

HETEROSIS IN PAPAYA: INTER AND INTRAGROUP ANALYSIS¹

DEISY LÚCIA CARDOSO², LUCAS NUNES DA LUZ³, CELIA MARIA PEIXOTO DE MACÊDO⁴,
LEANDRO GONÇALVES SIMÕES AZEREDO⁵, MESSIAS GONZAGA PEREIRA⁶

ABSTRACT- Papaya (*Carica papaya* L.) is a typical crop of tropical areas, and Brazil is one of the leading world producers. In recent decades, papaya culture has expanded to different regions of the country, but the number of cultivars available is still limited. In the present study, a complete diallel cross was carried out using eight accessions of papaya from the UENF/Caliman germplasm bank. Four genotypes belong to the Formosa heterotic group and four, to the Solo group. This study aimed to evaluate the occurrence and viability of exploring heterosis in heterotic intragroup hybrids. Fifty-six hybrid progenies were generated and evaluated. Among the Formosa intragroup hybrids, two hybrid combinations (MR x J4 and MR x SK) showed heterosis for all traits, as well as good average total fruit production. Among the Solo intragroup hybrids, three hybrid combinations (WM x GG, WM x SS and WM x SM) stand out for fruit production and high content of soluble solids. In Formosa x Solo hybrids, all hybrid combinations with the parent JS (JS x WM, JS x GG, JS x SS and JS x SM) showed high fruit quality and good average for fruit production. The heterotic profile of the hybrids tested allowed the identification of promising hybrids within Formosa and Solo heterotic groups. The analysis of the canonical variables also allowed the visualization of distinct groups of hybrids, depending on the provenance of the parents.

Index terms - *Carica Papaya* L., diallel cross, fruit crops.

HETEROSE NO MAMÃO: ANÁLISE INTER E INTRA-GRUPO

RESUMO - O mamão (*Carica papaya* L.) é uma cultura típica de áreas tropicais e o Brasil é um dos principais produtores mundiais. Nas últimas décadas, a cultura de mamão se expandiu para diferentes regiões do país, mas o número de cultivares disponíveis ainda é limitado. No presente trabalho, um cruzamento dialélico completo foi realizado com oito acessos de mamão do banco de germoplasma da UENF/Caliman. Quatro genótipos pertencem ao grupo heterótico Formosa e quatro, ao grupo Solo. Este trabalho teve como objetivo avaliar a ocorrência e viabilidade de explorar a heterose em híbridos heteróticos intra-grupo. Cinquenta e seis progênies híbridas foram geradas e avaliadas. Entre os híbridos intra-grupo Formosa, duas combinações híbridas (MR x J4 e MR x SK) apresentaram heterose para todas as características, bem como uma boa produção média total de frutos. Entre os híbridos intra-grupo Solo, três combinações híbridas (WM x GG, WM x SS e WM x SM) destacam-se pela produção de frutas e alto teor de sólidos solúveis. Em Formosa x híbridos de solo, todas as combinações híbridas com o progenitor JS (JS x WM, JS x GG, JS x SS e JS x SM) apresentaram frutos de alta qualidade e boa média para produção de frutos. O perfil de heterose dos híbridos testados permitiu a identificação de híbridos promissores dentro dos grupos heteróticos Formosa e Solo. A análise das variáveis canônicas também possibilitou a visualização de grupos distintos de híbridos, de acordo com a proveniência dos progenitores.

Termos para indexação: *Carica Papaya* L., cruzamento dialélico, culturas de frutas.

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²Dra. em Genética e Melhoramento de Plantas. Universidade Anhanguera Uniderp. Campo Grande - MS. E-mail: deisycardoso@hotmail.com

³Dr em Genética e Melhoramento de Plantas. Universidade Estadual do Norte Fluminense Darcy Ribeiro – UENF. Campos dos Goytacazes - RJ. E-mail: lucasluzbreder@gmail.com

⁴Dra em Produção Vegetal. Universidade Estadual do Norte Fluminense Darcy Ribeiro – UENF. Campos dos Goytacazes - RJ. E-mail: celiampm@yahoo.com.br

⁵Dr Genética e Melhoramento de Plantas. Universidade Estadual de Londrina – UEL. Londrina – PR. E-mail: leandrosag@uel.br

⁶PhD em Plant Breeding. Universidade Estadual do Norte Fluminense Darcy Ribeiro – UENF. Campos dos Goytacazes - RJ. E-mail: messiasgpereira@gmail.com

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INTRODUCTION

Papaya (*Carica papaya* L.) is one of the main fruit crops in tropical and subtropical regions in the world. Brazil is one of the world leading producers and exporters, with a production of 1.9 million tons in 2011, which accounts for 17% of total world production (AGRIANUAL, 2011). One of the key barriers to continued expansion of the culture is the small number of cultivars and hybrids available for the producers in the market, besides viral and fungal diseases.

Despite the higher profitability of hybrids, nearly 80% of the Brazilian crops use inbred varieties, followed from afar by hybrids, estimated at 20%, mainly the hybrid from Taiwan, 'Tainung 01' and, more recently, the UENF/Caliman hybrid Calimosa.

Hybrid cultivars in papaya are commercially exploited through heterosis capitalized in F_1 hybrids (MARIN et al., 2006a; MARTINS et al., 2009). Papaya breeding is usually based on hybrids obtained between different heterotic groups (MARIN et al., 2006b). Two heterotic groups are reported in papaya, i.e., "Solo" and "Formosa", but the definition of the groups is based almost exclusively on the trait fruit weight, which is around 500 g per fruit for genotypes from the Solo group, and above 800 g per fruit for genotypes from the Formosa group.

Some recent researches have discussed the formation of groups based on a wide spectrum of morphoagronomic descriptors associated with molecular information (BARBOSA et al., 2011; QUINTAL et al., 2012). However, the limits of a heterotic group are not totally clear (REIF et al., 2005). Information about F_1 hybrids between, and within groups and about heterosis capitalized in them, could contribute to a better understanding of the scope of the heterotic group in papaya. Otherwise, the variability commonly observed within the heterotic groups Solo and Formosa may contribute to the development of hybrids aimed to meet specific market demands, as example, papaya hybrids with small fruits.

Heterosis expression results from the genetic divergence between parents and dominance deviations (FALCONER and MACKAY, 1996). Thus, in a heterotic group generally composed of germplasms with common ancestors (HALLAUER et al., 2010; JARADAT et al., 2010), the heterosis capitalized among hybrids from different groups is expected to be high, compared to hybrids obtained from a same group. Therefore, this study to evaluate the viability of the exploitation of the Solo and

Formosa intragroup hybrid in papaya, in comparison to the Formosa x Solo traditional hybrids.

MATERIAL AND METHODS

Obtainment of F_1 hybrids and data collection

Fifty-six hybrid progenies (F_1 and reciprocal) were obtained from crosses among four lines of the Formosa heterotic group (1-Maradol, 2-JS 12, 3-JS 12/4 and 4-Sekati) and four of the Solo group (5-Waimanalo, 6-Golden, 7-SS 72/12 and 8-São Mateus), described in Table 1. The crosses were carried out in 2008, between and within the groups of parents, on the farm Fazenda Caliman Agrícola S.A. (Linhares-ES).

The experiment was conducted in 2009/2010 and consisted of 64 treatments, 56 hybrids and eight parents, arranged in a randomized block design with four replications and ten plants per plot. Eight traits were assessed: external firmness of the fruit (EFF) and internal firmness of the pulp (IFP), expressed in Newton; content of total soluble solids (CSS) expressed in °Brix; total number of marketable fruits (NMF); average fruit weight (AFW), in grams; and productivity (PROD), expressed in $t\ ha^{-1}$.

Data analysis

The data were subjected to the analysis of variance and the averages of the treatments in hybrids and reciprocals were compared by Tukey test at 5%. Then, a multivariate analysis was performed by canonical variables. To evaluate the performance of hybrids and reciprocals, the scores obtained from the analysis were observed by projection onto a plane. The statistical analysis were made in Genes software system, version 2009.7.0, and the graphics were generated by the Sigma Plot 10 software system. Since no effects of reciprocal crosses were found in the traits evaluated, the average between hybrids and reciprocals were used for heterosis (%) estimations. The performance of the hybrids was determined according to the expression proposed by Fehr (1987):

$$\text{Heterosis (\%)} = \frac{F_1 - \mu P}{\mu P} \cdot 100$$

Where, heterosis (%) - percentage of heterosis for the average of the parents; F_1 - hybrid performance; and μP - average of the parents.

RESULTS AND DISCUSSION

The mean squares for the evaluated traits are described in Table 2, as well as the averages of the parents for the mentioned traits. Significant differences were observed among the groups of parents, for the six traits evaluated, which demonstrates that, for both individual parents “*per se*” and the average of the groups, there is variability that can be exploited for the traits, which is corroborated by the significance of the treatments (Table 2).

Table 3 shows the mean values for traits related to fruit quality, external firmness of the fruit (EFF), internal firmness of the pulp (IFP) and total soluble solids (CSS), and the heterosis for each trait assessed. The highest values of heterosis percentage for EFF were 13.5% (MR x J4) in Formosa hybrids, and 7.2% (MR x SS) in Formosa x Solo hybrids. However, despite heterosis, there was no statistical difference in the average EFF for the combinations (MR x J4) and (MR x SS). Among the Solo hybrids, all heterosis values were negative, which demonstrates that the trait obtained no heterotic gains. The highest average values for EFF were found in hybrid combinations that use the parent (JS), which also presented the highest average for EFF among the parents.

The highest heterosis for IFP was 8.6% in the Formosa intragroup hybrid MR x SK (Table 3) and 14.1% in the Formosa x Solo hybrid MR x SM. Regarding the average trait, no difference was observed in the two hybrid combinations (MR x SK) and (MR x SM). Similarly to EFF, no positive heterosis was found for IFP among the Solo intragroup hybrid combinations. The parents involved in this cross did not present the best performance for IFP. The parent JS, which presented the highest average for the trait, did not participate in the composition of this hybrid.

Heterosis estimates for content total soluble solids (CSS) ranged from -3.1% (SS x GG) to 16.4% (JS x GG) (Table 3). Among the Solo hybrids, only two hybrids did not show positive heterosis for CSS. The other hybrids showed positive heterosis, which indicates that this trait may increase by exploring hybrid vigor. Solo intragroup combinations presented high averages for CSS, in contrast to Formosa intragroup hybrids. The Formosa x Solo intergroup hybrids (JS x GG, JS x SM and J4 x WM) presented the highest heterosis estimates; in this case, heterobeltiosis, thus exceeding the average of the best parent for CSS. A small increase in heterosis was observed in Formosa hybrids, excepting for (JS

x J4), -3.8%.

The content of soluble solids is one of the most important trait in papaya breeding because it directly affects fruit flavor. It is noteworthy that there was an increase of 2.15 °Brix on average, in hybrid combinations with the parent Maradol. The absolute value of CSS for hybrid (MR x JS), which presented the best performance, was 10.9 °Brix. This is considerable higher than the content found in the parent Maradol (7.9 ° brix). This increased CSS value allows expanding exports to North American countries, mainly the United States, since people in these countries prefer consuming the genotype Maradol. Here, the hybrid combinations involving the parent Maradol are feasible both in combinations with Solo parents (MR x GG, MR x SS and MR x SM) and intragroup combinations (MR x JS, MR x J4 and MR x SK).

The heterotic profile of the hybrids evaluated here for EFF, IFP and CSS can be better seen in a projection onto a plane (Figure 1A, 1B and 1C), respectively. Additionally, an overview of the hybrids is available in Figure 2, from the canonical variables associated with the traits. The first two canonical variables accounted for 86.06% of the existing variation, which is a good indicator of the accuracy of the data.

Few studies about papaya breeding described the heterotic behavior in hybrids. This highlights the importance of the present investigation. However, Marin et al. (2006a) evaluated different traits of papaya and reported low heterosis (2.79%) for traits such as CSS, as well as heterobeltiosis in some traits, in Formosa x Solo hybrids, though. Otherwise, Marin et al. (2006b) corroborated the possible exploitation of Formosa intragroup heterosis, and indicated the parent Maradol as a candidate. They also reported that good intragroup hybrid combinations can be achieved for Solo parents, but the genotypes used by the authors are not included in this analysis.

Besides the aspects related to fruit quality, the traits related to production are crucial to estimate the commercial viability of a hybrid. In this aspect, traits such as total number of commercial fruits (NMF), average fruit weight (AFW) and total production (PROD) are good indicators of the productive profile of a genotype.

In general, estimates of heterosis for NMF ranged from (-33.0%) MR x SS to (59.7%) SK x WM (Table 4) in hybrid combinations as a whole. Particularly for SK x WM, 59.75% of heterosis, this value is due to genetic complementation between the parents, once the parents Sekati and Waimanalo “*per se*” present low fruit production (Table 2). For

the combination MR x SS, -33.0% of heterosis, it can be partly explained by the “*per se*” behavior of the parent SS, whose average for the trait is high (Table 2).

The highest heterosis estimates are found in Formosa intragroup combinations JS x SK and J4 x SK, 37.8% and 20.7%, respectively, with good increase in the average trait. Among Solo hybrids, two hybrid combinations involving the parent Waimanalo (WM x GG and WM x SM) showed high heterosis, 23.6% and 48%, respectively. However, the combination WM x SS showed low heterosis, 4.1%, and average NMF (61.9b), which is higher than the hybrids WM x GG (48.8c) and WM x SM (39.1d).

Projection onto a plane (Figure 1E) shows gains for all groups of hybrids (FxF, SxS and FxS). However, it must be pointed out that hybrids with the highest absolute values for NMF showed negative heterosis. Among these, hybrids (GG x SS and SS x SM), from Solo intragroup combinations, and the parent SS 72/12, present in both, provided the best averages for NMF (93.45a).

In general, heterosis values for average fruit weight (AFW) ranged from -24.7% (J4 x SS) to 133.1% (WM x GG) (Table 4). High heterosis values were observed among Solo intragroup combinations (133.1%, 62.6% and 62.3%) for some hybrid combinations (WM x GG, WM x SS and WM x SM), respectively. The highest average for AFW within the Solo group was observed exactly in the combination with the highest heterosis (WM x GG). For the Formosa intragroup combinations, heterosis ranged from 7.5% (MR x JS) to 30.2% (JS x SK), but the highest absolute value for AFW was 1.82a (MR x J4), with heterosis of 5.8%. In general, the highest heterosis occurred in the presence of the parent Waimanalo. The hybrids of this parent showed an increase of 300 g (intragroup). An increase of 400 g observed in the intergroup combination (WM x SK). Figure 1D presents an overview of AFW.

Increasing the values of traits related to income is a major concern of breeders in the exploitation of the beneficial effects of heterosis. Thus, productivity is one of the traits to which the highest gains are expected in breeding. Heterosis estimates for productivity ranged from -6.0% (J4 x SS) to 256.1% (WM x GG). Hybrids WM x GG, SK x WM and WM x SM stood out for their higher heterosis estimates (Table 4).

In Solo intragroup combinations, the highest heterosis estimate found, 256.1% (WM x GG), coincided with one of the highest values for average production for the group (86.4 t ha⁻¹), which is below the production in Formosa group and Formosa x Solo

intergroup. However, it is relevant, mainly when compared to the production of parent Waimanalo (Table 2). This hybrid also stands out for the trait average fruit weight.

The combinations with the highest production values are found in Formosa intragroup and Formosa x Solo intergroup. The most productive hybrid (MR x GG), with 121.2 t ha⁻¹, was not the one presenting the highest heterosis estimate. High heterosis values alone do not mean high production, since heterosis shows superiority (or not) for the average parent. Only two hybrids were below the cutting line, namely, showed negative heterosis, for the trait productivity (Figure 1F).

The canonical variables (Figure 2) reveal a tendency for genotype distribution, with the formation of three groups of hybrids: Solo, Formosa and Formosa x Solo. The Solo hybrids were plotted close to the axis x, y, while Formosa x Solo hybrids were in an intermediate position, and Formosa hybrids were farther from the axis x, y. This configuration shows that hybrids that are similar as for the trait fruit weight tend to cluster.

The joint analysis of hybrid combinations, considering the quality and production traits of fruits, allows predicting that certain hybrid combinations stand out within each group. Among the Formosa intragroup hybrids, the combinations MR x J4 and MR x SK showed positive heterosis for all traits assessed, as well as good average total fruit production. Among the Solo intragroup hybrids, the combinations WM x GG, WM x SS and WM x SM stand out for fruit production and high CSS. In Formosa x Solo hybrids, all combinations with the parent JS (JS x WM, JS x GG, JS x SS and JS x SM) showed high fruit quality and good production.

Somehow, the findings of this study do not agree with Hamilton (1954), who reports that it is not viable to exploit heterosis among papaya genotypes with a very close genetic relationship. It must be highlighted that it can be exploited, but under a less comprehensive perspective, compared to the Formosa x Solo hybrids, which is the case of Formosa intragroup hybrids involving the parent Maradol and the Solo intragroup hybrids involving the parent Waimanalo.

Considering heterosis as the product of genetic divergence and effects of dominance of traits, it is important to know how much the genotypes are in fact divergent to better assess their heterotic behavior. Their distribution in the heterotic groups already known (Solo and Formosa), based only on the descriptor fruit weight, may not be sufficient to accurately discriminate them. Barbosa et al. (2011)

analyzed 37 accessions of papaya from the UENF/Caliman germplasm bank via neural networks, so that four groups were formed. Genotypes said to be Formosa and Solo grouped in an unusual way, formed mixed groups of Formosa and Solo, and originated new groups.

Besides, Quintal et al. (2012) analyzed 46 accessions from the UENF/Caliman germplasm bank through qualitative and quantitative descriptors, and performed the groupings based on descriptors, first individually and then together. When the groups took into account only the qualitative variables, the genotype said to belong to the Solo group clustered cohesively. Moreover, with quantitative data alone, there were unusual groupings, and Formosa genotypes were distributed in several groups. The authors suggest that there is more variation within the Formosa group, compared to the Solo group. This perhaps helps to understand the relative success of

Formosa intragroup hybrids, compared to the Solo intragroup hybrids described in this study.

In papaya, which is a culture of low variability (OLIVEIRA et al., 2010; RAMOS et al., 2012), knowledge of the degree of relatedness between genotypes is essential to define the crosses and achievement of hybrids, since the small number of cultivars available in the market is a limiting factor for the advance of the culture, which has increased in non-traditional regions in recent years, including the states of Rio Grande do Norte and Ceará.

In general, we observe that the achievement of Formosa intragroup hybrids was able to increase fruit quality and production, compared to the average parents and intergroup hybrids. Productivity above the average for the group of parents and very close to that the intergroup hybrids were observed in Solo intragroup hybrids. Besides, a soluble solid for the Solo hybrids was higher than the average for the group of parents and intergroup hybrids.

TABLE 1 - Description of papaya parents used in crosses from the UENF/Caliman germplasm bank.

Identification	Heterotic group	Weight (Kg)	Provenance
1. Maradol (MR)	Formosa	2000	Mexico
2. JS 12 (JS)	Formosa	900	CNPMFT
3. JS12/4 (J4)	Formosa	900	UENF/CALIMAN
4. Sekati (SK)	Formosa	900	Malaysia
5. Waimanalo (WM)	Solo	550	CNPMFT
6. Golden (GG)	Solo	350	CALIMAN
7. SS 72/12 (SS)	Solo	400	Hawaii
8. São Mateus (SM)	Solo	550	INCAPER

TABLE 2 - Analysis of variance for six agronomic traits in papaya hybrids and parents.

Mean Square							
SV	DF	EFF	IFP	CSS °Brix	NMF (1+2+3)	AFW	PROD
Blocks	3	247.25	78.61	0.64	139.16	26020.24	2068.09
Genotypes	63	342.25**	221.67**	3.78**	823.29**	695226.65**	2095.65**
Error	189	77.93	26.60	0.45	49.03	12500.38	383.52
Average		94.86	69.12	10.86	40.72	908.74	83.45
CV(%)		9.30	7.46	6.23	17.19	12.30	23.46
Average of genitors							
1. MR		87.6 c	58.8 e	7.9 d	21.5 e	1990 a	110 a
2. JS		119.8 a	94.7 a	10.6 c	37.8 d	820 f	77.9 c
3. J4		97.1 b	76.7 c	10.2 c	28.4 e	1000 e	72.6 c
4. SK		95.5 c	70.4 d	8.8 d	25.6 e	890 e	58.9 c
Average		100	75.1	9.3	28.3	1180	79.8
5. WM		91.6 c	67.8 d	10.7 b	13.35 f	400 h	13.5 d
6. GG		87.3 c	71.9 c	10.8 b	62.2 b	201 h	32.8 d
7. SS		98.0 b	69.2 d	12.3 a	93.4 a	275 h	65.9 c
8. SM		90.4 c	61.4 e	10.1 c	40.27 d	610 g	63.1 c
Average		91.8	67.5	10.9	52.3	370	43.8

TABLE 3 - Average values and heterosis for traits associated with fruit quality in papaya hybrids.

Genotypes/ Hybrids	EFF	H%	IFP	H%	CSS	H%
Formosa x Formosa Hybrids						
MR x JS	99.6 b	-4.1	77.8 c	-0.1	10.9 b	13.8
MR x J4	96.9 b	13.5	66.9 d	4.7	10.0 c	11.5
MR x SK	91.8 c	1.3	69.5 d	8.6	9.2 d	9.2
JS x J4	116.8 a	6.6	85.7 b	-4.8	10.0 c	-3.8
JS x SK	113.5 a	1.1	82.3 b	0.1	10.6 c	8.3
J4 x SK	105.3 b	7.2	82.6 b	7.6	9.6 c	4.6
Average	103.9		77.4		10	
Solo x Solo Hybrids						
WM x GG	86.2 c	-3.7	60.8 e	-13.5	12.0 a	8.5
WM x SS	79.2 c	-11.6	60.5 e	-9.2	11.9 a	4.5
WM x SM	92.1 c	-1.7	62.7 e	-4.0	11.6 b	10.0
GG x SS	83.7 c	-10.0	61.3 e	-12.6	11.3 b	-3.1
GG x SM	84.7 c	-3.2	60.1 e	-8.7	10.9 b	6.3
SS x SM	83.5 c	-14.5	61.1 e	-5.2	10.9 b	-1.0
Average	84.9		61.0		11.43	
Formosa x Solo Hybrids						
MR x WM	88.4 c	-1.2	57.5 e	-6.3	10.6 c	11.2
MR x GG	89.4 c	2.8	65.8 d	1.1	9.9 c	8.0
MR x SS	97.8 b	7.2	70.2 d	5.8	10.2 c	4.8
MR x SM	92.4 c	3.2	69.6 d	14.1	9.7 c	7.3
JS x WM	97.1 b	-5.6	77.3 c	-7.7	11.2 b	3.3
JS x GG	106.8 b	0.1	76.1 c	-10.5	12.4 a	16.4
JS x SS	106.7 b	-4.6	76.5 c	-7.9	13.0 a	14.6
JS x SM	99.5 b	0.9	74.3 c	-8.5	12.0 a	13.1
J4 x WM	100.4 b	1.7	69.5 d	-7.8	12.1 a	12.9
J4 x GG	88.3 c	-0.3	68.5 d	-3.9	11.0 b	7.2
J4 x SS	86.7 c	-9.4	72.2 c	-3.7	11.9 a	4.4
J4 x SM	93.1 c	-3.7	70.0 d	-1.1	10.7 b	6.8
SK x WM	88.1 c	-6.3	63.6 e	-12.6	9.8 c	1.1
SK x GG	101.4 b	6.0	69.9 d	-6.3	11.5 b	15.7
SK x SS	90.9 c	-6.5	68.9 d	-1.9	11.5 b	7.2
SK x SM	91.9 c	-1.8	64.6 e	-0.7	10.3 c	10.2
Average	94.9		69.65		11.1	

TABLE 4 - Average values and heterosis for the traits associated with fruit production in papaya hybrids.

Genotypes/ Hybrids	NMF (1+2+3)	H%	AFW	H%	PROD	H%
Formosa x Formosa Hybrids						
MR x JS	30.4 e	-7.7	1420 c	7.5	110.6 a	11.8
MR x J4	21.4 e	10.2	1820 a	5.8	99.1 b	18.5
MR x SK	25.9 e	12.5	1640 b	10.5	109.4 a	29.1
JS X J4	27.0 e	-9.2	1260 d	20.0	87.1 b	10.0
JS X SK	34.5 d	20.7	1250 d	30.2	111.1a	58.6
J4 X SK	35.4 d	37.8	1140 d	9.9	102.1 a	51.1
Average	29.1		1420		103.2	
Solo x Solo Hybrids						
WM x GG	48.8 c	23.6	700 f	133.1	86.4 b	256.1
WM x SS	61.9 b	4.1	550 g	62.6	89.2 b	95.8
WM x SM	39.1 d	48.0	730 f	62.3	73.9 c	117.9
GG x SS	68.2 b	-16.2	270 h	26.4	48.6d	-4.2
GG x SM	51.4 c	-0.4	470 g	9.7	61.3c	21.3
SS x SM	59.6 b	-3.6	440 h	-6.7	67.6 c	4.9
Average	54.83		520		71.16	
Formosa x Solo Hybrids						
MR x WM	22.6 e	21.9	1530 b	33.8	88.6 b	39.4
MR x GG	38.7 d	-5.3	1220 d	9.3	121.2 a	69.3
MR x SS	40.0 d	-33.0	1010 e	-5.5	104.2 a	19.6
MR x SM	28.5 e	-14.6	1660 b	16.0	121.1 a	19.5
JS x WM	29.7 e	25.8	970 e	65.7	73.8 c	80.4
JS x GG	45.2 d	-13.3	700 f	29.7	82.4 b	33.7
JS x SS	47.1 c	-23.0	620 g	22.2	74.9 c	20.7
JS x SM	39.6 d	4.1	860 e	16.4	87.8 b	23.0
J4 x WM	24.4 e	5.8	780 f	17.9	49.8 d	8.8
J4 x GG	45.8 c	-3.6	580 g	8.4	68.4 c	37.7
J4 x SS	53.5 c	-13.8	360 h	-24.7	50.0 d	-6.0
J4 x SM	41.0 d	23.4	850 e	0.9	90.2 b	31.0
SK x WM	27.7 e	59.7	1270 d	102.1	90.3 b	188.5
SK x GG	43.9 d	0.8	620 g	27.0	70.0 c	73.3
SK x SS	52.6 c	-5.8	610 g	12.2	82.0 b	50.0
SK x SM	40.6 d	42.5	790 f	6.3	81.4 b	57.7
Average	38.8		900		83.5	

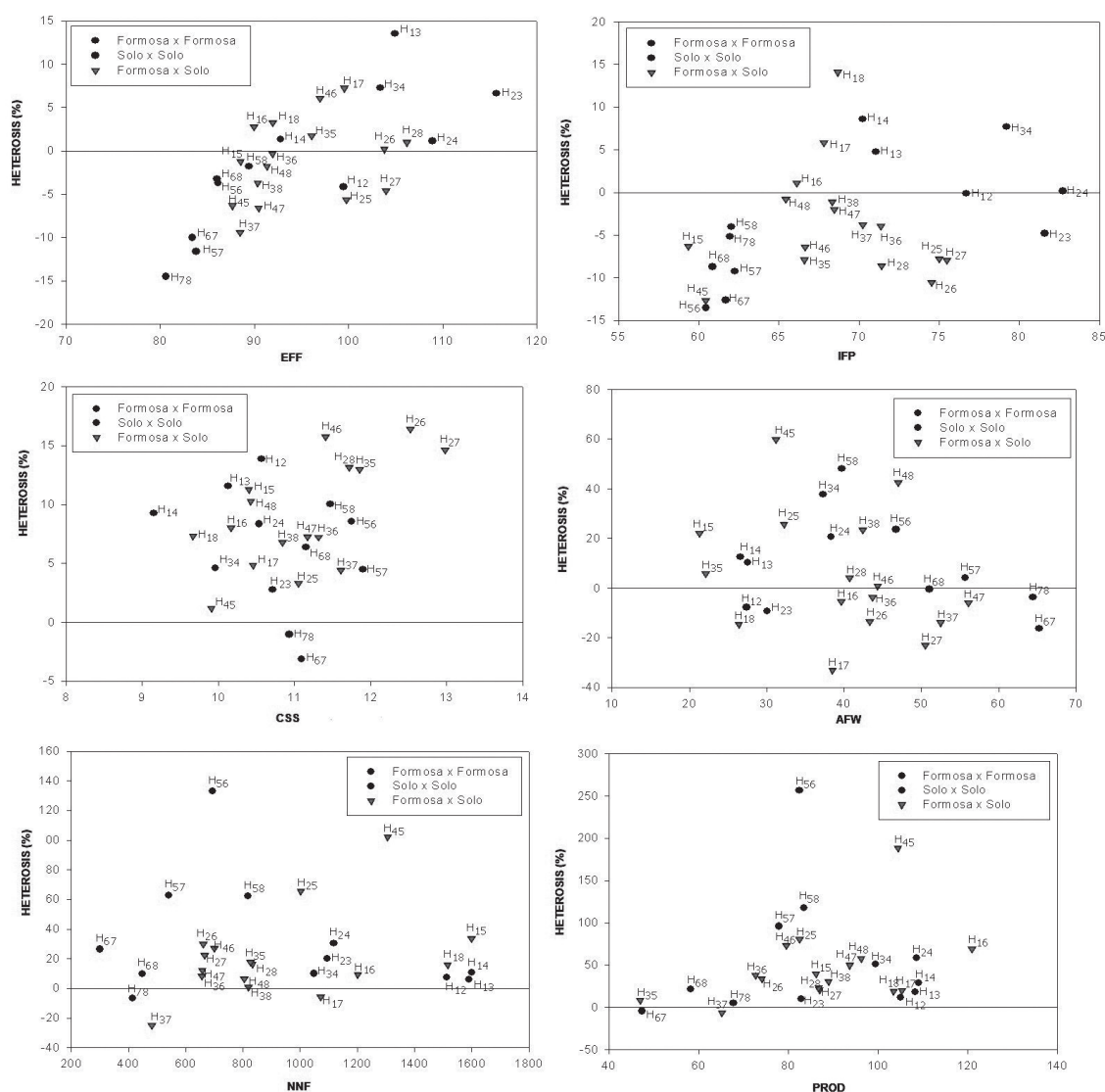


FIGURE 1 – Graphic dispersion of percentage heterosis for external firmness, internal firmness, content of total soluble solids, number of fruits, fruit weight and productivity in 28 papaya hybrids (For the identification of the hybrids, it was considered two numbers indicating the combination of the parental lines - Formosa: 1.MR, 2.JS, 3.J4, 4.SK and Solo: 5.WM, 6.GG, 7.SS, 8.SM).

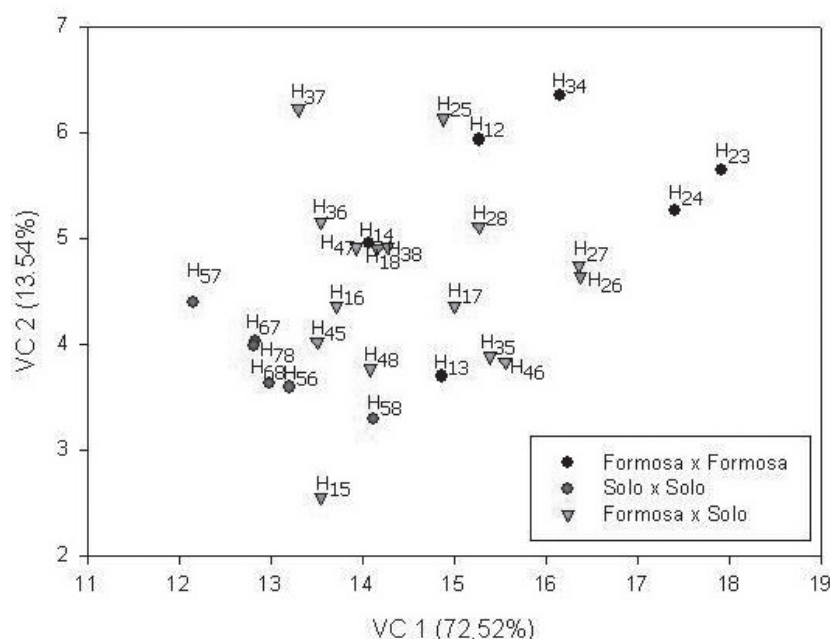


FIGURE 2 – Graphic dispersion of scores for the axes representing the first and second canonical variables (VC1, VC2) for six traits evaluated in 28 papaya hybrids.

CONCLUSION

The viability of the hybrids obtained here, mainly in the Solo hybrids, is very important to papaya culture, due to two main factors. First, their high productivity is almost the double the value obtained by the group of parents, namely, 44.8 t ha⁻¹ (Solo parents), against 71.16 t ha⁻¹ (Solo hybrids). Second, the Solo hybrids obtained in this study can replace the most consumed type of papaya, the small fruit type (“Hawaiian type”), which comes totally from varieties and, as already mentioned, accounts for about 80% of the planted area in Brazil. Furthermore, papaya of the type “Papaya” cannot be replaced in the market by intergroup hybrids due to its intrinsic trait, which is being a small fruit for individual consumption. Thus, solo hybrids meet a specific demand in the consumer market, the papaya “Hawaiian type”.

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