

DEVELOPMENT OF A NEW PAPAYA (*Carica papaya* L.) HYBRID

IBP 42-99

Laisyn Posada Pérez, Rafael Gómez Kosky, Juan Pérez Ponce, Maritza Reyes Vega and Osvaldo Norman Montenegro

SUMMARY

The most important papaya (*Carica papaya* L.) variety in Cuba is Red Maradol, with a total cultivated area of 4377ha, a yearly production of 51659ton and a yield of 17ton/ha. This variety produces large fruits with a low °Brix (10-11%). The objective of this work was to obtain papaya hybrids from the Red Maradol variety with higher quality (higher °Brix and smaller fruits) through the crossing with other commercial varieties (Red Laidy, Sunrise, Cotove, Solo Kapoho). Elite plants from Red Maradol and other papaya varieties were selected as progenitors for crossing. Resultant hybrid plants were planted

in field conditions. After 50 days of cultivation the first evaluation of plant height was done in order to detect early differences with the progenitors. Hybrid F (Red Maradol Strawberry) plants differentiated from the rest, showing a greater number of fruits with a smaller diameter compared to all other evaluated fruits. Plant #2 of this hybrid was selected as it had the best characteristic fruits with 14.5% of °Brix and 1kg of fresh weight, and was named IBP 42-99. Plant material from IBP 42-99 was further introduced in vitro from field plant apices.

Introduction

Papaya (*Carica papaya* L.) occupies an important place worldwide, mainly due to the use of its fruits in human consumption. In addition, papaya production is economically advantageous. Plant stems, leaves and fruits contain high levels of proteins and vitamins and are used in the elaboration of cosmetics and medications (Teixeira da Silva *et al.*, 2007). The main difficulties with this crop are low plant performance and poor fruit quality. Thus, the search for new varieties and hybrids with better characteristics becomes desirable.

The main papaya variety cultivated in Cuba is the Red Maradol, with a total cultivated area of 4377ha, a production of 51659ton/year and a yield of 17tons/ha (FAOSTAT, 2010). The main

disadvantage of Red Maradol is the large size of its fruits, which have a low to medium °Brix (10-11%). This variety is also susceptible to viral diseases (i.e. ring spot virus (PRSV; MINAGRI, 2005) and has been in exploitation for many years. Ongoing efforts are directed to the development of new papaya varieties and the introduction of others from abroad (MINAGRI, 2005).

Internationally, genetic improvement programs are heading towards the development of F₁ Papaya hybrids with the objective of exploiting heterocysts to increase yield. Efforts are also aimed to obtain plants with smaller fruits (Chan, 1992; Elder and Macleod, 2000). In Cuba, research activities concerning this crop have been mainly intended to study the acclimatiza-

tion of different varieties to the local conditions. Donor countries have been Nicaragua, Taiwan, Hawaii and Colombia (R. Ramos, personal communication, 2003). Despite its economical relevance, an appropriate papaya hybrid has not been so far obtained in Cuba.

The present work was carried out to evaluate the behavior of different papaya varieties and a hybrid, for their selection as progenitors, and to obtain hybrids with better fruit qualities, such as higher °Brix and smaller fruits than the Red Maradol variety.

Materials and Methods

Field trials were conducted at the experimental station "Pedro Lantigua", near the city of Remedios, north of the Villa Clara province,

from January 2005 to September 2007. The local mean temperature was 27.5°C and the mean annual precipitation is 1060mm.

The behavior of different varieties and a papaya hybrid were first evaluated in a red ferralitic soil, to further select elite progenitor plants. The varieties evaluated were Red Maradol, Sunrise, Red Lady, Cotové, and Solo Kapoho.

The experimental design used was that of a random block with five replicates per variety, with 20 plants each. Planting was done in a triangular area with 3m inter-row and intra-row distances, covering an extension of 0.54ha. Cultural practices, fertilization and phytosanitary treatments were carried out according to the technical instructions for this crop (MINAGRI,

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Laisyn Posada Pérez. M.Sc., Universidad Central "Marta Abreu" de Las Villas (UCLV), Cuba. Researcher, UCLV, Cuba. Address: Instituto de Biotec-

nología de las Plantas, UCLV. Carretera a Camajuaní km 5½. Santa Clara, Villa Clara, Cuba. e-mail: laisyn@ibp.co.cu

Rafael Gómez Kosky. Ph.D. Researcher, UCLV, Cuba.

Juan Pérez Ponce. Dr.Sc. Valencia, España. Researcher, UCLV, Cuba.

Maritza Reyes Vega. M.Sc. Technical personal, UCLV, Cuba.

Osvaldo Norman Montenegro. M.Sc. Researcher, UCLV, Cuba.

DESARROLLO DE UN NUEVO HÍBRIDO DE PAPAYA (*Carica papaya* L.) IBP 42-99

Laisyn Posada Pérez, Rafael Gómez Kosky, Juan Pérez Ponce, Maritza Reyes Vega y Osvaldo Norman Montenegro

RESUMEN

En Cuba la variedad más importante de papaya (*Carica papaya* L.) es la Maradol rojo con un área total cultivada de 4377ha, una producción de 51659ton/año con un rendimiento de 17ton/ha. Esta variedad produce frutos grandes con °Brix bajos (10-11%). El objetivo de este trabajo fue obtener un híbrido de papaya a partir de la variedad Maradol rojo, con una mayor calidad (mayor °Brix y frutos pequeños) a través del cruce con otras variedades comerciales (Red Laidy, Sunrise, Cotove, Solo Kapoho). Las plantas híbridas obtenidas de cada cruce fueron plantadas en condiciones de campo y a los 50 días fue realizada la primera evaluación de la altura de las plantas, con el ob-

jetivo de buscar diferencias a esta edad temprana. El híbrido F₁ resultado del cruce Maradol Rojo Strawberry tuvo un comportamiento superior según las características buscadas, con diferencias con el resto de los genotipos en cuanto a mayor número de frutos por planta, diámetro de los frutos y °Brix, y además constituye el tipo ideal buscado, o por lo menos fue el mejor de los híbridos. De esta población híbrida se seleccionó la planta # 2 (IBP 42-99) por presentar las mejores características (frutos con °Brix de 14,5% y 1kg de peso fresco) para ser introducida in vitro a partir de ápices de plantas en campo.

DESENVOLVIMENTO DE UM NOVO HÍBRIDO DO MAMÃO (*Carica papaya* L.) IBP 42-99

Laisyn Posada Pérez, Rafael Gómez Kosky, Juan Pérez Ponce, Maritza Reyes Vega e Osvaldo Norman Montenegro

RESUMO

Em Cuba, a variedade mais importante de mamão (*Carica papaya* L.) é a Maradol roxo com uma área total cultivada de 4377ha, uma produção de 51659ton/ano com um rendimento de 17ton/ha. Esta variedade produz frutos grandes com °Brix baixos (10-11%). O objetivo deste trabalho foi obter um híbrido de mamão a partir da variedade Maradol roxo, com uma maior qualidade (maior °Brix e frutos pequenos) através do cruzamento com outras variedades comerciais (Red Laidy, Sunrise, Cotove, Kapoho solo). As plantas híbridas obtidas de cada cruzamento foram plantadas em condições de campo e aos 50 dias foi realizada a primeira avaliação de altura das plantas, com o

objetivo de buscar diferenças a esta idade precoce. O híbrido F₁ resultado do cruzamento Maradol Roxo×Morango teve um comportamento superior de acordo às características buscadas, teve diferenças em relação ao restante dos genótipos em quanto a maior número de frutos por planta, diâmetro dos frutos e °Brix, e além disso constitui o tipo ideal buscado, ou pelo menos foi o melhor dos híbridos. Desta população híbrida foi selecionada a planta # 2 (IBP 42-99) por ter apresentado as melhores características (frutos com °Brix de 14,5% e 1kg de peso fresco) para ser introduzida in vitro a partir de ápices de plantas em campo.

2005). Irrigation was provided by means of sprinklers at an interval of 3 to 4 days during 2-5h each time.

For all the varieties and the hybrid, after 7-9 months from planting, depending on the harvest time of each variety, the following evaluations were performed: plant height (m) at time of harvest, height (m) of fruit formation, number of fruits per plant, °Brix, length (cm), diameter (cm), and average weight (g) of the fruits, color of the pulp, yield (t/ha), and type of flowers.

Comparisons of the means for the evaluated variables were done using a simple ANOVA test and the statistical significance of the results was assessed by means of a Duncan multiple range test.

Crossing and hybrids selection

To obtain F₁ hybrids from the crossing of Red Maradol and selected varieties according to desirable characteristics, elite progenitors were first selected. Crossing was carried out by placing pollen grains on hermaphrodite flowers.

Flowers that were used as female organ were eliminated, squeezing the anthers before they became dehiscent. For this purpose, undesirable pollen was isolated in a paper bag. Hermaphrodite flowers were used as pollen donors. Hybridization was done when the stigmata were receptive, using brushes, forceps, magnifying glass and alcohol. Pollinated flowers were covered with

an impermeable paper bag. Fruits from hybrid plants were harvested when the skin color changed from dark green to light green and yellow areas started to develop from the base upwards. Seeds were then collected and planted in a greenhouse covered with a plastic mesh that reduces the light intensity by 70%. Irrigation was carried out with a microjet system with a frequency of 2 irrigations per day and 2 minutes of duration. With this frequency a good humidity was guaranteed. Planted seeds stayed in polystyrene boxes with 50 orifices for seven weeks until germination. The hybrid plants obtained in this way were planted in field conditions. Fifty days after planting, the first evaluation of

plant height was performed to detect differences among them at an early stage.

After six months of cultivation, 20 hybrid plants per crossing group were pre-selected, depending on the progenitor. Vigor was the main criteria for selection and the same morphological variables evaluated for the progenitors (see above) were measured at this time. Data processing was done with the statistical package SPSS v6.0 for Windows®. When comparing different hybrids, non parametric techniques were used since the data did not follow a normal distribution. The Kruskal Wallis test was used for variance analysis and the Mann Whitney test for contrast analysis between different hybrid groups.

TABLE I
THE CROSSINGS WERE DONE ACCORDING TO THE FOLLOWING SCHEME

| Females | Males | Key |
|-------------|-------------|-----|
| Solo Kapoho | Red Maradol | A |
| Red Maradol | Solo Kapoho | B |
| Sunrise | Red Maradol | C |
| Red Maradol | Sunrise | D |
| Strawberry | Red Maradol | E |
| Red Maradol | Strawberry | F |

TABLE II
RESULTS ON THE EVALUATIONS OF THE CHARACTERISTICS OF THE FRUITS IN THE HYBRID AND THE DIFFERENT VARIETIES STUDIED

| Variety | Fruit length (cm) | Fruit diameter (cm) | Average weight (g) | °Brix |
|-------------------|-------------------|---------------------|--------------------|---------|
| Red Lady (hybrid) | 24.94 ab | 15.86 a | 2595.80 ab | 11.52 b |
| Maradol | 23.04 b | 14.13 b | 2384.40 b | 11.96 b |
| Cotové | 12.76 c | 12.60 c | 1357.00 c | 9.76 c |
| Sunrise | 13.66 c | 9.84 d | 767.16 d | 12.21 a |
| Solo Kapoho | 25.52 a | 15.90 a | 2783.72 a | 8.36 d |

Different letters in the same column represent significant differences by the Duncan test $p < 0.05$.

TABLE III
RESULTS OF YIELDS AND PHENOTYPIC CHARACTERISTICS IN THE HYBRID AND THE VARIETIES OF PAPAYA STUDIED OF GREATEST INTEREST

| Variety | Yield (t/ha) | Type of flowers | Color of the pulp |
|-------------|--------------|--------------------------|-------------------|
| Red Lady | 160.3 a | Hermaphrodite and female | Red |
| Red Maradol | 142.95 b | Hermaphrodite and female | Red |
| Cotové | 131.67 b | Female and male | Yellow |
| Sunrise | 87.78 c | Hermaphrodite and female | Red |
| Solo Kapoho | 88.10 c | Hermaphrodite and female | Orange-Yellow |

Different letters in the same column represent significant differences by the Duncan test $p < 0.05$.

The selection of the best hybrid among the 12 pre-selected plants was guided by a quality function defined as $Z_{poten} = Z_{brix} + Z_{thickness}$, where Z_{brix} and $Z_{thickness}$ are the °Brix and the thickness of the fruit internal mass, respectively. Defined in this way, Z_{poten}

included the main characteristics of the ideal hybrid fruits. Notice that a °Brix of 14% is internationally accepted as a measure of fruit quality. For a more robust estimation of the best hybrid plant Z_{poten} values were used as input for a cluster analysis.

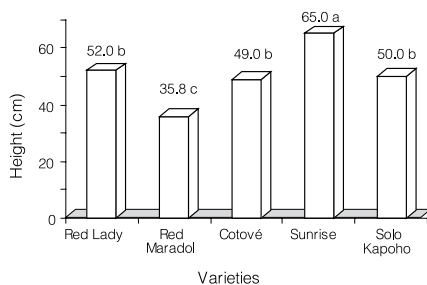


Figure 1. Height of fruit formation of different varieties of Papaya. Different letters were significantly different by the Duncan test, $p < 0.05$.

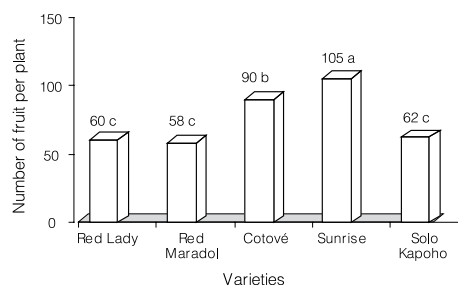


Figure 2. Number of fruits per plant for each Papaya varieties. Different letters were significantly different by the Duncan test, $p < 0.05$.

Results

Selection of elite progenitors

When comparing the five papaya varieties, non significant differences were observed in the plant height. Red Lady and Sunrise varieties showed the highest height with an average of 2.10m in both cases. Plant height was also determined at fruit formation. Red Maradol formed fruits when plants were on average only 38.5cm high. That value differed significantly from the rest of the studied varieties (Figure 1).

Another evaluated variable was the number of fruits per plant (Figure 2). The Sunrise variety showed the highest number of fruits per plant with an average of 105 units.

Considering the results on the evaluated fruit quality parameters (fruit length and diameter, average weight and °Brix) the variety with the best integral behavior was Sunrise, showing significant differences with the rest. This variety had small fruits, of low weight, and a high sugar content of its pulp (Table II).

In relation to the yields, the results obtained showed that the Red Lady hybrid had the best behavior in this parameter, with significant differences with the others (Table III).

Other botanical characteristics evaluated were pulp color and the type of flowers (Table III). All the varieties and the hybrid presented a red pulp color with the exception of Cotové, which was yellow. With respect to the type of flowers, no male plants were found in the population evaluated in the varieties Red Maradol, Red Lady and Sunrise. Cotové, which is a dioecious plant, was disregarded as an ideal genotype for crossing among the other characteristics mentioned previously.

The varieties that presented the best behavior for its selection as progenitors to obtain hybrids with desirable characteristics of high °Brix, red pulp, small fruit size, and greater number of fruit per plant were Sunrise and Solo Kapoho.

Crossing and selection of the hybrids

Figure 3 shows the results obtained with respect to the evaluation done on the height of the hybrids at 50 days after planting. In this parameter, a significant superiority was observed in the hybrid obtained from the cross between Sunrise, used as the female and Red Maradol, used as the male, this being the best combination used. The other three

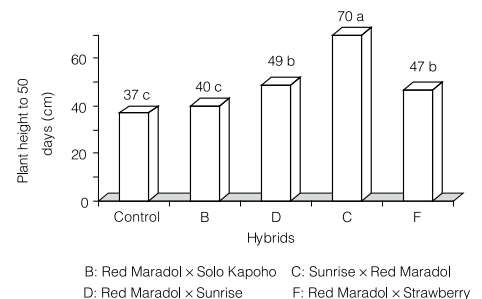


Figure 3. Behaviour of the height of the different hybrids of Papaya at 50 days after planting in the fields. Different letters were significantly different by the Duncan test, $p < 0.05$.

TABLE IV
COMPARISON OF THE DIFFERENT F₁ HYBRIDS WITH THE PROGENITOR
RED MARADOL AT EIGHT MONTHS AFTER PLANTING

| Genotype | Fruit number/ plants | Fruit length (cm) | Fruit diameter (cm) | Internal mass thickness (cm) | Brix | Plant height at harvest (m) | Fruit weight (kg) |
|------------|-------------------------|----------------------|---------------------------|------------------------------------|----------|-----------------------------------|-------------------------|
| Hybrid B | 47.36 B* | 22.30 Bc | 11.79 A | 4.73 a | 9.98 bc | 1.67 c | 1.40 Ab |
| Hybrid C | 46.36 Bc | 21.29 D | 11.99 A | 2.87 b | 9.89 c | 1.80 b | 1.33 B |
| Hybrid D | 34.54 C | 21.80 Cd | 11.23 C | 2.83 bc | 10.36 b | 1.64 c | 1.24 D |
| Hybrid F | 50.16 A | 21.58 Cd | 11.10 B | 2.76 c | 12.00 a | 1.87 ab | 1.30 Cd |
| Progenitor | 24.30 D | 23.09 A | 11.80 A | 2.85 bc | 10.18 bc | 1.25 d | 1.40 Ab |

The hybrids are B: Red Maradol Solo Kapoho, C: Sunrise Red Maradol, D: Red Maradol Sunrise, F: Red Maradol Strawberry, and the Progenitor is Red Maradol.

*Means with distinct letters in the same column differ for values of $p < 0.05$ by the Mann Whitney test.

TABLE V
RESULTS FROM USING
THE CLUSTER METHOD
"CLOSEST NEIGHBOR"

| Case | 3 Clusters |
|--------------|------------|
| 1:Hybrid B | 1 |
| 2:Hybrid C | 2 |
| 3:Hybrid D | 2 |
| 4:Hybrid F | 3 |
| 5:Progenitor | 2 |

hybrids; Red Maradol as female Sunrise as male, Red Maradol as female Solo Kapoho as male, and Solo Kapoho as female Red Maradol as male, did not show hybrid vigor in this evaluation, since there was no significant difference with the control, nor among them.

The results presented in Table IV show significant differences between the distinct genotypes for all the characters evaluated. The hybrid F, resulting of the

TABLE VI
RESULTS FROM USING
THE CLUSTER METHOD
"CENTROID"

| Case | 3 Clusters |
|--------------|------------|
| 1:Hybrid B | 1 |
| 2:Hybrid C | 2 |
| 3:Hybrid D | 2 |
| 4:Hybrid F | 3 |
| 5:Progenitor | 2 |

crossing between Red Maradol and Strawberry had a superior behavior, according to the desirable characteristics, with differences for to genotypes regarding a greater number of fruits per plant, smaller diameter of the fruit and °Brix. However, with the Mann Whitney test it is difficult to select the best F₁ hybrid. Only with the cluster analysis it was possible to discriminate, in the groups of hybrids resulting from the crossings,

TABLE VII
RESULTS FROM A COMPARATIVE
STATISTICAL ANALYSIS BETWEEN
THE DISTINCT HYBRIDS
ACCORDING TO THE POTENTIAL

| Genotypes | Potential | Significance |
|------------|-----------|--------------|
| Hybrid F | 14.76 | A |
| Hybrid B | 13.71 | B |
| Hybrid D | 13.11 | B |
| Progenitor | 13.03 | BC |
| Hybrid C | 12.45 | C |

which had a better behavior according to the desire characteristics.

As observed in Tables V and VI, the same results were obtained with both methods, indicating that case 4 (hybrid F) is separated from the rest in a unique cluster, demonstrating its difference with the other hybrids when taking into account all the measurements.

These results, added to the potential results (Table

VII) allowed to conclude that the hybrid F from the cross between Red Maradol as female and Strawberry as the male constitutes the ideal type that was searched for or, at least, was the best hybrid analyzed.

Between the hybrid, plant #1 and #2 of the crossings between Red Maradol as the female and Strawberry as the male, there were no statistical differences with respect to the fruit's potential; however, plant #2 was selected as the best and was named the papaya hybrid IBP 42-99, because it was the one that presented fruits of lesser weight (1.0kg), which was one of the desired characteristics (Table VIII). The same happened with its average °Brix of 13.4. With respect to

the thickness of the internal mass, plant #9 had the thickest mass (2.80cm), but was not significantly different to plant #2.

Discussion

The observed behaviour in the red Maradol variety was similar to the results presented by MINAGRI (2005), which is an advantage because it is easier and faster to harvest the first fruits as the plant continues its growth. In second place was Cotové, which started fruit formation at a height of 49.0cm, and similar results were obtained with Red Lady and Solo Kapoho. Red Maradol was the first to be harvested, being the most precocious in the present work. This variety was harvested between seven and eight months after planting in the fields. Otero (2003) pointed out similar results, which corroborates those obtained in this work. The variety with the greatest amount of fruit produced was Sunrise. These results are in accordance with Sankat and Maharaj (1997),

TABLE VIII
RESULTS OF THE DIFFERENT PARAMETERS EVALUATED FOR THE SELECTION
OF THE BEST PLANTS WITHIN THE CROSS RED MARADOL STRAWBERRY

| Plant number | Fruit length (cm) | Fruit diameter (cm) | Internal mass thickness (cm) | °Brix | Fruit number/plant | Plant height (m) | Weight of fruits (kg) | Fruit potential |
|--------------|-------------------|---------------------|------------------------------|----------|--------------------|------------------|-----------------------|-----------------|
| 1 | 27.6 b | 10.40 b | 2.84 ab | 14.00 a | 80.00 a | 1.85 e | 1.64 a | 16.84 a |
| 2 | 17.2 d | 13.20 a | 2.80 ab | 13.40 ab | 51.00 c | 1.61 j | 1.00 b | 16.2 ab |
| 3 | 22.4 b | 11.10 ab | 2.76 bc | 12.20 bc | 47.00 d | 1.18 k | 1.35 b | 14.9 bc |
| 4 | 19.2 cd | 10.50 b | 2.42 c | 12.40 b | 39.00 e | 2.30 b | 1.11 b | 14.8 bcd |
| 5 | 21.8 b | 11.00 ab | 2.72 bc | 12.00 c | 28.00 e | 1.80 g | 1.28 b | 14.7 bcd |
| 6 | 20.2 c | 12.40 ab | 2.56 c | 12.40 b | 59.00 c | 2.60 a | 1.26 b | 14.9 bcd |
| 7 | 20.4 c | 11.30 ab | 2.58 c | 11.60 c | 49.00 d | 2.10 c | 1.11 b | 14.2 bcd |
| 8 | 23.0 a | 10.70 b | 2.90 ab | 11.40 c | 70.00 b | 1.68 h | 1.44 ab | 14.3 bcd |
| 9 | 21.4 bc | 10.80 b | 3.00 a | 11.80 bc | 45.00 d | 1.82 e | 1.31 b | 14.8 bcd |
| 10 | 21.6 bc | 11.50 ab | 2.80 b | 11.20 cd | 32.00 e | 2.05 d | 1.24 b | 14.0 cd |
| 11 | 21.6 bc | 11.20 b | 2.86 ab | 10.80 d | 54.00 c | 1.78 f | 1.29 b | 13.6 d |
| 12 | 22.6 bc | 10.70 b | 2.96 a | 10.80 d | 48.00 d | 1.70 g | 1.46 ab | 13.7 cd |

who referred to Sunrise as a very productive variety. Chan and Mak (1994) also obtained similar results.

These characteristics match the information provided by Teixeira da Silva *et al.*, (2007) in Taiwan, even though for the conditions studied in the present work, the average weight of the fruits was superior (767g) with respect to that of the literature cited, which is 400g. This could have been due to the optimal agronomic and phytosanitary conditions in which they developed, and to the local climatic conditions, which favored the crop.

Chan (1992) obtained similar results upon crossing the variety Exotic with Sunrise in the search of an F1 hybrid of smaller fruits with less weight. In the literature consulted, no articles have been found showing the use of Red Maradol as a progenitor.

Fruit number is a major factor which contributes towards higher yield (Muthulakshmi *et al.*, 2007). With respect to the number of fruits per tree, the hybrid F recorded greater fruits than other hybrids and Red Maradol.

Conclusions

1-The varieties Sunrise and Solo Kapoho presented the best behavior for their selection as progenitors along with Red Maradol for the achievement of hybrids with the desired characteristics (high °Brix, red pulp, small fruit and greater number of fruits/plant).

2-A hybrid was obtained from the cross between Red Maradol Strawberry with better characteristics than those of Red Maradol.

3-The hybrid IBP 42-99 from the cross Red Maradol Strawberry was

selected for its lesser weight, smaller fruit size and high °Brix.

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