Behavior of Ten Chironja Clones at Three Sites: III. Interaction of Genotype × Environment[1]

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ABSTRACT

Ten chironja clonal varieties were evaluated at the Isabela, Corozal and Adjuntas Substations for a 6-year period. Statistical analyses of the evaluation data provided estimates on the nature and magnitude of the variance components in 15 characteristics studied.

The components of variance of some characteristics in the clonal varieties were significantly greater than those of the first and second order interactions.

Of the 15 characteristics studied in the interaction of varieties × locations, only the component of variance for the scion diameter was highly significant, which fact indicates that adequate locations have to be tested in order for chironjas to be grown profitably.

In the interaction of variety × location × year, the only characteristics with significant components of variance were weight of fruits per tree, Brix and citric acid content, while in the interaction of clones × years, in none of the characteristics significance was found.

Explanations are advanced in the text to explain the genotype × environment interaction.

The plot error variance (σ_e^2) was very large as compared to the genotypic components; this variance indicates that in an experiment like this one, the number of replicates should be increased.

INTRODUCTION

The demand for fresh and processed citrus fruits in Puerto Rico keeps increasing. However, the increase in fruit production is not enough to supply the great demand for this fruit, although Espinet-Colón (1) suggested in 1968 that there existed a marked interest among the growers to improve their plantings with new varieties.

The chironja is a very promising new citrus fruit which could help in the recuperation of the citrus industry because a 7-year old chironja tree may produce from 300 to 500 fruits per year (3, 5) as compared to a 7-year old grapefruit tree, which produces only around 70 fruits (1).

Hodson (2) reported that some characteristics of citrus trees and fruits are markedly affected by environmental influences, climate having a paramount effect. Among the characters affected by climate, according to Hodson, are fruit size and form, flesh color, peel, juice content, flavor, brix/acid ratio, fruit color, and tree growth aspects, such as compactness and density of foliage.

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A test to determine the relative magnitude of varietal and environmental effects on the behavior of chironja clones should be of great importance. Therefore, this study was initiated to consider the implications of such variance components as varieties, locations and years in the selection of chironja clones.

MATERIALS AND METHODS

Three regional experiments comparing the behavior of 10 chironja clones as to growth, yield and fruit quality were performed at the Isabela, Corozal and Adjuntas Substations. The 10 chironja clones were selected (4) from an orchard established at the Corozal Substation. The establishment of the three experiments, orchard management, experimental designs and data collection are described elsewhere (4, 5).

Most of the data was collected from 1970 to 1976, and the combined analysis were submitted to analysis of variance to calculate and test the expected mean squares with the F test.

Table 1 shows the determination of variance components, the analysis of variance and the expectation of mean squares.

The genetic component of variance in the analysis of the pooled data was derived from the expected values of the mean squares by use of the following formulas:

$$\text{Varieties } (\sigma_c^2) = \frac{M5 + M2 - M3 - M4}{rpy}$$

$$\text{Varieties} \times \text{locations } (\sigma_{cp}^2) = \frac{M4 - M2}{ry}$$

$$\text{Varieties} \times \text{years } (\sigma_{cy}^2) = \frac{M3 - M2}{rp}$$

$$\text{Varieties} \times \text{years} \times \text{locations } (\sigma_{cpy}^2) = \frac{M2 - M1}{r}$$

$$\text{Error } (\sigma_e^2) = M1$$

RESULTS AND DISCUSSION

Table 2 shows the estimates of the pertinent variance components for the 15 traits studied. The relative importance of the variance component is indicated by statistical significance.

The magnitudes of the plot error variances (σ_e^2), are generally larger than the ones for the genotypic components, except for the diameter-height relation of fruit, number of seeds per fruit and scion rootstock ratio. These data indicate that these characteristics should be evaluated in a larger number of replicates since their plot error variances are large relative to those of their genetic effects, in order to maximize the genetic effects relative to the environmental and interaction effects. The genetic

TABLE 1.—*Form of the analysis of variance*

Source of variation	Degrees of freedom	Mean square	Expectation of mean squares
Locations	(p-1)		
Years	(y-1)		
Years × locations	(y-1) (p-1)		
Repetions × locations × years	(py) (r-1)		
Varieties	(c-1)	M5	$\sigma_e^2 + r\sigma_{cpy}^2 + ry\sigma_{cy}^2 + ryp\sigma_c^2$
Varieties × locations	(c-1) (p-1)	M4	$\sigma_e^2 + r\sigma_{cpy}^2 + ry\sigma_{cp}^2$
Varieties × years	(c-1) (y-1)	M3	$\sigma_e^2 + r\sigma_{cpy}^2 + ry\sigma_{cp}^2$
Varieties × locations × years	(c-1) (p-1) (y-1)	M2	$\sigma_e^2 + r\sigma_{cpy}^2$
Error	(c-1) (p-1) (y-1)	M1	σ_e^2

TABLE 2.—*Estimated variance components by combined analysis of 10 chironja clones*

Characteristics	σ_c^2	σ_{cy}^2	σ_{cp}^2	σ_{cpy}^2	σ_e^2
Number of fruits per tree	0.4	0.03	0.24	−0.006	25,184.08
Average weight per fruit	−1.16	−0.99	−0.32	−0.86	6,155.2
Weight of fruits per tree	3.3**[1]	−0.55	−0.41	1.52*[2]	3,502.3
Weight of fruit shell	0.85	0.53	0.097	−0.081	412.65
Diameter-height relation of fruit	0.135	−4.75	−0.025	−54.00	−0.0002
Number of seeds per fruit	16.43**	0.028	0.004	−0.066	10.00
Weight of juice per fruit	1.18	0.004	0.003	0.007	1,019.11
Percent of juice per fruit	1.65	0.002	−0.025	0.016	48.68
°Brix	0.40	0.92	−0.43	1.70*	45.75
Citric acid content	6.03**	−0.55	−0.37	1.57*	14,220.66
Brix-acid relation	1.22	−0.036	−0.037	0.19	13.62
Juice pH	−14.88	0.44	−0.44	0.067	0.45
Rootstock diameter	2.90*	−0.004	0.082	0.17	6.35
Scion diameter	−0.73	2.15	2.85**	−3.98	9.11
Scion-rootstock ratio	1.03	−0.20	−0.39	1.12	0.011

[1] Significant at the 1% probability level.
[2] Significant at the 5% probability level.

clone component was significant at the 1% level for weight of fruits per tree, number of seeds per fruit and citric acid content and at the 5% level for rootstock diameter. Pérez-López et al. (4) have reported that chironja trees propagated by seed vary greatly in many important commercial traits; therefore, they must be propagated by grafting to establish uniform orchards. These data tend to confirm this finding.

For all traits studied, it is observed that the variety × year source of variation is small and nonsignificant. In seven of the cases, negative estimates have been obtained for variety × year interaction (table 2). Many authors have suggested that since these tree parameters cannot be

negative, these values must be interpreted as being estimates of variances which are zero or small positive quantities. Such small interactions indicate that these were nonconsistent but substantial year effects on differential clonal response in these trials.

Significant genotype × location interaction, as suggested by the data for scion-diameter, indicates that it is necessary to evaluate this characteristic in an adequate sample of locations for which the chironja is to be developed.

The second order interaction of clones × locations × years, showed significance for weight of fruits per tree, Brix and citric acid content. The significance of these interactions, although of less magnitude than that for clones, suggests that some genotype × environment interaction does occur and that most of the effect should be attributed to locations since there was no significant clone × year interaction. This can explain the differences found between Adjuntas and the other two locations and the slight difference between Isabela and Corozal (5, 6).

RESUMEN

Diez clones de chironja se evaluaron por 6 años en las Subestaciones Experimentales Agrícolas de Isabela, Corozal y Adjuntas. El análisis estadístico de los datos proveyó estimados sobre la naturaleza y magnitud de los componentes de varianza de las 15 características que se presentan en el cuadro 2.

Los componentes de variación para las características de los clones fueron mayores que en las interacciones de primero y segundo orden.

En la interacción variedad × localidad, la única característica que tuvo componente de variación significativo (al 1%) fue el diámetro del injerto, lo cual indica la necesidad de sembrar en varias localidades cuando se llevan a cabo experimentos similares a los que se informan.

En la interacción variedad × localidad × año, las únicas características con sus componentes de variación significativos fueron el peso de las frutas por árbol, el Brix y el contenido de ácido cítrico, mientras que en ninguna de las características de la interacción de clones × años hubo componentes de variación significativos.

La explicación sobre la interacción de genotipo × ambiente se presenta en el texto.

La varianza para error entre parcelas (σ_e^2) fue bien grande relativamente, lo cual sugiere que en un experimento de esta índole debe aumentarse el número de repeticiones.

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