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Genotypic correlations of morpho-agronomic traits in papaya and implications for genetic breeding

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ABSTRACT - *It is essential to study the correlations between traits of genetic breeding, principally, when selection for a trait is impaired by low heritability or difficulties with measurement and identification. This study aimed to estimate genotypic correlations among 15 morpho-agronomic traits in papaya. Results indicated that early selection for greater stem diameter (SD) can result in more productive plants. Although correlations between normal flowers and commercial fruits, estimated in the same period of evaluation, cannot be recommended for the selection procedures, the correlations between deformed flowers and carpelloid and pentandric fruits are reliable enough to be used in the selection procedures if measured in the same period. Deformed flowers and sexual reversion affect the commercial fruit yield, indicating the need for the development of segregating generations for selection in the main producing regions of Brazil.*

Key words: *Carica papaya*, papaya, fruit yield, carpelloidy, sexual reversion.

INTRODUCTION

In the tropical and subtropical regions around the world, papaya (*Carica papaya* L.) is one of the most cultivated and exploited fruit species (Chen et al. 1991). In Brazil, pear-shaped fruits of the hermaphrodite plants, destined for the domestic and foreign markets, are preferred over the round fruits female plants produce. Still, papaya is founded on a narrow genetic base and few varieties and/or commercial hybrids for planting are available that meet the demands of the national as well as the international market. Moreover, the high price of papaya hybrid seed of the Formosa group, generally imported from Taiwan at 3000 to 4000 dollars per kilogram (Pereira 2003), has prompted many fruit producers to use the F_2, F_3 and F_4 generations of these hybrids in successive plantings, which raises a series of problems, above all the loss of vigor and segregation for fruit shape (Marin et al. 2006). Genetic breeding programs must therefore be reinforced, which provide a broader genetic base and give rise to varieties with tolerance or resistance to the main diseases, such as ring spot and sticky disease virus, besides desirable agronomic characteristics, to meet the standards of the market (Silva et al. 2007a).

The understanding of the correlations between traits is of great importance in the studies of genetic breeding, principally if selection of one of them is impaired by low heritability or problems of measurement and identification (Cruz and Regazzi 1997), or when

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selection of one character entails modifications in other correlated traits. Generally, in a genetic breeding program several traits are targeted simultaneously, so that the understanding of the genetic associations helps to refine the choice of the most appropriate procedures (Santos and Vencovsky 1986).

The existing relationships between traits are, generally, determined by the genotypic, phenotypic and environmental correlations. The phenotypic correlation measures the degree of association of two variables and is determined by genetic and environmental factors. The latter is mainly responsible for the correlation of traits of low heritability, such as grain yield, for instance (Falconer 1987). The genotypic correlation on the other hand, which represents the genetic portion of the phenotypic correlation, is the only one of inheritable nature and therefore used to orient breeding programs (Ferreira et al. 2003).

No studies have been developed with papaya to determine the relationships between different agronomic traits (Fraife Filho et al. 2001). Currently, there is still a lack of studies of this nature. Besides, despite the leading position of Brazil as the largest producer of papaya worldwide (Nehmi et al. 2002) and the restricted availability of varieties and/or commercial hybrids for planting, few studies have been developed to investigate the inheritance of the main characteristics of importance for papaya breeding.

In this sense, the purpose of this paper was to estimate the coefficients of genotypic correlations between 15 morpho-agronomics traits in papaya segregating generations and varieties, in the north of the state of Espirito Santo.

MATERIAL AND METHODS

Plant material

Hermaphrodite papaya trees of the following genotypes were used: $16BC_1S_1$, $52BC_1S_1$, $115BC_1S_1$, SS 72/12 x 4 BC_1, BC_2, SS 783 and Golden. The first five are segregating populations derived from an initial cross between the dioecious genotype Cariflora and the cultivar Sunrise Solo 783 (SS 783) and the two latter are cultivars of the Solo group. The populations "$16BC_1S_1$, $52BC_1S_1$ and $115BC_1S_1$" were obtained by selfing BC_1 plants, derived of the first backcross with the genotype Cariflora (BC_1) and the BC_2 generation was obtained by a second backcross with genotype Cariflora (BC_2). On the other hand, SS 72/12 x 4 BC_1 was obtained by the cross between a segregating BC_1 tree (4) (pollen donor) and a tree of the cultivar Sunrise Solo 72/12 (SS 72/12).

The genotype Cariflora is a dioecious selection with fruits of moderately firm, yellow pulp and mean weight of around 1.67 kg, besides a pleasant taste and odor (Conover et al. 1986). According to these authors, in the edaphoclimatic conditions of the south of the Florida – EUA the tolerance level of this genotype to papaya ringspot virus (PRSV) is high.

The cross of Cariflora with genotypes of the Solo group results in very vigorous and productive, though rather heterogeneous hybrids, with a high degree of loci in heterozygosis. On the other hand, SS 783 is a cultivar with pear-shaped fruit that weigh on average 0.52 kg, with red pulp of good quality (Marin et al. 2006).

The fruits of cultivar SS 72/12 are of good quality, pear-shaped, small-sized and weigh 0.35 to 0.45 kg, with red-orange, consistent and transport-resistant pulp (Marin et al. 1986, Manica 1996). Cultivar Golden was originated by mass selection on the production fields of Sunrise Solo, of the company Caliman Agrícola S/A, in the state of Espirito Santo. Fruits are pear-shaped and have salmon-pink pulp and an average weight of about 0.45 kg.

Installation of the experiment

The experiment was installed in the commercial area of the company Caliman Agrícola S/A (Fazenda Romana), in Linhares, state of Espírito Santo-Brazil, on January 25, 2005. By the Köppen classification the regional climate is an Awi type (wet tropical), with rainy summers and dry winters. The mean annual rainfall was estimated at 1224.3 mm for the period of 1975 through 1995, with a mean temperature of 23 ^{o}C and relative air humidity of 83.5% (Rolim et al. 1999). The soils of the company were predominantly with sandy-clay texture, sub-evergreen forest phase, and flat to slightly undulated relief (coastal tablelands).

The experiment was arranged in a complete random block design with seven treatments ($16BC_1S_1$, $52BC_1S_1$, $115BC_1S_1$, SS 72/12 x $4BC_1$, BC_2, SS 783 and Golden) and two replications. The seedlings were transplanted to the field in double rows with a spacing of 1.5 m x 2.0 m x 3.6 m. Plots consisted, originally, of 36, 33, 17, 24, 63, 15, and 15 plants of the treatments $16BC_1S_1$, $52BC_1S_1$, $115BC_1S_1$, SS 72/12 x $4BC_1$, BC_2, SS 783 and Golden, respectively. The variation in the number of plants per plot was related to the availability of seedlings and, the plots with 63 BC_2 plants were used for selection and establishment of BC_3. The commonly used fertilization, management, pest and disease control, and cultural practices in the commercial plantations of the company Caliman Agrícola S/A were applied.

Evaluation of the experiment

The following traits were measured in 2005 (a) plant height (PH), using a graded ruler, in cm, 260 days after transplanting (DAT); (b) stem diameter (SD), determined at 20 cm from the soil level with a digital pachymeter, in cm, 260 DAT; (c) insertion height of the first fruit (IHFFr), by a graded ruler, in cm, 140 DAT; (d) total number of flowers (TNF), by counting individually all flowers of hermaphrodite plants, 260 DAT; (e) number of deformed flowers (NDF) (carpelloid and pentandric), determined by counting individually all deformed flowers in hermaphrodite plants, 260 DAT; (f) number of sterile flowers (NSF) (suppression of ovary), determined by counting individually all sterile flowers in hermaphrodite plants, 260 DAT; (g) number of normal hermaphrodite flowers (elongated) (NHF), determined by subtracting the sterile and deformed flowers from the number of total flowers, 260 DAT; (h) total number of fruits (TNFr), determined by counting all fruits of hermaphrodite plants individually, 240 DAT; (i) number of carpelloid fruits (NCFr), determined by counting individually all carpelloid fruits of hermaphrodite plants, 240 DAT; (j) number of pentandric fruits (NPFr), determined by counting individually all pentandric fruits of hermaphrodite plants, 240 DAT; (k) number of commercial fruits (NComFr), determined by subtracting the carpelloid and pentandric fruits from the number of total fruits, 240 DAT; (l) mean weight of commercial fruits (MFrW), obtained by weighing a sample of three fruits per plant in maturation stage 1 (green fruits with a yellow stripe), on analytical scales in kg; (m) mean length of commercial fruits (MFrL), determined by a pachymeter, in three fruits per plant, in mm; (n) mean diameter of commercial fruits (MFrD), determined by a pachymeter, in the equatorial region (central), in three fruits per plant, in mm; (o) production per plant (Prod/Plt), determined by multiplying the number of commercial fruits, 240 DAT, by the mean weight of a sample of three fruits, in kg.

Statistical analysis

The data were subjected to analysis of variance considering the effect of genotypes as fixed and the block and error effects as random. The following statistical model was used: $Y_{ijk} = \mu + t_i + b_j + \varepsilon_{ij} + \delta_{ijk}$ Where: μ = overall treatment mean; t_i = fixed effect of the i^{th} treatment (i = 1, 2, 3,....,t); b_j = effect of the j^{th} block (j = 1 and 2); ε_{ij} = experimental error associated to observation $Y_{ij.}$ and δ_{ijk} = phenotypic effect of the variation among plants within the plot. The significances of the mean squares in Table 1 are based on the F test and the coefficients of phenotypic and genotypic variation were estimated according to Fehr (1987).

The estimates of the genotypic correlation coefficients among the traits studied were obtained by the analysis of genetic covariance, according Cruz and Regazzi (1997). The statistical analyses were performed using the software package SAS (SAS Institute 1992). For the multivariate analysis of variance and generation of the genetic variance-covariance matrices the PROC GLM procedure was used, function MANOVA, type III sums of squares, due to the unbalanced data.

The significance of the genotypic correlation coefficients was obtained by a table with significance values of the correlations, based on the error degree of freedom (6 DF) and on the number of independent variables (treatment and replication) (Steel and Torrie 1980).

RESULTS AND DISCUSSION

The summary of the analysis of variance of the traits in the seven evaluated treatments, besides the values of the coefficients of experimental (CV_e) and genetic variation (CV_g) is given in Table 1. In all traits, significant variances were observed in the genotypes by the F test, at 1 and 5% probability. This indicates satisfactory reliability of the quality of the estimated correlation coefficients among the traits.

The CV_e for most of the traits was less than 20 %, indicating good experimental precision and the CV_g were all higher than the CV_e values. The ratio of CV_g to CV_e is designated variation index (I_v) and values higher than the unity evidence broad genetic variability in the genotypes in all traits measured, useful for genetic breeding of papaya.

Table 1. Summary of the analysis of variance of the morpho-agronomic traits of papaya in segregating generations and cultivars, with the genotype mean square (GMS) values and respective significances, means, coefficient of experimental variation (CV_e) and coefficient of genetic variation (CV_g)

Traits	GMS	Mean	CV_e (%)	CV_g (%)
PH	26862.69*	246.09	6.14	8.47
SD	20.02*	10.98	3.15	5.39
IHFFr	3074.00**	74.97	4.98	9.98
TNF	2710.67**	16.35	12.26	44.70
NDF	344.19**	2.28	19.15	115.79
NSF	986.64**	4.09	41.92	106.01
NHF	623.09**	10.06	13.50	34.26
TNFr	11695.90**	30.54	11.72	49.72
NCFr	22.46**	0.85	23.53	78.04
NPFr	110.68*	1.13	66.25	124.21
NComFr	13667.75**	28.87	9.61	57.41
MFrW	2.89**	0.62	3.22	45.62
MFrL	16887.48**	142.99	1.83	14.73
MFrD	6664.80**	93.51	1.28	14.18
Prod Plt^{-1}	818.03**	20.13	10.46	22.06

PH = plant height in cm 260 DAT; SD = stem diameter in cm 260 DAT; IHFFr = insertion height of the first fruit in cm 140 DAT; TNF = numbers of total flowers 260 DAT; NDF = numbers of deformed flowers 260 DAT; NSF = number of sterile flowers 260 DAT; NHF = numbers of normal flowers 260 DAT; TNFr = number of total fruits 240 DAT; NCFr = number of carpelloid fruits 240 DAT; NPFr = number of pentandric fruits 240 DAT; NComFr = number of commercial fruits 240 DAT; MFrW = mean fruit weight in kg; MFrL = mean fruit length in mm; MFrD = mean fruit diameter in mm; Prod Plt^{-1} = yield per plant in kg.
** = significant at 1 % probability; * = significant at 5 % probability

The coefficients of genotypic correlations were estimated (Table 2), in view of the practical value in genetic breeding programs. Of the trait pairs 19.05% were significant at 1 or 5% level, varying from -0.87 to 0.99.

For the pairs constituted by the traits plant height (PH) and insertion height of first fruit (IHFFr) the genotypic correlations were not significant. The trait stem diameter (SD) was highly and positively correlated with yield per plant (Prod/Plt) (0.84), suggesting that selection for higher SD can result in more productive plants. This is an interesting piece of information since the stem diameter is an easily measurable trait even in young plants and can therefore facilitate early selection of more productive plants. Fraife Filho et al. (2001) evaluated papaya varieties of the Solo and Formosa groups and also detected a high phenotypic correlation (0.93) between the mean annual yield and SD in the beginning of flowering. The strong association of SD with Prod/Plt may be related with a greater capacity of the plants to take up water and nutrients from the soil, resulting in greater vigor and favorable performance of the yield components.

The yield components total number of fruits (TNFr) and number of commercial fruits (NComFr) were negatively correlated, at a significance level of 5%, with the traits total number of flowers (TNF), number of normal flowers (NHF), mean fruit weight (MFrW) and mean fruit length (MFrL). Besides, the correlation between NComFr and the mean fruit diameter (MFrD) was negative (-0.80). As expected, the observed correlation between TNFr and the NComFr was high and positive (0.99).

The negative correlations of TNFr and NComFr with the traits MFrW and MFrL, as well as of NComFr with MFrD had been expected since this genetic performance is also observed in other crops, as for example, of watermelon, in which Ferreira et al. (2003) verified negative correlation (-0.75) between the number of fruits per plant and the mean fruit weight. This may be related with the limitations of photoassimilates for the filling of a greater number of fruits, requiring the practice of fruit thinning when larger and heavier fruits are desired in some species.

The evaluations of the flowering traits, TNF and NHF, and the traits of fructification, TNFr and NComFr, simultaneously, resulted in negative genotypic correlations of these latter with TNF and NHF, i.e., the greater the number of fruits per plant, the lower TNF and NHF will tend to be in the same period of evaluation,

Table 2. Estimates of the coefficients of genotypic correlations between 15 morpho-agronomic traits of papaya in segregating generations and cultivars

Traits	IHFFr	SD	TNFr	NCFr	NPFr	NComFr	TNF	NDF	NSF	NHF	MFrW	Prod Plt^{-1}	MFrL	MFrD
PH	0.49	0.50	0.41	-0.18	-0.24	0.40	-0.64	-0.51	-0.47	-0.59	0.06	0.44	0.02	-0.01
IHFFr		-0.06	0.37	-0.59	-0.64	0.41	-0.65	-0.77	-0.28	-0.68	-0.45	-0.30	-0.39	-0.58
SD			0.67	-0.23	-0.27	0.65	-0.58	-0.27	-0.49	-0.58	-0.20	0.84*	-0.25	-0.12
TNFr				-0.63	-0.61	0.99**	-0.87*	-0.50	-0.71	-0.86*	-0.80*	0.41	-0.80*	-0.78
NCFr					0.99**	-0.69	0.49	0.89**	0.03	0.51	0.78	0.01	0.61	0.79*
NPFr						-0.67	0.52	0.93**	0.04	0.54	0.73	-0.01	0.58	0.75
NComFr							-0.86*	-0.56	-0.67	-0.85*	-0.82*	0.38	-0.79*	-0.80*
TNF								0.55	0.84*	0.97**	0.63	-0.24	0.70	0.67
NDF									0.05	0.57	0.51	-0.04	0.38	0.56
NSF										0.74	0.44	-0.19	0.63	0.44
NHF											0.61	-0.31	0.62	0.60
MFrW												0.14	0.95**	0.98**
Prod Plt^{-1}													0.18	0.19
MFrL														0.92**

PH = plant height in cm 260 DAT; SD = stem diameter in cm 260 DAT; IHFFr = insertion height of the first fruit in cm 140 DAT; TNF = number of total flowers 260 DAT; NDF = numbers of deformed flowers 260 DAT; NSF = numbers of sterile flowers 260 DAT; NHF = numbers of normal flowers 260 DAT; TNFr = number of total fruits 240 DAT; NCFr = number of carpelloid fruits 240 DAT; NPFr = number of pentandric fruits 240 DAT; NComFr = number of commercial fruits 240 DAT; MFrW = mean fruit weight in kg; MFrL = mean fruit length in mm; MFrD = mean fruit diameter in mm; Prod Plt^{-1} = yield per plant in kg

evidencing that this performance is an adaptive mechanism of the plant to avoid/circumvent excessive physiological energy expenditure. Therefore, these results must be carefully analyzed and should not underlie selection procedures since they reflect a momentary situation only. We therefore suggest that this kind of associations should be established between the flowering traits of a certain period with the traits of their respective fruits, in a later evaluation.

The traits number of carpelloid fruits (NCFr) and number of pentandric fruits (NPFr) were positively correlated with the number of deformed flowers (NDF) at magnitudes of 0.89 and 0.93, respectively. Besides, the traits NCFr and NPFr were highly correlated (0.99), indicating that selection against carpelloidy results indirectly in selection against pentandry of papaya fruits and vice-versa. Carpelloid fruits occur when the stamen of hermaphrodite flowers are transformed into similar structures as the carpels. The phenomenon begins during the early flower development and results in defective, commercially worthless fruits, popularly known as “cat-faced”. Pentandry in fruits occurs due to the insertion of the stamen in the ovary wall of a pentandric hermaphrodite flower, forming deep furrows in the ovary wall. Pentandric fruits are very similar to the ones produced by female plants, rounded, with large internal cavity and visible external furrows that depreciate the commercial value.

Although the correlations of the TNF and of the NHF with the TNFr and NComFr, estimated in the same period of evaluation, are not recommended for the selection procedures, the correlations of NDF with NCFr and NPFr should be used in the selection procedures when these traits are measured in the same period. This shows that aside from the influence of the environment on the trait expression, mainly fluctuations of air temperature, there is also a considerable genetic component, that is, depending on the genotype, the traits can be expressed simultaneously in any season of the year.

Despite the high positive correlation between the TNF and the NHF (0.97), the marked correlation with the number of sterile flowers (NSF) (0.84) should also be considered. The normal or elongated flowers are responsible for the production of commercial fruits (pear-shaped or elongated). Sterile female flowers (suppression of ovary of hermaphrodite flowers), also known as male, generally occur during the hot summer months (Awada 1958, Storey 1941). Low nitrogen levels and water stress also favor sexual reversion (males) (Awada 1953, Awada 1958). Therefore, despite the widespread acceptance of the hypothesis of monogenic inheritance of papaya sex forms, it may be assumed that there is a group of modifying genes interacting complexly in the expression of the secondary traits of the flowers of hermaphrodite plants (sexual reversion, carpelloidy and pentandry).

The high correlation of TNF with NSF (0.84) is undesirable since it indicates that genotypes with greater flower production tend to express sexual reversion. However, the magnitude of the correlation does not express complete linking and indicates a possibility of developing recombinant plants with high flower production capacity and low female sterility. Much the same as carpelloidy and pentandry of the fruits, female sterility or sexual reversion is associated to the reduction of the commercial fruit yield in hermaphrodite papaya trees.

Considering that hermaphroditism in papaya is recent, originated by the dioecious condition (Horovitz and Jimenez 1967), Silva et al. 2007b suppose that the manifestation of variations of the elongated hermaphrodite flower (normal) to the deformed and female sterile might represent an evolution strategy to overcome seasonal stresses and warrant the plant maintenance. In this sense, the expression of the flower deformations in the carpelloid and pentandric forms could represent a tendency of the plant to return to the female sex, since female plants seem to be more stable and more efficient in the allocation of the photoassimilates for fruit production. On the other hand, female sterility indicates how a plant saves energy without affecting the allele distribution in the population. Thereby, the plant prioritizes the reproductive over the productive effort, since in some cases fruit production ceases completely. Evidently this represents a tendency since these events are dynamic due to the fluctuations of the climatic, nutritional and genetic factors in the field and can occur, to a greater or lesser degree, in any season of the year.

As expected, the traits mean fruit length (MFrL) and mean fruit diameter (MFrD) were positively correlated with mean fruit weight (MFrW), with magnitudes of 0.95 and 0.98, respectively. A high positive correlation was also observed between MFrL and MFrD (0.92), that is, the fruits of these generations grew proportionally in diameter and length. The positive correlation between MFrD and NCFr (0.79) is undesirable, although the magnitude of correlation does not represent complete linking, and the fruit diameter for the consumer market should also be slimmer than that of female plants and fruits should not be carpelloid. The pear-shaped or elongated, oblong or slightly oblong fruits, derived from hermaphrodite plants, are easier to be wrapped than the round fruits, derived from female plants, aside from having a higher commercial value (Marin and Gomes 1999).

CONCLUSIONS

Based on the results of the estimates of genotypic correlations, some important conclusions can be presented:

1. In papaya breeding programs the trait stem diameter (SD) can be used in the initial stage of plant development to select higher-yielding plants. Together with the flowering traits, the SD can could be a possibility of performing soft selection of hermaphrodite plants and selfing them early (4 to 5 months after transplanting), before evaluating fructification. Later, with a detailed characterization of the other yield components, a more rigorous selection including the early selfed plants can be performed.

2. The undesirable correlation between TNF and NSF (0.84) does not represent complete linking, indicating a possibility of developing recombinant plants with a high capacity of flower production and low expression of sexual reversion. In this context, new cultivars better adapted to fluctuations in the main climatic variables (mainly air temperature) must be developed in breeding programs of papaya, to warrant the constancy in the growth of normal flowers and, consequently, in the production of commercial fruits all year long.

3. Although the correlations of TNF and NHF with TNFr and NComFr, estimated in the same period of evaluation, are not recommended for the selection procedures, the correlations of NDF with NCFr and NPFr should be used in the selection procedures, given that the traits are measured in the same period.

4. Deformed flowers (*carpelloid and pentandric*) *and* sexual reversion affect commercial fruit production negatively, and the identification of plants further

adapted to the fluctuations of the main climatic variables, mainly air temperature, should be considered one of the overall objectives of genetic breeding of papaya. There is a clear need for the development of segregating generations with a view to selection in breeding programs, specific for the main producing regions of Brazil.

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Correlações genotípicas de caracteres morfoagronômicos em mamoeiro e suas implicações para o melhoramento genético

RESUMO - *O conhecimento das correlações entre caracteres é de grande importância nos trabalhos de melhoramento genético, principalmente, se a seleção de um deles é dificultada em razão da baixa herdabilidade ou de problemas de mensuração e identificação. Este trabalho objetivou estimar as correlações genotípicas entre quinze caracteres morfoagronômicos em mamoeiro. Os resultados indicaram que a seleção precoce para maior diâmetro de caule (DC) pode resultar em plantas mais produtivas. Embora as correlações entre flores normais e frutos comerciais, estimadas numa mesma época de avaliação, não sejam recomendadas para os procedimentos de seleção, as correlações entre flores deformadas e frutos carpelóides e pentândricos são confiáveis de serem utilizadas nos procedimentos de seleção quando estes caracteres forem mensurados na mesma época. Os distúrbios florais refletem negativamente na produção de frutos comerciais, indicando a necessidade de se conduzir gerações segregantes para fins de seleção, nas principais regiões produtoras do Brasil.*

Palavras-chave: *Carica papaya*, mamão, produção de frutos, carpelloidy, reversão sexual.

REFERENCES

Awada M (1953). Effects of moisture on yield and sex expression of the papaya plants (*Carica papaya* L.). **Hawaii Agricultural Experiment Station Progress, Notes** nº 97.

Awada M (1958) Relationships of minimum temperature and growth rate with sex expression of papaya plants (*Carica papaya* L.). **Hawaii Agricultural Experiment Station, Technical Bulletin 38**: 1-16.

Chen MH, Chen CC, Wang DN and Chen FC (1991) Somatic embryogenesis and plant regeneration from immature embryos of Carica papaya x Carica cauliflora cultured in vitro. **Canadian Journal of Botany 69**: 1913-1918.

Conover RA, Litz RE and Malo SE (1986) Cariflora, a papaya for South Florida with tolerance to papaya ringspot virus. **Florida: Agricultural Experiment Station, University of Florida**, (Circular, 329), 3p.

Cruz CD and Regazzi AJ (1997) **Modelos biométricos aplicados ao melhoramento genético**. 2nd ed., Universidade Federal de Viçosa, Viçosa, 390p.

Falconer DS (1987) **Introdução à genética quantitativa**. Universidade Federal de Viçosa, Viçosa, 279p.

Fehr WR (1987) Principles of cultivar development: **Theory and Technique**. Iowa State University, vol.1, 525p.

Ferreira MAJF, Queiroz MA, Braz LT and Vencovsky R (2003) Correlações genotípicas, fenotípicas e de ambiente entre dez caracteres de melancia e suas implicações para o melhoramento genético. **Horticultura Brasileira 21**: 438-442.

Fraife Filho GA, Dantas JLL, Leite JBV and Oliveira JRP (2001) Avaliação de variedades de mamoeiro no extremo sul da Bahia. **Magistra 13**: 37-41.

Horovitz S and Jimenez H (1967) Cruzamientos interespecíficos e intergenéricos en Caricaceas y sus implicaciones fitotécnicas. **Agronomia Tropical 17**: 353-359.

Manica I (1996) Cultivares e melhoramento do mamoeiro. In: Mendes LG, Dantas JLL, Morales CFG. Mamão no Brasil. Cruz das Almas: **EUFBA/EMBRAPA-CNPMF**, p. 93-120.

Marin SLD and Gomes JÁ (1999) Biologia floral do mamoeiro: aplicação na sexagem e no raleio de flores e frutos. Vitória: **EMCAPA**, 20p. (EMCAPA. Circular Técnica 11).

Marin SLD, Gomes JA and Salgado JS (1986) Recomendações **para a cultura do mamoeiro cv. Solo no Estado do Espírito Santo**. 2nd ed., EMCAPA, Belo Horizonte, 62p. (Circular Técnica, 2).

Marin SLD, Pereira MG, Amaral Júnior AT, Martelleto LAP and Ide CD (2006) Heterosis in papaya hybrids from partial diallel of 'Solo' and 'Formosa' parents. **Crop Breeding and Applied Biotechnology 6**: 24-29.

Nehmi IMD, Ferraz JV, Nehmi Filho VA and Silva MLM da (2002) Consultoria & Comércio 2002. In: **AGRIANUAL 2003: anuário da agricultura brasileira**. FNP, São Paulo, p. 378-386.

Pereira MG (2003) Melhoramento genético do mamoeiro (*Carica papaya* L.): desenvolvimento e recomendação de híbridos. **Seahortes 1**: 61-65.

Rolim SG, Couto HTZ and Jesus RM (1999) Mortalidade e recrutamento de árvores na Floresta Atlântica de Linhares (ES). **Scientia Forestalis 55**: 49-69.

Santos JB and Vencovsky R (1986) Correlação fenotípica e genética entre alguns caracteres agronômicos do feijoeiro (*Phaseolus vulgaris* L.). **Ciência Prática 103**: 265-272.

SAS Institute INC. (1992) **Statistical Analysis System**. Release 6.12, (Software). Cary, 1992.

Silva FF, Pereira MG, Campos WF, Damasceno Junior PC, Pereira TNS, Souza Filho GA, Ramos HCC, Viana AP and Ferreguetti GA (2007a) DNA marker-assisted sex conversion in elite papaya genotype (*Carica papaya* L.). **Crop Breeding and Applied Biotechnology 7**: 52-58.

Silva FF, Pereira MG, Damasceno Junior PC, Pereira TNS, Viana AP, Daher RF, Ramos HCC and Ferreguetti GA (2007b) Evaluation of the sexual expression in a segregating BC_1 papaya population. **Crop Breeding and Applied Biotechnology 7**: 16-23.

Steel RGD and Torrie JH (1980) Principles and Procedures of Statistics: **A Biometrical Approach**. 2^{nd} ed., McGraw-Hill, New York, 633p.

Storey WB (1941) The botany and sex relationships of the papaya. In: Papaya production in the Hawaiian Islands. **Hawaii Agricultural Experiment Station, Bulletin 87**: 5-22.