Crop Breeding and Applied Biotechnology 8: 65-73, 2008
Brazilian Society of Plant Breeding. Printed in Brazil

Estimation of genetic parameters related to morpho-agronomic and fruit quality traits of papaya

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Received 07 June 2006

Accepted 31 August 2006

ABSTRACT - *The estimation of genetic parameters allows an identification of the genetic variability in a population and underlies the choice of the most suitable improvement methods. This study aimed to estimate the genetic parameters related to morpho-agronomic and fruit quality traits in the following papaya genotypes: 16BC_1S_1, 52BC_1S1, 115BC_1S_1, SS 72/12 x 4BC_1, BC_2, SS 783 and Golden. Based on the means and respective standard deviations and on the estimates of genetic parameters of the evaluated traits, it was concluded that selection in the segregating generations has great chances of success, in view of the wide genotypic variability among them, with values of H^2 (coefficient of genotypic determination) of over 80% for most evaluated phenotypic attributes. Considering the importance of the flowering and fruiting attributes, the high H^2 indicates that improvement programs can achieve great increases in papaya yield.*

Key words: *Carica papaya*, fruit yield, carpelloidy, pentandry, female sterility.

INTRODUCTION

Although Brazil is the world's largest papaya producer (Nehmi et al. 2002), nowadays in this country there are restricted possibilities for the choice of varieties and/or commercial hybrids for planting that could meet national as well as international market demands. Furthermore, little research has been done so far in the area of the inheritance of the main traits of importance for crop improvement.

The denomination parameter refers to the constant traits of a population, particularly mean and variance. In the case of populations used in improvement programs, the nature of the parameters of interest is two-fold: genetic and non-genetic (Morais et al. 1997). Estimates of genetic parameter are of fundamental importance for improvement programs, as they allow the identification of the nature of a gene action involved in the control of quantitative traits and the evaluation of the efficiency of different improvement strategies at achieving genetic gains and maintaining an appropriate genetic basis (Cruz and Carneiro 2003). According to these authors, the most important genetic parameters are additive and non-additive genetic variances, heritability and correlations.

When estimating genetic parameters, one should bear in mind that estimates are only valid for the population represented in the experimental material by some type of sample and for the environmental conditions the experiment was conducted in. Therefore,

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when estimating genetic variances experimentally, the genotypes as much as the environments of experimentation must be representative of the population and the geographic area of interest, respectively (Cockerham 1956, Robinson and Cockerham 1965, cited by Morais et al. 1997). It is also noteworthy that the component of the genetic variation cannot be estimated independently from the component due to genotype x environment interaction, when a trial is conducted in one environment only (Gardner 1963).

Associated to the calculation of genetic variances and of means, the establishment of estimates of other genetic parameters, such as the coefficient of heritability and of genetic variation, variation index and genetic correlations, is essential to predict gains, to evaluate the feasibility of determined improvement program and as orientation in the choice of the most efficient selection strategy (Vencovsky 1969).

According to the above considerations, the objective of our study was to estimate the genetic parameters related to traits of fruit reproduction, yield and quality in papaya segregating generations and elite genotypes, grown in the northern region of Espirito Santo State.

MATERIAL AND METHODS

Plant material

In this study, hermaphrodite plants of the following genotypes were used: $16BC_1S_1$, $52BC_1S_1$, 115 BC_1S_1, SS 72/12 x $4BC_1$, BC_2, SS 783 and Golden. The first five are segregating genotypes and the two latter cultivars of the Solo group.

The segregating generations were derived from an initial cross between the dioecious genotype Cariflora and cultivar Sunrise Solo 783 (SS 783). The SS 783 populations segregate for sex in a proportion of 2 hermaphrodite plants to 1 female plant and are called ginoic-andromonoic. The first three genotypes were obtained by selfing BC_1 plants, derived from a first backcross with genotype Cariflora (BC_1) and the BC_2 segregating generation was obtained by a second backcross with Cariflora (BC_2). On the other hand, SS 72/12 x $4BC_1$ was obtained by a cross between a segregating BC_1 plant and a plant of Sunrise Solo 72/12 (SS 72/12).

Cariflora is a dioecious selection with fruits of yellow pulp and moderate firmness, weighing on average 1.67 kg, with pleasant taste and flavor (Conover et al. 1986). Crossing it with genotypes of the Solo group results in very vigorous and productive hybrids, although quite heterogeneous, due to the high degree of loci in heterozygosis. SS 783 on the other hand is a cultivar with pear-shaped fruit weighing on average 0.52 kg, with red pulp and of good quality (Marin et al. 2006).

The fruit quality traits of cultivar SS 72/12 are good: its fruits with red-orange pulp are pear-shaped, small-sized, weigh between 0.35 and 0.45 kg, and are consistent and transport- resistant (Marin et al. 1986, Manica 1996).

Cultivar Golden was derived by mass selection in the production areas of Sunrise Solo of the company Caliman Agrícola S/A, in the state of Espirito Santo. It has pear-shaped fruits, with salmon-pink pulp and a mean weight of about 0.45 kg.

Experiment installation and evaluation

The experiment was installed in the commercial fields of the company CALIMAN AGRÍCOLA S/A (Fazenda Romana), municipality of Linhares, Espirito Santo, Brazil, on January 25, 2005.

The experimental design consisted of complete random blocks 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 spaced 1.5 x 2.0 x 3.6 m. The plots consisted 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 of the number of plants per plot was a result of the availability of seedlings; the plots with 63 plants (BC_2) were designated to select and to obtain the BC_3 generation. The fertilization, management, pest and disease control, and the cultural treatments were the same as in the commercial plantations of the cited company.

During the year 2005 the yield components and qualitative fruit aspects were evaluated as described below: **a) Plant height (PH)**: expressed in cm, determined by a ruler in cm, from the soil level up to the highest pair of leaves, 140 (PH1) and 260 (PH2) days after transplanting (DAT) the seedlings to the field; **b) Stem diameter (SD)**: expressed in cm, determined 10 cm and 20 cm above soil level 140 DAT (SD1) and 260 DAT (SD2), respectively, measured by a digital pachymeter; **c) Insertion height of the first fruit (IHFF)**: expressed

in cm, assessed by a ruler in cm, from the soil level to the point of insertion of the first fruit, 140 DAT; **d) Number of total flowers (NTF)**: the number of total flowers was determined by counting all flowers of hermaphrodite plants individually, 140 DAT (NTF1) and 260 DAT (NTF2). For this purpose, flowers in the different development stages were considered, to make the distinction possible between normal flowers and variations to female sterile (suppression of ovary) and deformed (carpelloid or pentandra) **e) Number of deformed flowers (NDF)**: determined by counting all deformed flowers in hermaphrodite plants individually, 140 DAT (NDF1) and 260 DAT (NDF2). The NDF represents the sum of the carpelloid and pentandra flowers; **f) Number of sterile flowers (NSF)**: the number of sterile female flowers (suppression of ovary) was determined by counting all sterile flowers in hermaphrodite plants individually, 140 DAT (NSF1) and 260 DAT (NSF2); **g) Number of normal flowers (NNF)**: the number of normal hermaphrodite flowers (elongated) was determined by subtracting sterile and deformed flowers from the total number of flowers, 140 DAT (NNF1) and 260 DAT (NNF2); **h) Total number of fruits (TNFr)**: determined by counting all fruits of hermaphrodite plants individually, 140 DAT (TNFr1) and 240 DAT (TNFr2); **i) Number of carpelloid fruits (NCFr)**: determined by counting all carpelloid fruits of hermaphrodite plants individually, 140 DAT (NCFr1) and 240 DAT (NCFr2); **j) Number of pentandric fruits (NPFr)**: determined by counting all pentandric fruits of hermaphrodite plants individually, 140 DAT (NPFr1) and 240 DAT (NPFr2); **k) Number of commercial fruits (NComFr)**: determined by subtracting the carpelloid and pentandric fruits of the number of total fruits, 140 DAT (NComFr1) and 240 DAT (NComFr2); **l) Mean fruit weight (MFrW)**: the mean commercial fruit weight was expressed in kg, obtained by weighing on analytical scales, a three-fruit sample per plant in the stage of maturation 1 (green fruits with a yellow stripe); **m) Mean fruit length (MFrL)**: determined by a pachymeter in three fruits per plant and expressed in mm; **n) Mean fruit diameter (MFrD)**: determined by a pachymeter in three fruits per plant and expressed in mm. For this measurement, the equatorial (central) region of the fruit was considered; **o) Plant yield (Yld Plt^{-1})**: the fruit yield per plant was determined by multiplying the number of commercial fruits 240 DAT by the mean weight of a three-fruit sample and expressed in kg; **p) External fruit firmness (EFrF)**: determined by a penetrometer (Fruit Pressure Tester, Italy: model 53205) and expressed in Newton (N). For this purpose, three equidistant points were used in the fruit equator (center) region of the three-fruit sample per plant; **q) Internal fruit firmness (IFrF)**: after cutting the fruit in half transversally in the equatorial (center) region, the internal firmness was determined by a penetrometer (Fruit Pressure Tester, Italy: model 53205) and expressed in Newton (N). Three equidistant points were measured approximately 0.5 cm beneath the peel of a three-fruit sample per plant; **r) Soluble solids content (^{o}Brix)**: obtained by a hand-held refractometer (Atago N1) and expressed in ^{o}Brix, in a three-fruit sample per plant.

Analysis of variance and estimation of genetic parameters

The analysis of variance and estimations of the genetic parameters of the evaluated traits in an experimental design type 1 (fixed model) were carried out using software SAS (SAS Institute 1992) . For this purpose, the following statistical model was used: $Y_{ijk} = \mu + t_i + b_j + \varepsilon_{ij} + \partial_{ijk}$

Where: μ = overall mean of the treatments; 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 ∂_{ijk} = phenotypic effect of the variation among plants within the plot. The genetic parameters were estimated according to Fehr (1987).

RESULTS AND DISCUSSION

The analysis of variance presented significant differences by the F test among treatments for most traits, indicating the existence of genetic variability among the treatments (Table 1). One must however take into consideration that, aside from the content of soluble solids (^{o}Brix), the other traits without significant differences among treatments had been measured preliminarily for a soft selection within the segregating treatments in the initial fruiting phase.

The coefficient of experimental variation (CV_e) was below 20 % for most traits, indicating good experimental precision. Nevertheless, for the traits "NDF_1 – number of deformed flowers 140 DAT (26,09 %), NSF_1 – number of sterile flowers 140 DAT (28.67 %), $TNFr_1$ – total number of fruits 140 DAT (24.86 %), $NCFr_2$ – number of

Table 1. Analysis of variance of the morpho-agronomic and fruit quality traits in papaya segregating generations and cultivars, with mean square values of genotype (MSG) and respective significances, means, coefficiet of experimental variation (CV_e) and coefficiet of genetic variation (CV_g)

Trait	MSG	Mean	CV_e (%)	CV_g (%)
PH_1	11633.16*	179.25	4.28	7.61
PH_2	26862.69*	246.09	6.14	8.47
SD_1	15.79*	9.71	3.25	5.04
SD_2	20.02*	10.98	3.15	5.39
IHFF	3074.00**	74.97	4.98	9.98
NTF_1	7207.94*	48.03	13.68	22.03
NTF_2	2710.67**	16.35	12.26	44.70
NDF_1	97.70**	1.15	26.09	115.36
NDF_2	344.19**	2.28	19.15	115.79
NSF_1	9459.92**	19.63	28.67	64.33
NSF_2	986.64**	4.09	41.92	106.01
NNF_1	1869.01	27.25	19.14	16.83
NNF_2	623.09**	10.06	13.50	34.26
$TNFr_1$	414.64	7.83	24.86	30.73
$TNFr_2$	11695.90**	30.54	11.72	49.72
$NCFr_1$	0.88	0.15	66.67	66.67
$NCFr_2$	22.46**	0.85	23.53	78.04
$NPFr_1$	1.49	0.13	133.23	108.78
$NPFr_2$	110.68*	1.13	66.25	124.21
$NComFr_1$	310.53	8.46	25.71	23.61
$NComFr_2$	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
Yld Plt^{-1}	818.03**	20.13	10.46	22.06
EFrF	3778.65**	114.22	3.50	8.86
IFrF	2111.92**	92.29	4.09	7.99
°Brix	9.88	11.40	3.28	3.82

PH_1 = plant height in cm 140 DAT; PH_2 = plant height in cm 260 DAT; SD_1 = stem diameter in cm 140 DAT; SD_2 = stem diameter in cm 260 DAT; IHFF = insertion height of the first fruit in cm 140 DAT; NTF_1 = number of total flowers 140 DAT; NTF_2 = number of total flowers 260 DAT; NDF_1 = number of deformed flowers 140 DAT; NDF_2 = number of deformed flowers 260 DAT; NSF_1 = number of sterile flowers 140 DAT; NSF_2 = number of sterile flowers 260 DAT; NNF_1 = number of normal flowers 140 DAT; NNF_2 = number of normal flowers 260 DAT; $TNFr_1$ = number total of fruits 140 DAT; $TNFr_2$ = number total of fruits 240 DAT; $NCFr_1$ = number of carpelloid fruits 140 DAT; $NCFr_2$ = number of carpelloid fruits 240 DAT; $NPFr_1$ = number of pentandric fruits 140 DAT; $NPFr_2$ = number of pentandric fruits 240 DAT; $NComFr_1$ = number of commercial fruits 140 DAT; $NComFr_2$ = number of commercial fruits 240 DAT; MFrW = mean fruit weight in kg; MFrL = mean fruit length in mm; MFrD = mean fruit diameter in mm; Yld Plt^{-1} = plant yield in kg; EFrF = external fruit firmness in N; IFrF = internal fruit firmness in N; °Brix = content of soluble solids of fruit pulp, ** = significant at 1% probability; * = significant at 5% probability

carpelloid fruits 240 DAT (23.53 %) and $NComFr_1$-number of commercial fruits 140 DAT (25.71 %)" the values were high and very high for the traits "NSF_2 – number of sterile flowers 260 DAT (41.92 %), $NCFr_1$ – number of carpelloid fruits 140 DAT (66.67 %), $NPFr_1$ – number of pentadric fruits 140 DAT (133.23 %) and $NPFr_2$ – number of pentadric fruits 240 DAT (66.25 %).

The high and very high values of CV_e observed here are partly due to the ample variation for these traits in the treatments, above all in the traits measured 140 DAT, in which some plants within a treatment or actually entire treatments presented complete absence of these traits. Likewise, the traits measured 240 DAT had the same tendency, in other words, there were plants in which $NCFr_2$, NSF_2 and $NPFr_2$ were absent. These traits also seem to be very influenced by the environment which may have contributed to the high and very high CV_e. It is worth remembering that the coefficient of

genetic variation (CV_g) also high and, with exception of $NPFr_1$, higher than CV_e reflect the wide genetic variability for these traits, usable for genetic improvement of papaya.

The means and respective minimum significant differences (MSD) of the morpho-agronomic and fruit quality traits are presented in (Table 2). For the traits PH_2 and IHFF, the lowest means were observed in the treatment $52BC_1S_1$, followed by $16BC_1S_1$. On the other hand, the mean for these traits as well as of female sterility was higher in treatment $115BC_1S_1$. According to Nakasone and Lamoureux (1982), very tall plants are undesirable due to the generally longer internodes, more spaced fruits and shorter longevity of production. Besides, hermaphrodite plants with high rates of female sterility and male plants are nearly always taller than plants with lower expression of female sterility.

The mean NDF, which reflects the variation of the elongated hermaphrodite flowers to carpelloid and pentadra shapes, was higher in the $52BC_1S_1$ and BC_2 treatments and zero for treatment $115BC_1S_1$, in both evaluations. Likewise, the mean values of the traits NCFr and NPFr, resultant of the deformed flowers, were higher in the $52BC_1S_1$ and BC_2 treatments and lower in $115BC_1S_1$. Nevertheless, these traits were little significant in the treatments SS 783 and Golden, which are genetically very close.

Considering that the segregating treatments were derived from the initial cross between SS 783 and genotype Cariflora, the conclusion may be drawn that, probably, the stronger expression of flower deformations, of carpelloid and pentandric fruits verified in the treatments $52BC_1S_1$ and BC_2 , was inherited from the parent Cariflora, since in the dioecious condition these traits would never be expressed in this genotype (Silva et al. 2007a, Silva et al. 2007b).

The NTF and NSF means were higher 140 DAT than 260 DAT in all treatments and significantly higher in the $115BC_1S_1$ treatment. In a comparison of NTF and NSF, a tendency of stronger expression of female sterility was observed in the treatments with higher NTF, mainly in $115BC_1S_1$.

In spite of the significant variation of the NTF and NSF between the two evaluations in all treatments, the mean NNF (NTF minus the sum of NSF and NDF) varied little in the treatments $16BC_1S_1$ and $115BC_1S_1$, indicating a greater stability in the trait expression in these treatments. It was further observed that 140 DAT, there was generally no significant difference for NNF among the treatments. But 260 DAT there was already a relevant difference for NNF among the treatments, with the tendency of superiority of the segregating material over the cultivars Golden and SS 783, especially in the treatments $16BC_1S_1$, $52BC_1S_1$ and $115BC_1S_1$.

The female sterility and carpelloid and pentadric fruits in hermaphrodite plants, affect the commercial fruit yield. This evidences the need for selection of plants with a minimal expression of these traits in segregating generations, in the main papaya producing regions of Brazil (Silva et al. 2007a).

The trait Yld Plt^{-1} (kg), result of the multiplication of NComFr2 by MFrW, was significantly higher in treatment $115BC_1S_1$, followed by SS 783 and by SS 72/12 x $4BC_1$. Nevertheless, all segregating treatments were significantly or slightly superior to Golden, one of the most planted cultivars in the papaya producing regions of Espirito Santo. The trait MFrW indicates that the segregating genotypes have a potential for selection of plants for production for the national market, where fruits must weigh between 0.80 and 1.50 kg, as well as for the foreign market, where fruits of around 0.50 kg are demanded.

The ratio fruit length $diameter^{-1}$ was on average 1.60, 1.50, 2.02, 1.51, 1.50, 1.60 and 1.50 in the treatments $16BC_1S_1$, $52BC_1S_1$, $115BC_1S_1$, SS 72/12 x $4BC_1$, BC_2, Golden and SS 783, respectively. Only treatment $115BC_1S_1$ presented fruits with a length/diameter ratio of approximately 2:1, and was therefore characterized as elongated (Giacometti and Ferreira 1988). Elongated fruits find good acceptance on the domestic market. The values of the ratio fruit length/ diameter were over 1:1 (round) and below 2:1 (comprises the other fruit shapes) in the other treatments.

Pear-shaped or elongated, oblong or slightly oblong fruits, derived from hermaphrodite plant, are easier to be wrapped than round fruits of female plants, apart from the higher commercial value (Marin and Gomes 1999).

The estimate of the external (EFrF) and internal firmness (IFrF), in the maturation stage 1 (green fruits with a yellow stripe), expressed a significant or slight

Table 2. Mean values and respective standard deviations related to the morpho-agronomic and fruit quality traits in papaya segregating generations and cultivars, and the respective minimum significant differences at 5 % probability (MSD)

Trait	Treatments							MSD (t. 5%)
	$16BC_1S_1$	$52BC_1S_1$	$115BC_1S_1$	SS 72/12 x $4BC_1$	BC_2	Golden	'SS 783'	
PH	161.67+24.05	162.95+16.09	192.76+36.27	185.77+21.00	90.15+30.58	178.77+18.67	187.57+22.00	26.56
PH_2	224.31+36.53	218.79+26.86	272.94+55.99	267.45+41.94	261.47+40.72	245.00+23.89	258.67+35.60	52.38
SD_1	9.10+1.29	9.56+1.14	9.47+1.83	10.23+1.38	9.98+1.43	9.02+1.13	10.63+1.17	1.12
SD_2	10.45+1.37	11.02+1.31	10.96+1.66	11.65+1.46	10.75+1.47	10.36+1.28	12.44+1.60	1.20
IHFF	73.00+10.09	66.77+16.00	93.79+27.40	75.33+16.15	72.76+18.99	89.20+8.54	78.20+9.92	12.94
NTF_1	41.52+20.40	51.95+21.28	75.51+27.49	46.00+15.76	50.59+22.52	30.00+7.15	35.43+11.12	22.77
NTF_2	24.58+17.19	16.61+8.04	33.41+13.22	9.89+5.65	15.39+11.94	8.30+3.28	7.83+2.72	6.95
NDF_1	0.09+0.45	1.59+3.54	0.00+0.00	0.00+0.00	2.75+5.31	0.00+0.00	0.30+0.65	1.05
NDF_2	0.35+1.45	3.66+4.93	0.35+1.06	0.00+0.00	5.46+6.58	0.07+0.25	0.00+0.00	1.51
NSF_1	23.82+22.75	21.80+21.03	52.48+29.63	16.08+15.33	16.161+7.10	3.53+2.79	4.70+2.76	19.50
NSF_2	9.61+13.83	2.42+2.96	14.94+11.76	1.48+3.20	2.54+4.53	0.83+0.98	0.93+1.46	5.94
NNF_1	17.60+10.84	28.56+13.36	23.03+15.10	29.91+12.19	31.69+15.40	26.47+5.63	30.43+9.98	-
NNF_2	14.62+8.41	10.51+7.80	18.12+8.89	8.63+5.66	7.53+10.16	7.40+3.40	6.90+2.83	4.71
$TNFr_1$	6.52+4.54	9.21+7.38	3.73+6.09	12.25+8.09	5.94+6.29	10.13+4.53	11.27+4.01	-
$TNFr_2$	21.15+10.56	35.41+13.74	14.71+17.89	51.49+16.77	17.02+10.79	46.40+11.77	51.77+14.58	12.41
$NCFr_1$	0.04+0.21	0.26+0.60	0.00+0.00	0.07+0.45	0.28+0.58	0.00+0.00	0.07+0.36	-
$NCFr_2$	0.58+1.26	1.27+1.70	0.05+0.22	0.13+0.61	1.62+2.26	0.17+0.53	0.33+1.06	0.68
$NPFr_1$	0.00+0.00	0.12+0.77	0.00+0.00	0.00+0.00	0.35+1.15	0.00+0.00	0.00+0.00	-
$NPFr_2$	0.18+0.68	1.29+3.62	0.00+0.00	0.00+0.00	3.11+5.73	0.00+0.00	0.00+0.00	2.59
$NComFr_1$	7.06+4.24	9.11+7.29	6.47+6.87	12.73+7.74	6.30+6.20	10.13+4.53	11.20+3.96	-
$NComFr_2$	20.39+10.58	32.85+14.90	15.10+18.03	51.36+16.70	12.79+10.44	46.23+11.76	51.43+14.57	9.61
MFrW	0.67+0.21	0.58+0.16	1.02+0.34	0.41+0.12	1.05+0.39	0.24+0.04	0.48+0.11	0.07
MFrL	153.25+18.82	137.11+12.25	209.05+28.12	127.72+9.28	167.82+27.74	115.16+5.68	131.42+9.80	9.07
MFrD	95.72+12.14	93.33+11.30	103.63+19.62	84.34+12.12	114.10+15.37	71.92+3.78	88.11+7.79	4.15
Yld/Plt	16.23+8.62	20.67+9.88	31.40+19.58	23.92+8.76	19.00+12.13	13.29+3.81	26.96+9.63	7.29
EFrF	114.23+16.11	119.50+17.09	94.07+4.25	105.41+15.38	131.48+18.88	105.48+16.26	104.80+12.19	13.87
IFrF	96.62+12.38	93.22+11.95	66.67+19.24	89.82+9.82	103.79+16.15	81.71+7.16	84.92+6.99	13.08
°Brix	11.62+1.38	11.50+0.94	12.27+1.21	11.86+1.39	11.33+1.35	11.23+0.69	10.24+0.56	-

PH_1 = plant height in cm 140 DAT; PH_2 = plant height in cm 260 DAT; SD_1 = stem diameter in cm 140 DAT; SD_2 = stem diameter in cm 260 DAT; IHFF = insertion height of the first fruit in cm 140 DAT; NTF_1 = number of total flowers 140 DAT; NTF_2 = number of total flowers 260 DAT; NDF_1 = number of deformed flowers 140 DAT; NDF_2 = number of deformed flowers 260 DAT; NSF_1 = number of sterile flowers 140 DAT; NSF_2 = number of sterile flowers 260 DAT; NNF_1 = number of normal flowers 140 DAT; NNF_2 = number of normal flowers 260 DAT; $TNFr_1$ = number total of fruits 140 DAT; $TNFr_2$ = number total of fruits 240 DAT; $NCFr_1$ = number of carpelloid fruits 140 DAT; $NCFr_2$ = number of carpelloid fruits 240 DAT; $NPFr_1$ = number of pentandric fruits 140 DAT; $NPFr_2$ = number of pentandric fruits 240 DAT; $NComFr_1$ = number of commercial fruits 140 DAT; $NComFr_2$ = number of commercial fruits 240 DAT; MFrW = mean fruit weight in kg; MFrL = mean fruit length in mm; MFrD = mean fruit diameter in mm; Yld Plt^{-1} = plant yield in kg; EFrF = external fruit firmness in N; IFrF = internal fruit firmness in N; °Brix = content of soluble solids of the fruit pulp; - = refers to the traits without significant difference by the F test

superiority of treatment BC_2 over the others and that treatment $115BC_1S_1$ was significantly or moderately inferior. Nevertheless, with exception of the treatments $115BC_1S_1$ and SS 72/12 x $4BC_1$, all segregating treatments were significantly or moderately superior to the cultivars Golden and SS 783, indicating the possibility of selection of superior plants for these traits. These are directly related with fruit resistance to transport and must therefore be taken into consideration in papaya improvement programs.

For the soluble solids content (°Brix), determined in maturation stage 1, though there was no significant difference among the treatments, the segregating genotypes were moderately superior to the cultivars Golden and SS 783. With exception of SS 783, the other treatments presented mean °Brix values close to those found by Jacomino et al. (2002) in fruits of the cultivar Sunrise Solo 72/12, where the °Brix values varied from 11.15 to 12.01.

The estimates of some genetic parameters, important for the procedures of genetic improvement of the evaluated traits, are presented in Table 3. According to Cruz and Carneiro (2003), the use of genetic parameters in plant improvement allows an identification of the genetic variability of the population and an evaluation of the efficiency of different improvement strategies to achieve genetic gains and maintain an adequate genetic basis.

Comparing the evaluations realized 140 DAT and 240 and 260 DAT, it is observed by means of the coefficient of genotypic determination (H^2) and the variation index (I_v) that, with exception of plant height (PH), these latter were more effective to reveal the availability of genetic variability in the treatments evaluated here. Plant yield (Yld Plt^{-1}) was therefore estimated based on the number of commercial fruits of the second evaluation ($NComFr_2$). H^2 is not the coefficient of heritability (h^2), nevertheless, its high values (of over 80 %) reflect the expectative of high genetic gains in the selection procedure. I_v represents the ratio between thecoefficient of genetic variation (CV_g) and the coefficient of experimental variation (CV_e) and therefore, a value superior to the unit also indicates wide variability of the population for a particular trait.

An analysis of the traits measured 240 DAT and 260 DAT, the insertion height of the first fruit (IHFF) 140 DAT, besides the mean fruit weight (MFrW), mean fruit length (MFrL), mean fruit diameter (MFrD), Yld Plt^{-1}, EFrF and IFrF shows that, with exception of PH2, the H^2 values were higher than 80% and the I_v values were quite high, indicating wide genetic variability of the segregating plant material, evaluated for these traits.

H^2 for plant height was high in the first evaluation and close to 80 % in the second evaluation, while I_v was superior to the unit in both evaluations, demonstrating high genetic variability of this trait in the segregating treatments. In this case, plants of shorter plant architecture should be preferred since according to Nakasone and Lamoureux (1982), very tall plants are undesirable in view of the generally longer internodes, fruits spaced farther apart and a shorter production cycle. The H^2 of the content of soluble solids (°Brix), determined in maturation stage 1, was less than 80 %, whereas I_v superior to the unit indicated genetic variability available in the segregating plant material.

In view of the reduced number of segregating treatments (five), no selection was performed among them. However, based on these results, the advancing of generations with 30 plants was recommended, selected from a total of 345 plants, taking all segregating treatments into consideration. In this way, selection among and within treatments will be possible in the following segregating generations.

According to the mean values and respective standard deviations, and to the estimate of genetic parameters of morpho-agronomic and fruit quality traits, we inferred that selection in segregating generations has great chances of success, since these presented high genotypic variability, with H^2 values of over 80 % for most phenotypic attributes studied.

Considering the importance of the attributes of flowering and fruiting, the high H^2 found indicates that improvement programs can achieve considerable increments in papaya yield.

ACKNOWLEDGEMENTS

We thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for granting a graduate scholarship to one of the authors and the Financiadora de Estudos e Projetos (FINEP) and the company Caliman Agrícola S/A (CALIMAN) for support with funds and data processing.

Table 3. Estimate of the phenotypic ($\hat{\sigma}^2_P$) and experimental variances ($\hat{\sigma}^2_E$), of the genotypic variability ($\hat{\phi}_G$), of the coefficient of genotypic determination (H^2) and of the variation index (I_v) of morpho-agronomic and fruit quality traits in papaya segregating generations and cultivars

Trait	$\hat{\sigma}^2_P$	$\hat{\sigma}^2_E$	$\hat{\phi}_G$	H^2	I_v
PH_1	215.59	58.77	186.20	86.37	1.79
PH_2	549.34	228.60	435.04	79.19	1.38
SD_1	0.29	0.10	0.24	82.27	1.55
SD_2	0.41	0.12	0.35	85.36	1.71
IHFF	63.00	13.96	56.03	88.92	2.00
NTF_1	133.38	43.17	111.99	84.00	1.61
NTF_2	55.43	4.02	53.42	97.00	3.65
NDF_1	1.81	0.09	1.76	97.45	4.42
NDF_2	7.07	0.19	6.97	98.65	6.05
NSF_1	175.30	31.67	159.47	91.00	2.24
NSF_2	20.27	2.94	18.80	92.75	2.53
NNF_1	34.64	27.22	21.03	60.70	0.88
NNF_2	12.80	1.84	11.88	92.79	2.54
$TNFr_1$	7.68	3.79	5.79	75.30	1.24
$TNFr_2$	236.99	12.82	230.58	97.00	4.24
$NCFr_1$	0.02	0.01	0.01	70.00	1.00
$NCFr_2$	0.46	0.04	0.44	95.81	3.32
$NPFr_1$	0.03	0.03	0.02	53.00	0.82
$NPFr_2$	2.26	0.56	1.97	87.78	1.87
$NComFr_1$	6.36	4.73	3.99	62.84	0.92
$NComFr_2$	278.59	7.69	274.74	98.62	5.97
MFrW	0.08	0.0004	0.08	99.75	14.53
MFrL	447.35	6.85	443.92	99.23	9.07
MFrD	176.55	1.43	175.83	99.59	11.08
Yld Plt^{-1}	21.95	4.43	19.73	89.89	2.11
EFrF	110.36	16.03	102.33	92.72	2.53
IFrF	61.54	14.26	54.40	88.41	1.95
°Brix	0.26	0.14	0.19	73.68	1.16

PH_1 = plant height in cm 140 DAT; PH_2 = plant height in cm 260 DAT; SD_1 = stem diameter in cm 140 DAT; SD_2 = stem diameter in cm 260 DAT; IHFF = insertion height of the first fruit in cm 140 DAT; NTF_1 = number of total flowers 140 DAT; NTF_2 = number of total flowers 260 DAT; NDF_1 = number of deformed flowers 140 DAT; NDF_2 = number of deformed flowers 260 DAT; NSF_1 = number of sterile flowers 140 DAT; NSF_2 = number of sterile flowers 260 DAT; NNF_1 = number of normal flowers 140 DAT; NNF_2 = number of normal flowers 260 DAT; $TNFr_1$ = number total of fruits 140 DAT; $TNFr_2$ = number total of fruits 240 DAT; $NCFr_1$ = number of carpelloid fruits 140 DAT; $NCFr_2$ = number of carpelloid fruits 240 DAT; $NPFr_1$ = number of pentandric fruits 140 DAT; $NPFr_2$ = number of pentandric fruits 240 DAT; $NComFr_1$ = number of commercial fruits 140 DAT; $NComFr_2$ = number of commercial fruits 240 DAT; MFrW = mean fruit weight in kg; MFrL = mean fruit length in mm; MFrD = mean fruit diameter in mm; Yld Plt^{-1} = plant yield in kg; EFrF = external fruit firmness in N; IFrF = internal fruit firmness in N; °Brix = content of soluble solids of fruit pulp

Estimação de parâmetros genéticos relacionados a variáveis morfoagronômicas e de qualidade de frutos em mamoeiro

RESUMO *- A estimação de parâmetros genéticos possibilita identificar a variabilidade genética de uma população e estabelecer a base para a escolha dos métodos de melhoramento mais apropriados. Este trabalho objetivou estimar os parâmetros genéticos relacionados a variáveis morfoagronômicas e de qualidade de frutos nos seguintes materiais genéticos de mamoeiro: 16RC_1S_1, 52RC_1S_1, 115RC_1S_1, SS 72/12 x 4RC_1, RC_2, 'SS 783' e Golden. De acordo com os valores das médias*

e respectivos desvios-padrão, e das estimativas de parâmetros genéticos das variáveis avaliadas, conclui-se que, a seleção nas gerações segregantes apresenta grandes possibilidades de sucesso, uma vez que essas apresentaram ampla variabilidade genotípica entre, com valores de H^2 (coeficiente de determinação genotípico) superior a 80 % para a maioria dos atributos fenotípicos avaliados. Considerando a importância dos atributos de floração e de frutificação, o elevado H^2 encontrado indica que os programas de melhoramento podem conseguir grandes progressos de incremento de produtividade do mamoeiro.

Palavras-chave: *Carica papaya*, produção de frutos, carpeloidia, pentandria, estrilidade feminina.

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