zero. As in the absence of genotype-environment interactions, genotypic correlations among environments should be the unit, the low values found point out the enormous importance of the mentioned interactions, and oblige to consider temporal earliness under plastic-house as a character different from temporal earliness under open-air cultivation conditions. Although not quite so evidently, genotypic correlations among environments for production earliness are also very low: r_G $(EPI_Y)=0 \cdot 277$, r_G $(EPI_N)=0 \cdot 417$. Consequently, improvement programs regarding early hybrids, will have to take the cultivation conditions they are meant for into very serious account.

The existence of genotype-environment, interactions advises not to use Jinks-Haymann's diagram to determine inheritance mode. Nevertheless, direct comparison of F_1 hybrids with their parents, on the basis of the differences found by analysis of variance of randomized blocks, allows drawing some conclusions. Whilst under plastic-house all types of inheritance present themselves with a symmetry of heterotic or dominant situations in one or another sense, under open-air cultivation conditions there is a clear heterosis and dominance predominanbly towards greater earliness, both with EPI and with ETI.

Combining ability variance analysis belonging to each one of the indexes, shows high significance both for GCA and for SCA (Table 3). The greater importance of K^2_{SCA} with regard to K^2_{GCA} is particularly remarkable under open-air cultivation conditions. This fact points out that dominance variance and dominance epistatic, must have a great importance in the variation structure, particularly under open-air cultivation conditions, and in harmony with the above mentioned way of inheritance. Burdick (1953) finds results in this same sense, by attributing dominance to the period days elapsed between appearance of the 1st flower and 1st ripe fruit.

TABLE 3

Analysis of variance for combining ability according to Griffing's method

			EPI_Y	ETI_Y	EPI_N	ETI_N
P.H.	Mean squares	Mg	202030	0.432	5.730	0.452
		Ms	56563	0.143	1.492	0.164
		Me	9787	0.038	0.216	0.042
	K^2	GCA	14788**	0.030**	0.424**	0.032**
		SCA	46775**	0.105**	1.276**	0.122**
O.A.	Mean squares	Mg	28860	0.057	5.046	0.112
		Ms	15147	0.073	1.448	0.079
		Me	3326	0.016	0.234	0.018
	K^2	GCA	1964**	0.003**	0.370**	0.007**
		SCA	11821**	0.056**	1.214**	0.060**

P.H. = Plastic-house; O.A. = Open-air **: $p<0 \cdot 01$

For a certain cultivation environment, GCA estimations (Table 4) lead to ETI_Y and ETI_N of similar order. Correlations between these indexes are: plastic-house, r_{GCA} (ETI_Y, ETI_N) $= 0 \cdot 950$; open-air, r_{GCA} (ETI_Y, ETI_N) $= 1 \cdot 977$ (Table 5). Orders corresponding to EPI_Y and EPI_N are remarkably different, as the respective correlations are much lower than the ones existing between ETI indexes. Orders corresponding to EPI_Y and ETI_Y in the open-air are also quite different, showing a certain in variability under plastic-house. EPI_N and ETI_N show a similar relative order in variability, although Ace variety has a medium GCA for ETI_N, which is much tardier for EPI_N. Varieties Manalucie and Harold also suffer important changes. By comparing GCA relative orders under plastic-house and in the open-air, important changes can also be observed. Varieties Piervil and Marglobe show smallest GCA values under plastic-house, and have a much more early GCA in the open-air. GCA correlations between cultivation methods, are very low in all cases, showing the strong interaction of genotype's additive fraction with the cultivation method. An environmental aspect to be taken into account, when interpreting these facts, is the use of setting-regulators under plastic-house, which method is not carried out in the open-air. These treatments seem to modify precocity in a different way.

TABLE 4

GCA estimates

	EPI_Y		ETI_Y		EPI_N		ETI_N	
	P.H.	O.A.	P.H.	O.A.	P.H.	O.A.	P.H.	O.A.(1)
1. Valenciana	–25.25	–48.54	–0.14	–0.052	0.52	0.152	–0.26	–0.046
2. Piervil	–48.90	68.64	0.17	–0.012	–0.35	0.056	0.21	–0.015
3. Ace	114.54	80.60	–0.16	–0.040	–0.65	–0.552	–0.13	–0.064
4. Marglobe	–198.96	20.21	0.36	–0.079	–0.72	0.212	0.30	–0.072
5. Manalucie	–2.92	–2.48	0.07	0.005	–0.83	–0.715	0.16	–0.011
6. Early Pak	88.04	–27.84	–0.19	0.086	0.51	–0.505	–0.15	0.156
7. Muchamiel	–82.84	–72.05	0.11	0.077	–0.24	–0.185	0.10	0.074
8. Supersonic	–52.74	0.23	0.13	0.015	–0.27	–0.139	0.14	–0.007
9. Floradel	202.51	–4.15	–0.23	0.114	0.41	–0.352	–0.14	0.166
10. Harold	146.86	25.31	–0.03	–0.072	1.30	0.514	–0.11	–0.076
11. Red Top	–140.34	–39.98	–0.09	–0.042	0.33	1.516	–0.13	–0.105
D (gi)	26.16	15.25	0.05	0.034	0.12	0.128	0.05	0.036
D (gi–gj)	38.80	22.62	0.08	0.050	0.18	0.190	0.08	0.053

P.H. = Plastic-house; O.A. = Open air.

TABLE 5

Correlations of *GCA* (r_{SCA}) and *SCA* (r_{SCA}) *among precocity indexes*

	EPI_Y	ETI_Y	EPI_N	ETI_N
EPI_Y	—	-0.737* -0.707*	0.445 0.845*	-0.587 -0.795*
ETI_Y	-0.328 -0.852*	—	-0.550 -0.693*	0.950* 0.946*
EPI_N	-0.290 0.800*	-0.508 -0.768*	—	-0.713* -0.825*
ETI_N	-0.264 -0.814*	0.977* 0.985*	-0.563 -0.770*	—

*:$0.05>p>0.01$; Upper half; Plastic house; Lower half; Open air.
First figure in each cell in r_{GCK} and second figure is r_{SCA}

Although correlations between GCA (SCA) and average phenotypic values are medium-high (Table 6) they do not allow to carry out a sufficient GCA (SCA) estimation, on the basis of the average phenotypic value.

TABLE 6

Correlations between combining ability and average phenotypic values

Correlation	EPI_Y		ETI_Y		EPI_N		ETI_N	
	P.H.	O.A.	P.H.	O.A.	P.H.	O.A.	P.H.	O.A.(1)
r (GCA, $\bar{x}$)	0.740*	0.574	0.791*	0.818*	0.779*	0.768*	0.845*	0.899*
r (SCA, $\bar{x}$)	0.799*	0.867*	0.796*	0.935*	0.897*	0.788*	0.826*	0.896*

(1) P.H.=Plastic-house; O.A.=Open-air; *: $0.05>p>0.01$

SCA estimations lead to different orders according to the index used. Under open-air cultivation conditions, parentls generally present smaller SCA values than their hybrids; under plastic-house cultivation conditions, behaviour is not uniform. In the same way as pointed out for GCA, correlations of SCA values between both cultivation methods are very low: r (EPI_Y)=0·301, r (ETI_Y)=0·194, r (EPI_N)=0·427, r (ETI)=0·175. As an example of these genotype environment interactions, in Table 7 SCA estimations for EPI_Y index under plastic-house and in the open air are shown. *It is observable that among* the genotypes that present extreme values, coincidences are rare.

TABLE 7

SCA for index of production precocity (EPI_Y)

Varieties	1	2	3	4	5	6	7	8	9	10	11
1. Valenciana	205	–246	–217	–78	–84	–93	350	–158	–107	171	52
	–81										
2. Piervil		–466	62	—	61	58	115	75	652	39	–125
	–15	–87									
3. Ace			78	–154	–45	100	–284	373	30	—	—
	–61	23	–224								
4. Marglobe				64	66	206	–56	–207	–168	107	–84
	–201	—	–23	–237							
5. Manalucie					25	–39	85	9	299	–539	—
	–113	–180	227	88	–106						
6. Early Pak						–217	–201	–187	–41	106	529
	30	17	109	151	35	–239					
7. Muchamiel							42	163	–105	–283	—
	137	65	–27	180	–7	–32	–26				
8. Supersonic								128	–309	203	–219
	62	90	21	104	–41	–10	–50	29			
9. Floradel									–272	262	29
	125	123	123	93	34	–85	–41	–158	–201		
10. Harold										252	–416
	67	116	—	39	119	57	15	–95	101	-86	
11. Red Top											–87
	132	–52	—	54	—	207	–187	20	85	–243	–63

Error	Plastic-house	Open-air
D ($\hat{s}_{ii}$)*	83.07	48.43
D ($\hat{s}_{ij}$)	91.69	53.45
D ($\hat{s}_{ii}-\hat{s}_{jj}$)	116.41	67.87
D ($\hat{s}_{ij}-\hat{s}_{ik}$)	134.42	78.36
D ($\hat{s}_{ij}-\hat{s}_{ki}$)	128.70	75.03

*Griffing's notation; Upper half; Plastic house; Lower half ; Open air.

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