GRAPHICAL ANALYSIS OF VARIANCE AND COVARIANCE ESTIMATES OF MORPHLOGICAL , PHYSIOLOGICAL AND YIELD CHARACTERS FOR SOME TOMATO GENOTYPES

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ABCTRACT

Six tomato (Lycopersicon esculentum Mill.) genotypes were used. To study the magnitude of gene effcts and the distribution of both recessive and dominant genes controlling the morphological, physiological, quality and yield characters among the six tomato These genotypes included the two isogenic lines 83 and 80, the commercial Sherry tomato and another three varieties namely, Super Marmand, Pretchard and Money Maker.

Recessive genes were found to be higher in frequency than dominant ones in the parents for number of branches, number of leaves, dry stem weight, dry leaves weight per plant, titratable acidity, number of fruits per plant, plant growth rate and leaf area. However, more dominant genes were involved in controlling the rest of characters. Plant height and total fruits weight are controlled by the largest number of dominant gene groups, (14 and 15, respectively). Meanwhile, leaf area, carotenoids content, fruit shape index, pericarp thickness and ascorbic acid content were controlled by the least number of dominant gene groups. Number of branches, number of leaves, leaf area, dry stem weight, dry leaves weight and quality and yield characters had moderate to high heritability estimates except for total soluble solids, which had the least narrow-sense heritability estimate (0.14).

Association type of gene distribution was observed for average fruit weight, carotenoids content, fruit shape index, number of locules and pericarp thickness. But non-random gene distribution of the dispersion type might be mainly controlling the characters of plant height, number of branches per plant, number of leaves per plant, dry stem weight per plant, dry leaves weight, chlorophyll A content and total fruits weight per plant. Complementary type of interaction was observed among genes of the parents for leaf area and chlorophyll B content. An overestimation of the degree of dominance was observed for leaf area, plant growth rate and number of branches per plant. Meanwhile, underestimation of the degree of dominance was observed for pericarp thickness.

INTRODUCTION

Tomato, Lycopersicon esculentum Mill,(2n=24) is one of the most important vegetable crops grown in Egypt and throughout the world for both fresh fruit market and the processed food industries.

Great variability was noticed among the various cultivars and hybrids regarding productivity and fruit quality. In this connection, there is no commercial local hybrids show high yielding ability and good fruit characteristics until now. So, the increasing of the productivity together, with high quality are the major objectives of many plant breeders of this crop. In this respect, intervarietal crosses of tomato are very important to plant breeding before trying other breeding strategy programs to produce productive hybrids with high fruit quality.

Therefore, the object of most recent works was to obtain some tomato hybrids through intervarietal crosses, which require studies on the genetic behaviour of the important quantitative traits. There are many special aspects to be considered to improve any quantitative trait of economic usefulness. Information about the nature of gene action of these traits as well as the estimates of heritability in narrow sense should be investigated (Asins et al., 1993). Also, the gene effects in tomato were studied by Ghosh et al. (1996) using the graphical analysis .

In this work the graphical analysis of variance and covariance estimatis for some morphological and yield characters of six tomato genotypes and their hybrids were used to study the distribution of both recessive and dominant genes controlling these characters accroding to Hayman (1954 a and b) and Hill (1964) and to determine both the additive and non additive and additive components of variance among the parental genotypes.

MATERIALS and METHODS

The present investigation was carried out at the Experimental Farm of El-Kassasien Horticultural Research Station, Horticultural Research Institute, Agricultural Research Center, during the winter seasons of 2001-2002 and 2002 – 2003.

Six tomato (Lycopersicon esculentum Mill.) genotypes were used in this investigation. These include the two isogenic lines 83 (P1) and 80 (P2) which were kindly obtained from the Horticulture Department, Iowa State University, Ames, Iowa, USA, the commercial Sherry tomato; line 93 (P6) which was kindly obtained from the North Central Regional Plant Introduction Station, ARS, Ames, IA, USA and another three varieties namely Super Marmand (P3), Pretchard (P4) and Money Maker (P5) which were obtained from the Horticulture Research Institute, Agricultural Research Center, Giza, Egypt.

In the winter season of 2001-2002, seeds of the six parental tomato varieties were sown. Twenty seedlings of each parent were transplanted to represent the plant material for achieving the half diallel crosses for the 6x6 combinations without reciprocals.

Crosses were adopted by emasculation of flowers of the female parents in the afternoon just a day prior to anthesis. Artificial pollination was practiced between 7-9 am at the following morning by a gentle rubbing of the stigma with a glass slide covered with pollens from male parent flowers. Female flowers were coverd with craft paper bags after pollination and a tag was hanged on the pedicle of each pollinated bud. From the last week of February till the end of May in the same season, hybrid seeds from mature set fruits were harvested and extracted by fermentation method.

Evaluation Experiment:

Seeds from the six parental genotypes and their 15 F1 hybrids were sown in October 2002to produce the transplants. Each of the twenty-one genotypes was sown in thirty pots; ten pots per replicate. Two seeds were sown in each pot. The remmended agricultural practices were applied to keep transplants healthy. Measurements were recoded on both parental and F1 hybrid genotypes from the three replications.

The seedlings were transplanted in Nov., 2002 under low tunnel conditions in the Experimental Farm of El-Kassasien Horticulture Research Station. Each tunnel represents fifteen of each of parental and F1 hybrid plants in each of the three replicate ; Each replicate form a plot of 12 meters long and 120cm width. Plants were 40cm apart. Normal field practices and recommended quantitities of fertilizers were applied during the entire growing season until maturity. Control of diseases and pests was practiced according to recommendation of the Ministry of Agriculture.

Experimental Data:

I– Morphological and physiological characters:

Data of these characters were recorded on five randomly chosen plants of each replicate. The characters recorded were, plant height (cm), number of branches per plant, number of leaves per plant, plant growth rate (cm/day), leaf area (cm2), dry stem weight per plant (gm), dry leaves weight per plant (gm), chlorophyll A (mg/g fresh weight), chlorophyll B (mg/g fresh weight) and carotenoids (mg/g fresh weight).

Chlorophyll A, chlorophyll B and carotenoids, were recorded according the methods described by *Fadell (1962)*.

2 – Fruit quality characters:

Data were recorded on twenty-five fruits, randomly chosen from the yield of five randomly chosen plants from each replicate for the evaluation of six charaters. as fruit shape index,number of locules per fruit,pericarp thickness (mm) and total soluble solids (T.S.S %): which was determined as an average of five refractometer readings (Brix %) using juice drops from each of five fruits,Titratable acidity (%) which was calculated using the titration method according to the method described by *A.O.A.C (1990)* and the ascorbic acid (Vitamin C) content which was determined using 2,6 dichloro-phenol indophenol method as described by *A.O.A.C. (1990).*

3 – Yield and it's Components:

Total yield, was evaluated as total number of fruits per plant, It was evaluated as an average number of fruits per plant in all harvests of ten randomly chosen plants for each genotype in each replication.

Total fruits weight per plant (Kg) was estimated as an average weight of fruit yield in all harvests over ten plants for each genotype in each replicate.

Average fruit weight (gm) was evaluated as an average weight of fruit per plant of each genotype in each replication.

Diallel analysis:

The statistical analysis performed in the present investigation which involved the Hayman's approach of the theory of diallel developed by *Haymen (1954a,b)* was applied using Mather's concept of D,H components of variation as described in detail by *Mather and Jinks (1971)*. The calculation of different genetic estimates were made after *Singh and Chaudhary (1977).*

RESULTS and DISCUSSION

A- Analysis of verience of Wr+Vr and Wr-Vr:

Results of analysis of variance for Wr+Vr and Wr-Vr estimats for morphological,physiological, quality and yield characters are given in tables 1and 2.

The Wr+Vr mean square values between arrays were significant only for number of lecules per fruit .From Tables 1and 2 it can be seen that between arrays variances exceeded those withil arrays for number of branches per plant, laef area, fruit shape index, total soluble solids and average fruit weight. This clearly indicated that a considerable portion of non-additive genetic variations in these characters are due to allelic interaction. Allelic interaction was also shown in tomato for number of branches per plant by *Bhatt et al. (2001)* and for total soluble solids by *Wang-Lei et al. (1998)***.** Also, the results obtained by *Asins et al. (1993)* stated that non-additive genetic variance was greater than additive for average fruit weight. However, the rest characters with either non-significant Wr+Vr between arrays mean square values or smaller than their respective of within arrays variances, suggested that these characters are characterized with minimum portion of variation due to dominance gene effects in relation to the whole non-additive genetic variation (Table 1 and 2). *Cuartero (1985)* indicated that, number of fruits per plant were characterized with minimum portion of variation due to dominance gene effects.

Considering the Wr-Vr analysis of variance, mean square values between arrays were insignificant and lower, in magnitude, than the corresponding values of within arrays, except for number of leaves per plant and number of fruits per plant. These results indicate, that non additive genetic variation which are controlling, these characters, if there are, had a minimum portion of non-allelic interaction. Meanwhile, a considerable portion of non-allelic interaction was suggested to be involved in the non-additive gene effects controlling number of leaves and number of fruits per plant (Tables 1 and 2). *Asins et al. (1993***)** also, showed that non-additive effects are controlling number of fruits per plant. Moreover, larger MS values between arrays than that within arrays were observed in both Wr+Vr and Wr-Vr for number of leaves per plant. This could suggest that both allelic and non-allelic interaction are involved in the non-additive genetic variation of this character.

b- Parental Order of Dominance and Mean Values of Arrays;

From Table (3), it can be seen that the coefficients of correlation "r" are significantly positive for leaf area, number of locules per fruit, total soluble solids and average fruit weight indicating that, for these characters, dominant genes are the decreasing genes; the parents containing most dominant genes are those with the lowest values of Wr+Vr values are characterized with the lowest Yr values.

Moreover, correlation coefficients for plant height, fruit shape index and total fruits weight per plant were negative and significant, indicating that the parental genotypes have low values of parental order of dominance (Wr+Vr); P_1 (isogenic line 83) and P_5 (Money Maker), which are containing the most dominant genes had both the highest score (Yr) for plant height (90.6 and 88.3 cm), respectively . In additon, P_1 (isogenic line 83) which had the highest fruit shape index (0.97) also contained most increasing genes. This indicates that for these characters the dominant genes are the increasing genes and vice versa. However,the other characters were characterized by non-significant values of "r", suggesting that dominance in the parents is ambi-directional (Table 3).The "r^2" values could suggest the existence of regression of Y_r on Wr+Vr for plant height, leaf area, number of locules per fruit and average fruit weight (0.806, 0.894, 0.914 and 0.843). This shows that, P_5 (Money Maker) and P_1 (isogenic line 83) are the completely dominant parents for plant height. In the meantime, P_1 and P_3 are the most recessive parents for average fruit weight and also P_6 (Line 93) is the completely recessive parent for leaf area and P_3 (Super Marmand) for number of locules per fruit.As for the other characters none of r^2 values could suggest the existence of regression of Y_r on Wr+Vr, hence prediction of completely dominant and recessive parents was not possible (Table 3) .

c- The Graphical Analysis:

The graphic representations of the Wr/Vr relationship and the standardized Wr+Vr and Y_r are presented in Figures (1a) to (19a) and Figures (1b) to (19b), respectively.

1 – Variance/Covariance Relationship:

For arrays of five out of nineteen characters, the Wr/Vr regression does not significantly differ either from 1 or from 0, for plant growth rate, total soluble solids, titaratable acidity, ascorbic acid, and number of fruits per plant as appeared in Figures 4a, 14a, 15a, 16a and 17a, respectively. This suggests the presence of non-allelic interaction and/or non-random gene distribution among parental genotypes for these characters. This is also assured, since almost all parental points are scattered and lie below the dotted line of unit slope revealing the genetic diversity among the parents with regard to these characters, except for ascorbic acid (Fig. 16a), which shows only non random gene distributions among parental genotypes. Since, results for total soluble solids, in Table (2) revealed the presence of minimum amount of non-allelic interaction, suggesting that non-randomness of gene distribution in addition to the allelic type of interaction were the main causes of regression line departure from the slope of unit in this character.

From results of Tables (1) and (2) rest characters showed the presence of considerable amount of non-allelic interaction which appeared to be of a complementary type as central parental points lie to the right and/or below the dotted line of slope 1. An over-estimation of the degree of dominance was observed for plant growth rate. Although, the mean degree of dominance $(H_1/D)^{1/2}$ estimate was more than 1, its correspondent regression line of the graphical representation passes above the origin (Fig.4a) indicating the existence of partial dominance. This over-estimation indicated the presence of correlated gene distribution, non-random gene distribution, of the dispersion type. Similar explaination for overestimation degree of dominance was mentioned by *Hill (1964)*. However, for ascorbic acid content the regression line cuts the Wr axis above the origin (Fig. 16a) indicating that partial dominance of allelic interaction is controlling this character. Meanwhile, over dominance was assured for total soluble solids, titratable acidity and number of fruits per plant which their regression line pass below the origin (Figs 14a, 15a and 17a, respectively). In this concern, *Perera and Liyanaarachchi (1993)* stated that partial dominance is controlling of number of fruits per plant.

The slopes of Wr/Vr regression lines for carotenoids content (Fig. 10a), fruit shape index (Fig.11a), number of locules (Fig. 12a), pericarp thickness (Fig. 13a) and average fruit weight (Fig. 19a) differed significantly from 0 but not from 1, indicating the absence of non-allelic interaction for these characters. In the meantime, association type of gene distribution were observed for these characters since the central parental points lie to the left and above the line of slope 1 (Figs. 11a, 12a, 13a and 19a) except for carotenoids content which showed dispersion type of gene distribution since the central parental points lie to the right and below the line of slope 1 (Fig. 10a). Results in Tables (1) and (2) which showed the absence of non-allelic interaction, for fruit shape index, average fruit weight and number of locules per fruit , confirmed this conclusion .

It is worthy to mention that underestimation of the degree of dominance $(H_1/D)^{1/2}$ indicated partial dominance, 0.69, for pericarp thickness while the regression line cuts the ordinate below the origin indicating over-dominance for this character (Fig.13a). This clearly demonstrate the presence of correlated gene distribution among the parental genotypes of the association type for this character.This explaination of under-estimation of the dominance level is based on a similar reasoning mentioned by *Hill (1964).*

In spite of, Wr/Vr regression was significantly differ from unity and not from zero indicating the presence of non-allelic interaction .Scattered parental points to the right and below the dotted line of slope one indicated that non-random gene distribution of the dispersion type might be mainly controlling the characters of plant height, number of branches per plant, number of leaves per plant, dry stem weight per plant, dry leaves weight per plant, chlorophyll A content and total fruits weight per plant (Figs. 1a, 2a, 3a, 6a, 7a, 8a and 18a). Moreover, the results in Table (1) declared the presence of a considerable portion of allelic interaction for number of branches and number of leaves per plant.

An over-estimation of the degree of dominance was observed for number of branches per plant. Although, the mean degree of dominance $(H_1/D)^{1/2}$ estimate was more than 1 for this character, its correspondent regression line in the graphical representation (Fig. 2a) indicated the existence of partial dominance. This over-estimation confirmed the presence of correlated gene distribution of the dispersion type and the presence of non-randomness of genes controlling this character.

The case of Wr/Vr regression, which significantly differed from both of the slope of b=1 and the slope of b=0, was observed for leaf area and chlorophyll B content indicating that both additive and non-additive gene effects play a considerable role in the expression of these characters. The array points lie to the right and below the dotted line indicating the presence of complementary type of interaction among genes of the parents for these characters (Figs. 5a and 9a).

From Table (1), a considerable portion of non-additive gene effects play the main role in the expression of leaf area. An overestimation of the degree of dominance was observed for leaf area. Although, the mean degree of dominance $(H_1/D)^{1/2}$ estimate was more than 1, the correspondent regression line in the graphical representation (Fig. 5a), indicated the existence of partial dominance. This confirming the presence of complementary type of non-allelic interaction.

2 – Standardized parental measurements and order of dominance relationship:

The correlation of coefficients between standardized deviations of the parental order of dominance Wr+Vr and the parental measurements Yr for plant height, fruit shape index and total fruits weight per plant had negative and significant values; r= -0.898, -0.84 and –0.811, respectively, (Table 3). This indicates close association of dominance with high values of these charactres (Table 3, Figs. 1b, 11b and 18b).

However, significant positive correlation coefficients between the parental order of dominance (Wr+Vr) and parental measurements (Yr) where high values of total soluble solids in P_4 is found to be associated with recessive genes and the low values in P_3 to be associated with dominant genes (Table 3 and Fig. 14b).

Moreover, highly significant positive correlation coefficients between Wr+Vr and Yr values indicate that high values in each of leaf area in P_6, number of locules per fruit in P_3 and average fruit weight in P_1 and P_3 are found to be closely associated with recessiveness. In addition, low values in each of leaf area and number of locules per fruit in P_5 and for average fruit weight in P_6, are found to be associated with dominance (Table 3, Figs. 5b, 12b and 19b).

The considerable but insignificant positive correlation coefficients between Wr+Vr and Yr suggest a tendency for the high values of number of branches per plant in P_6, pericarp thickness in P_1 and ascorbic acid content in P_5 to be associated with recessiveness and low values of these characters with dominance (Table 3, Figs. 2b, 13b and 16b).

The insignificant negative correlation coefficients revealed that high values of P_6 for each of number of leaves per plant, dry stem weight, titratable acidity and number of fruits per plant in P_5 for plant growth rate; in P_4 for dry leaves weight and in P_1 for chlorophyll A and B and carotenoids content were associated with dominance genes. Also, the corresponding low values were found to be associated with recessiveness (Table 3, Figs. 3b, 4b, 6b, 7b, 8b, 9b, 10b, 15b and 17b). In this concern, *Hayman (1954b)* stated that the parental measurement Yr is closely correlated with the number of dominant homozygotes and the value (Wr+Vr) is correlated with the number of recessive homozygotes.

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الملخص العربي

" التحليل البيانى لتقديرات التباين والتغاير للصفات المورفلوجية والفسيولوجية والمحصول لبعض التراكيب الوراثية فى الطماطم "

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استخدمت في هذه الدراسة ستة آباء من الطماطم و التى اشتملت على:طرازين جينيين متشابهين جينيا وهما 80، 83 وكذلك صنف طماطم الشيري التجارى وثلاثة أصناف منزرعة في مصر. و قد استحدمت تلك التراكيب الوراثيه لدراسة توزيع كل من الجينات السائده و المتنحية التى تحكم بعض الصفات المورفولوجية و الفسيولوجية وصفات المحصول و الجودة وللحصول على معلومات حول مقدار التأثيرات الجينية لتقدير كل من مكونات التباين المضيف والغير مضيف سواء الأليلى أو الغير أليلى ، وتم اجراء هذه الدراسة فى كل من المزرعة التجريبية ومعمل التكنولوجيا الحيوية بمحطة بحوث البساتين بالقصاصين .

ظهرت الجينات المتنحية بصورة مرتفعة عن نظيرتها السائدة في الأباء في الصفات التالية: عدد الأفرع وعدد الأوراق ووزن الساق الجافة ووزن الأوراق الجافة ومعدل نمو النبات ومساحة الورقة والحموضة المعايرة.

وجد أن طول النبات والوزن الكلي للثمار فى النبات يتحكم فيهما خمسة عشر و اربعة عشر مجموعة جينية سائدة (على الترتيب)، بينما كل من مساحة الورقة والكاروتين وشكل الثمرة وسمك اللحم وفيتامين ج يتحكم فيها أقل عدد من المجموعات الجينية السائدة. بينما وجد أن عدد الأفرع وعدد الأوراق ومساحة الورقة والوزن الجاف للساق والوزن الجاف للأوراق وكل صفات الجودة والإنتاجية يظهر بها ارتفاع في معدل توريثها بمفهومه الضيق ماعدا صفة الأملاح الكلية الذائبة فقد تميزت بأقل نسبة في معدل التوريث بالمفهوم الضيق (0.14).

وجد أن توزيع الجينات من النوع Association قد تم ملاحظته في كل من متوسط وزن الثمرة والمحتوى من الكاروتين وشكل الثمرة وعدد الحجرات وسمك اللحم. لكن التوزيع الجيني الغير عشوائي من النوع dispersion ربما يتحكم بصورة أساسية في ارتفاع النبات وعدد الأفرع وعدد الأوراق والوزن الجاف لكل من الساق والأوراق لكل نبات وكلوروفيل A والوزن الكلي للثمار لكل نبات. ا لتفاعل بين الجينات الابوية من النوع Complementary ظهر فى مساحة الورقة وكلوروفيل B .ظهر over-estimation لدرجة السيادة فى كل من مساحة الورقة ومعدل نمو النبات وعدد الافرع لكل نبات بينما ظهر –under estimation لدرجة السيادة فى سمك اللحم.

Table 1: Mean square of Wr+Vr and Wr-Vr for ten morphological and physiological characters of 6x6 diallel crosses in tomato genotypes.

No. of leaves per plant	Plant growth rate	Leaf area	Dry stem weight per plant	Dry leaves weight per plant	Chlorophyll A	Chlorophyll B	Carotenoids
1.5^{9}	0.006	1136580	51652941	41005178	0.235	0.656	0.014
6.5^{8}	0.020	579422	99347059	7683116	0.312	0.898	0.015
7.8^{8}	0.003	134105	28271178	26957135	0.043	0.165	0.002
6.8^{8}	0.018	248137	78526697	76508653	0.145	0.406	0.005

*,** Significant at 5% and 1% levels, respectively.

Table 2: Mean square of Wr+Vr and Wr-Vr for nine quality and yield characters of 6x6 diallel crosses in tomato genotypes.

t shape ndex	No.of locules per fruit	Pericarp thickness	Total soluble solids	Titratable acidity	Ascorbic acid	No. of fruits per plant	Total fruits weight per	Avg. fruit weight

								plant	
.059	400.9**	0.0001	59.8	0.166	2.07	57529500	1.7^{6}	106476
.046	30.3	0.0005	20.7	0.394	2.66	70806924	6.9^{6}	70262
.011	1.79	0.00003	15.1	0.011	0.238	13987523	8.5^{5}	6163
.012	6.47	0.0001	18.8	0.103	0.54	13289515	7.4^{6}	10022

*,** Significant at 5% and 1% levels, respectively.

Table (3): Array variances and covariances as well as coefficients of determination for the parental order of dominance and mean values of arrays for characters of six parental tomato genotypes.

Characters	Array (Pi)	Wr	Vr	Wr-Vr	Wr+Vr	Yr	$^{r}(Wr+Vr),Y_r$
Plant height	1	0.37	122.5	-122.1	122.9	90.6	
(cm)	2	-97.2	265.8	-363.0	168.6	75.9	r = -0.898*
	3	5.4	592.7	-587.3	598.1	64.9	
	4	124.5	549.1	-424.6	673.6	63.4	r^2= 0.806
	5	-82.3	163.0	-245.3	80.7	88.3	
	6	85.1	629.9	-544.8	715.0	69.3	
No. of branches	1	15.7	10.7	5.0	26.5	10.1	
per plant	2	14.1	16.1	-2.1	30.2	8.1	r = 0.381
	3	45.8	97.9	-52.1	143.7	6.6	
	4	7.0	18.7	-11.7	25.7	10.2	r^2= 0.145
	5	4.4	4.9	-0.45	9.3	10.6	
	6	-8.2	41.1	-49.3	32.8	20.6	
No. of leaves	1	2551.4	4384.2	-1832.8	6935.6	130.7	
per plant	2	1732.7	4480.4	-2747.7	6213.1	102.3	r = -0.373
	3	6438.5	22659.8	-16221.3	29098.2	85.0	
	4	-1104.1	3736.0	-4840.1	2631.9	131.7	r^2= 0.139
	5	1785.8	3639.4	-1853.6	5425.2	113.0	
	6	-2830.0	11424.2	-14254.3	8594.2	214.0	
Plant growth	1	0.022	0.028	-0.006	0.050	0.997	
rate	2	0.018	0.057	-0.039	0.075	0.743	r = -0.298
(cm/day)	3	0.018	0.015	0.003	0.033	0.770	
	4	-0.010	0.031	-0.041	0.020	0.840	r^2= 0.089
	5	0.009	0.015	-0.006	0.024	1.143	
	6	0.012	0.042	-0.030	0.054	1.023	
Leaf area	1	18.7	114.0	-95.4	132.7	78.3	
(cm^2)	2	11.8	64.8	-53.0	76.6	75.6	r = 0.946**
	3	18.6	51.2	-32.6	69.7	73.3	
	4	148.3	211.1	-62.8	359.5	94.5	r^2= 0.894
	5	54.8	39.5	15.4	94.3	71.9	
	6	194.1	441.9	-247.8	636.0	98.0	
Dry stem	1	406.8	1065.5	-658.7	1472.3	78.7	
weight per plant	2	300.2	1714.1	-1413.9	2014.3	48.1	r = -0.796
(gm)	3	842.4	4701.4	-3858.9	5543.8	35.8	
	4	-252.0	1401.2	-1653.2	1149.1	66.7	r^2= 0.634
	5	188.5	1081.7	-893.2	1270.2	76.0	
	6	-589.4	2406.9	-2996.3	1817.5	81.2	
Dry leaves	1	331.4	684.3	-352.9	1015.6	47.0	
weight per plant	2	453.8	1747.4	-1293.6	2201.2	28.2	r = -0.728
(gm)	3	773.7	3628.9	-2855.2	4402.6	26.2	
	4	-313.2	871.8	-1185.0	558.6	61.1	r^2= 0.530
	5	243.2	593.3	-350.1	836.5	43.5	
	6	-259.4	1986.1	-2245.5	1726.7	59.7	

Table 3: Continued

Characters	Array (Pi)	Wr	Vr	Wr-Vr	Wr+Vr	Yr	$^r(Wr+Vr),Y_r$
Chlorophyll	1	0.025	0.038	-0.014	0.063	0.87	
A	2	0.003	0.087	-0.084	0.091	0.71	r = -0.421
(mg/g fresh	3	0.036	0.176	-0.140	0.213	0.65	
weight)	4	-0.024	0.034	-0.057	0.010	0.81	r^2= 0.177
	5	0.081	0.163	-0.082	0.244	0.81	
	6	0.024	0.126	-0.103	0.150	0.78	
Chlorophyl	1	-0.011	0.063	-0.074	0.052	0.97	
B	2	0.012	0.131	-0.119	0.143	0.77	r = -0.695
(mg/g fresh	3	0.074	0.321	-0.247	0.395	0.68	
weight)	4	-0.031	0.100	-0.131	0.069	0.82	r^2= 0.483
	5	0.094	0.284	-0.190	0.378	0.82	
	6	0.045	0.257	-0.212	0.301	0.78	
Carotenoids	1	0.006	0.010	-0.004	0.015	0.248	
(mg/g fresh	2	-0.008	0.006	-0.014	-0.002	0.218	r = -0.647
weight)	3	0.019	0.041	-0.022	0.060	0.178	
	4	-0.005	0.004	-0.009	-0.001	0.222	r^2= 0.419
	5	0.021	0.023	-0.002	0.044	0.223	
	6	0.002	0.015	-0.013	0.017	0.224	
Fruit	1	0.045	0.022	0.022	0.067	0.97	
Shape	2	0.042	0.016	0.026	0.058	0.95	r = -0.84*
index	3	0.084	0.080	0.004	0.164	0.67	
	4	0.034	0.026	0.008	0.060	0.89	r^2= 0.705
	5	0.005	0.001	0.004	0.005	0.92	
	6	-0.003	0.021	-0.024	0.018	0.91	
No. of locules	1	1.02	0.44	0.58	1.46	4.4	
Per fruit	2	1.53	0.35	1.18	1.88	4.0	r = 0.956**
	3	7.02	6.73	0.29	13.75	10.0	
	4	1.37	0.94	0.43	2.31	5.4	r^2= 0.914
	5	0.25	0.09	0.16	0.34	2.5	
	6	0.42	0.55	-0.13	0.97	2.6	
Pericarp	1	0.007	0.006	0.001	0.013	0.62	
thickness	2	0.005	0.003	0.002	0.008	0.58	r = 0.616
(m.m)	3	0.006	0.005	0.001	0.011	0.48	
	4	0.004	0.003	0.001	0.007	0.47	r^2= 0.379
	5	0.002	0.0016	0.0004	0.0036	0.49	
	6	0.0027	0.0028	-0.0001	0.0055	0.33	
Total soluble	1	-0.572	0.755	-1.328	0.183	6.05	
solides	2	0.269	0.450	-0.182	0.719	7.16	r = 0.857*
%	3	0.074	0.384	-0.311	0.458	5.48	
	4	2.03	3.585	-1.554	5.615	9.20	r^2= 0.735
	5	-0.362	1.585	-1.947	1.223	6.77	
	6	-1.294	1.574	-2.868	0.280	7.09	

Table 3: Continued

Characters	Array (Pi)	Wr	Vr	Wr-Vr	Wr+Vr	Yr	$^{r}(Wr+Vr),Y_r$
Titratable	1	0.077	0.172	-0.096	0.249	1.31	
acidity	2	0.020	0.181	-0.162	0.201	1.18	r = -0.051
%	3	0.063	0.185	-0.122	0.248	1.31	
	4	0.108	0.252	-0.144	0.359	1.34	r^2= 0.003
	5	0.054	0.147	-0.093	0.202	1.28	
	6	0.041	0.127	-0.087	0.168	1.47	
Ascorbic acid	1	0.291	0.393	-0.102	0.684	1.44	
mg/100g fruit	2	0.545	0.513	0.032	1.058	2.16	r = -0.650
	3	0.322	0.132	0.191	0.454	1.35	
	4	0.325	0.294	0.032	0.619	1.44	r^2= 0.423
	5	0.684	0.476	0.208	1.16	2.48	
	6	0.176	0.272	-0.096	0.448	2.16	
No. of fruits per	1	1277.2	1587.1	-309.9	2864.3	35.7	
plant	2	366.2	384.0	-17.8	750.2	31.3	r = -0.548
	3	1884.7	3622.7	-1738.0	5507.4	24.7	
	4	1166.7	1804.1	-637.4	2970.8	24.7	r^2= 0.30
	5	164.4	745.9	-581.5	910.3	74.0	
	6	-377.0	1665.8	-2042.8	1288.8	109.3	
Total fruits	1	0.036	0.370	-0.334	0.406	1.54	
weight per plant	2	-0.018	0.509	-0.527	0.491	1.11	r = -0.811*
(kg)	3	-0.035	0.589	-0.624	0.554	1.05	
	4	0.215	1.015	-0.80	1.23	0.77	r^2= 0.654
	5	-0.161	0.493	-0.654	0.332	1.59	
	6	0.037	0.431	-0.394	0.468	1.12	
Avg. fruit	1	106.1	91.8	14.3	197.9	42.5	
weight	2	67.5	49.5	18.0	117.0	34.7	r = 0.918**
(gm)	3	131.6	116.3	15.3	247.9	42.4	
	4	-125.2	43.9	-169.1	-81.3	32.4	r^2= 0.843
	5	61.6	35.9	25.7	97.5	21.6	
	6	10.4	20.5	-10.1	30.9	10.3	

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