Culture and fruit quality of rambutan (*Nephelium lappaceum* L.) in the Soconusco region, Chiapas, Mexico

Eva Johanna Maria VANDERLINDEN[a], H. Alfred Juergen POHLAN[b], Marc J.J. JANSSENS[c]*

[a] Hogeschool Gent, Voskenslaan 270, 9000 Gent, Belgium
eva_vanderlinden@yahoo.com

[b] Ecosur, El Colegio de la Frontera Sur, Carretera Antiguo Aeropuerto km 2,5, Apdo. Postal 36, CP 30700 Tapachula, Chiapas, México
drjpohlan@excite.com
pohlan@tap-ecosur.edu.mx

[c] Universität Bonn, Institut für Gartenbauwissenschaft, Auf dem Hügel 6, 53121 Bonn, Germany
marc.janssens@uni-bonn.de

* *Correspondence and reprints*

Fruits, 2004, vol. 59, p. 339–350

DOI: 10.1051/fruits:2004032

RESUMEN ESPAÑOL, *p. 350*

Culture and fruit quality of rambutan (*Nephelium lappaceum* L.) in the Soconusco region, Chiapas, Mexico.

Abstract — Introduction. In Mexico, the rambutan is not a well-known fruit tree, but it has great potential for its establishment and development in the Soconusco region because of the local good agro-ecological conditions for the production of its fruit. Currently, there are already 200 ha of plantations in the region with a good adaptation and a rewarding yield. Rambutan history, cultivation practices, post-harvest operation and commercialisation in the Soconusco region were studied to identify the possibilities of an expansion of the species. In particular, the work aimed at identifying different varieties inside the rambutan orchards. **Materials and methods**. Four areas were studied from a survey in 14 farms. Different parameters of fruit quality were analysed (ten trees sampled per farm): fruit diameter, fruit length, rind colour, spintern appearance, aril diameter, aril length, aril weight, flesh colour, flavour, succulence, adherence of flesh, and presence of pests and diseases. **Results**. Fruit quality was dissimilar for the four studied areas. Among the different fruit samples collected, it appeared that the environment and cultivation management play an important role in fruit size. The diversity of varieties planted in the different sites was determined by clustering analyses. Independent of their site of origin, at least six well-defined cluster classes could be identified. **Conclusion**. Fruit weight, spintern appearance and colour, as well as fruit diameter and aril to fruit weight appeared to be good indicators to identify fruit quality. The clustering analyses showed that there is a wide range of overlapping varieties to be found in the Soconusco region. Six major varietal groups were identified. Further varietal differentiation and characterisation of rambutan in the Soconusco region will be necessary for a better establishment of this fruit tree crop.

Mexico / *Nephelium lappaceum* / production location / cultivation / fruits / quality / market intelligence / varieties

Culture et qualité du fruit chez le ramboutan (*Nephelium lappaceum* L.) cultivé dans la région du Soconusco (état de Chiapas, Mexique).

Résumé — Introduction. Au Mexique, le ramboutan n'est pas un arbre fruitier bien connu, alors qu'il offre un potentiel de développement réel dans la région du Soconusco, en raison de conditions agro-écologiques propices à la production du fruit. Actuellement, il y a déjà 200 ha de plantations dans cette région ; l'arbre présente une bonne adaptation et des rendements intéressants. L'histoire du ramboutan, les pratiques culturales, les opérations d'après récolte et la commercialisation dans la région de Soconusco ont été étudiées pour identifier les possibilités d'une expansion de l'espèce. En particulier, nos travaux ont cherché à identifier différentes variétés à l'intérieur des vergers de ramboutan de la zone étudiée. **Matériel et méthodes**. Quatre zones ont été étudiées à partir d'une enquête effectuée sur 14 exploitations. Différents paramètres de la qualité du fruit ont été analysés (dix arbres prélevés par exploitation) : diamètre et longueur du fruit, couleur de l'écorce, aspect des poils, diamètre, longueur et poids de l'arille, couleur de la chair, saveur, succulence, adhérence de la chair, présence de parasites et maladies. **Résultats**. La qualité du fruit a été différente pour chacune des quatre zones étudiées. Les différents échantillons de fruit collectés ont montré que l'environnement et la gestion de la culture jouaient un rôle important sur la dimension de fruit. La diversité des variétés plantées dans les différents sites a été déterminée par une analyse typologique. Indépendamment de la localisation des arbres, au moins six classes ont été nettement identifiées par cette méthode. **Conclusion**. Le poids du fruit, la couleur de l'écorce, l'aspect des poils, ainsi que le diamètre du fruit ou le rapport (poids de l'arille / poids du fruit), ont semblé être de bons indicateurs pour évaluer la qualité du fruit. Les analyses typologiques ont montré qu'il existe une large gamme de variétés dans la région du Soconusco. Six groupes variétaux principaux ont été identifiés. Davantage de différentiation et de caractérisation des variétés de ramboutan seront nécessaires dans la région de Soconusco pour mieux développer cette culture dans la zone.

Mexique / *Nephelium lappaceum* / localisation des productions / pratique culturale / fruits / qualité / information sur le marché / variété

1. Introduction

The rambutan (*Nephelium lappaceum* L.), which belongs to the family of the Sapindaceae, is an exotic fruit tree native to the Malaysian-Indonesian region [1]. It prefers areas with high humidity and low evaporation rates. Although the fruit is not well known in Middle America and Mexico, the tree has great potential for establishment and development in this zone because of the good agro-ecological conditions for its cultivation.

The highly appreciated fruit is quoted at attractive prices on the national and international markets. Nevertheless, the Soconusco region growers are still hesitating to produce and commercialise this fruit, first in Mexico and later on the international market. The main problems for commercialising are the irregular fruit quality, the lack of information about sustainable cultivation practice and international market standards [2], the lack of post-harvest treatments, the implementation of international sanitary standards and the presence of big competitors in Southeast Asia. Consequently, in our study, we analysed the rambutan cultivation context in the Soconusco region, then we compared the fruit quality from fruit harvested in different cultivated areas, and we attempted to identify the number of currently grown varieties.

1.1. Rambutan in Mexico and Soconusco region

The rambutan has a short history in Latin America, being introduced into Mexico last century, somewhere in the fifties or sixties. Currently, there are approximately 200 ha of rambutan plantations in the Soconusco region (Mexico), with a good adaptation and a rewarding yield [3, 4].

Three different stories describe the introduction of the rambutan into Mexico. Pérez and Pohlan [4] reported that the rambutan was introduced into Mexico in the fifties. Gutiérrez (pers. commun.) emphasises that the first rambutan plants were brought to Mexico by Patiño in 1968. On the other hand, Quilantán (pers. commun.) maintains that the cultivation of rambutan was introduced into Mexico in 1976 via the port of Veracruz al Palmar, which is an experimental quarantine field. After that, it was displaced to the experimental field Rosario Izapa (INIFAP), situated in Tapachula (Chiapas state), where the plantation was established with seedling material. These seeds were selected on the most productive trees of the collection that were introduced in the seventies from Malaysia. Due to sexual propagation, the trees represent a great genetic heterogeneity. Rambutan is a dioecious crop (about 50% of all plants are male). Pronounced phenotypic differences are to be found among plants, this being expressed among other ways by a prolonged bloom of the plantation and a high variability in the colouring of the ripe fruits (red, yellow and green). The INIFAP will develop a second plantation in the upcoming years, yet with grafted material. In this case, a genetic uniformity of the plantation will be reached, with smaller trees, and the presence of non-productive trees (males) will be excluded [2]. Also, in the field Rosario Izapa, the original Malaysian material disappeared, so that only Quilantán still has three producing trees from the original material.

For almost 20 years, the demonstration garden of rambutan in the experimental Rosario Izapa field was a rather decorative garden. Investigations were minimal, as the technicians of this field concentrated on the other crops that were developing at that moment, while the rambutan garden was left unattended. A day labourer of this agricultural field discovered the exquisite flavour of the fruit and found seedlings under the trees. He decided to grow rambutan in the patio of his house. In this manner, he propagated and expanded the rambutan to nearly all the geography of the municipalities of Tuxtla Chico and Cacahoatán, as those municipalities were the place of residence of the agricultural day labourers.

In 1999, rambutan cultivation was still limited in Chiapas state. Hardly 1000 trees reached production in backyard orchards, and 50 ha existed in commercial orchards [4]. Currently, no commercial plantations exist in Veracruz. In 1999, there were trees, originating from Chiapas state, planted in Tabasco, Oaxaca, Guerrero and Campeche, but all on a small scale [5].

Today, the most famous rambutan area in Chiapas state and Mexico is Cacahoatán, which is situated at lat. 14° 59' N and long. 92° 10' W, at an altitude of about 480 m asl [6]. In this area, rambutan has been disseminated from family orchards and different commercial orchards. The San Alberto farm, near Cacahoatán, is found at an altitude of 600 m asl and was primarily dedicated to robusta coffee (*Coffea canephora*). Today, this farm, with a total area of 42 ha, is demonstrating the transformation of coffee areas by rambutan mixed with robusta coffee. In the beginning, rambutan trees were used as shade trees for the coffee. This project was started in 1990, as the coffee prices were decreasing and the producers looked for new sources of income. According to an owner of 22 trees of 12 years of age, there are eight varieties in his orchard. In 2001, he got a total yield of 2 500 kg. A grower neighbour has about 100 trees, which gave a rambutan production of about 4 500 kg. He is experimenting with different grafts and is searching for the tree with "ideal fruits", which have to be orange-red, weigh (50 to 55) g and have a sugar content of 25° Brix. The farm Santa Rita has 70 trees of which 45 are in production. The trees are 6–7 years old and each tree is said to produce 100 kg a year. One of the rambutan growers has three rambutan trees directly introduced from Asia. They were 7–8 years old, propagated by bud grafting and each produce about 100 kg a year [7]. This owner is probably the only one in the Soconusco region with original material.

The municipality of Metapa de Domínguez (lat. 14° 50' N, long. 92° 11' W and average alt. 100 m asl [6]) harbours the farm "El Herradero", which covers more than 30 ha, of which 7 ha are used for the cultivation of rambutan. This area is divided into three lots. Before rambutan was cultivated, the land was cropped with annual crops such as sorghum. One hundred rambutan trees were first planted in 1997, then another 200 trees were planted in 1998 and 300 more in 1999. On this date, the first rambutan fruits were harvested (500 kg). In 2000, the harvest was already 3 500 kg, and another 300 trees were planted, then 400 more trees in 2001. At this time, the farm harvested a total yield of 8 500 kg. In 2002, 50 new trees were planted and the productivity was estimated at a total of 21 000 kg, which means 3 $t \cdot ha^{-1}$. In those six years, 1 350 trees were planted on 7 ha, which means a density of approximately 200 trees per ha. About 12 trees were replaced, because they did not bear fruits.

In a Huehuetán station (lat. 15° 01' N, 92° 23' W, alt. 50 m asl [6]), there is "Chinita", another significant rambutan farm with a total area of 12 ha, of which 10 ha are for the cultivation of rambutan. On this area, 3 000 rambutan trees were planted between 1997 and 2001 at a density of 300 trees$\cdot ha^{-1}$. In 2001, the total production was 3 $t \cdot ha^{-1}$. In 2002, the production had already increased to a very satisfactory 7 $t \cdot ha^{-1}$. Before rambutan was planted, this farm was cropped with plantains (*Musa* sp.). In the first 3 years of rambutan growth, the area was intercropped with plantain to get more profit out of the land. As the rambutan trees are bigger now, all banana plants will be removed. Non-productive rambutan trees are marked and will be removed if they do not give a satisfying yield over 2 years (R. Ho, pers. commun.)

1.2. Rambutan cultivation practices

The growing methods for rambutan cropping have not been well studied under local conditions; however, the selection of certificated vegetative propagated planting material, irrigation facilities, the correct pruning method and adequate harvest and post-harvest activities will determine the success of a rambutan orchard.

It is well known that vegetative propagation is the only way to guarantee that all trees will be productive, that the fruit quality will be maintained and that the fruit set will come fast [1, 8]. Bud grafting is the most adequate propagation method for rambutan. Nevertheless, in Mexico, rambutan cultivars are not yet propagated vegetatively. Therefore, investigation focuses on determining the quality of the fruit and the trees that are already in production, and identifying trees with the quality standards of the international market. Vegetative propagation will be done in this way to assure commercialisation in export markets [4]. All material which is propagated today in Mexico came from national

nurseries without quality certification. This situation needs to change urgently. It is necessary to select the best rootstocks and to investigate the compatibility between the rootstock and the grafting materials. Consequently, the genetic variability in the Mexican orchards is high, and many producing trees bear fruit of inferior quality. On the other hand, the demand for quality plants is high.

In the Soconusco region, rainfall is generally adequate for rambutan cultivation, but occasionally, short dry periods exist during the blossom and fruit development phases. This situation, therefore, requires some form of irrigation. The owners of the orchards analysed recognise this and irrigate the trees by mobile water tank (in Metapa), temporary inundation (in Huehuetán) or mobile sprinklers (in Cacahoatán). Some projects for sprinkler irrigation will be started. This is essential for the production of large fruits, which are the basis for profitable commercialisation.

The planting system, tree habits and pruning activities normally form an integrated system in rambutan orchards. In the Soconusco, all these draw on empiric knowledge and personal experience. Those are the reasons for the heterogeneity of the orchards and the great difference in management practices. In Metapa, all branches lower than 20 cm from the ground are pruned. Fruited panicles are cut away after harvest to encourage growth of vigorous and fruit-bearing branches for the next harvest. In Huehuetán, growers use top pruning. Broken or diseased branches as well as off-season fruited bunches are removed. All low-hanging branches are cut away up to 50 cm from the ground. In Cacahoatán, farmers cut the bunch away during harvest. If this is not done, no new leaves or fruiting branches will grow. After harvest, trees are normally pruned to form an open-centred canopy.

Harvesting criteria, such as maturity indices, colour and fruit size, were used. The harvesting and post-harvesting techniques are problematic. Some farmers do not accept the need for harvesting schedules, selective harvest and fruit picking by shears. Only in Huehuetán, and in a few orchards in Cacahoatán, do they use string shears with long poles.

1.3. Post-harvest operation and commercialisation

Immediately after harvesting, fruits are rapidly transported to the packing shed. The harvested fruits are normally stored not longer than one day, and this under shaded conditions and ambient temperature, in plastic or wooden boxes of (20 to 30) kg. The fruits are not treated with water, but unripe and spoilt fruits are usually removed. Cool stores are not used. Every farmer realises his personal grading strategy. The low daily volumes of fruits for most orchards do not facilitate fruit sorting, based on fruit size and coloration. Only in the San Alberto farm are fruits sorted visually into three classes: excellent (exportation), very good (Mexico City) and good (local market). At this farm, the fruit size is also visually determined: more and less than 30 g, and the fruits must be uniform.

Depending on the market requirements, fruits are packed in plastic or wooden boxes, in cardboard boxes or in plastic punnets. Mexican rambutans were exported to Japan in 2000 for the first time. The current import requirements for Japan are cardboard boxes with 7 lbs (3.18 kg) and clamshell PVC boxes with nine fruits. To Canada and the USA, fruits are selected individually and packed in small cardboard boxes containing (2 or 5) kg of fruits, protected by Chinese paper. In 2003, 14 t were exported to Japan, 2 000 kg to Canada and 3 000 kg to the USA. The average price is 5.00 US$ per kg FOB. One farm sells, on the spot, its fruits at 1.05 US$·kg^{-1}. The dealers sell the same fruits in Guatemala at three times this price. All transport is arranged by these purchasers. In 2002, a Metapa orchard commercialised 21 t to Guatemala, packed in plastic boxes of 22 kg, and sold it at an average price of 1 US$·kg^{-1}. At the present time, cooling or treatment of the fruits by fungicide application or dips are not realised. Fruits for export to Mexico City were transported by aeroplane. The farm San Alberto sold in 2003 more than 100 t of fresh rambutans to Mexico City at an average price of 2.70 US$·kg^{-1} FOB. The fruits are packed in wooden boxes and protected completely by Chinese paper. The boxes contain (13 to 15) kg of fruits. Rambutans from the farm Chinita (Huehuetán Station)

also find their market in Mexico City and in Tapachula. Fruits destined for Mexico City are sold at about 1.2 US$·kg^{-1}. They are transported by air with cooling at 12–14 °C. In 2002, 7 t were exported to Mexico City.

At the local markets the fresh fruits are transported by lorries or pickups in plastic boxes or loose. These activities are in the hands of retailers, who purchase the fruits from the farmers and realise a profit of between (10 and 20)%. Some farmers sell their complete yield of the orchard to wholesalers, who then carry out all the operations from harvest and selection up to commercialisation. In this system the farmer obtains prices between (0.75 and 1.05) US$·kg^{-1}. The most significant farm with this type of commercialisation is Chinita (Huehuetán Station) with 120 t of fruit production in 2003. Many small farmers put their fruit up for sale at home. Approximately 80% of the production is commercialised this way. Prices oscillate between (1.40 and 2.20) US$·kg^{-1}. Fruits from different regional farmers are sold at more or less 2 US$·kg^{-1} in the Tapachula supermarkets, depending on the season.

It is obvious that, in the future, the different orchards need one common marketing strategy. This includes propagation of market preferred varieties, control of harvesting criteria and, finally, appropriate self-commercialisation. One important step in this direction was the constitution of the association *Asociación de productores y exportadores de Rambután y frutas no-tradicionales y exóticas del Soconusco* at the end of 2003.

As long as the fruit attains the quality standards for its agreeable and refreshing taste, ample possibilities exist that this fruit will be exported from Mexico to places such as the United States of America, Canada, Japan and Europe. The west coast of the United States, at a distance of only 6 h by air, is a potentially feasible export market. In September 2003, the Department of Agriculture of the United States dissolved the quarantine restrictions for Mexican rambutan and admitted that the fruit is not a carrier of the eggs of the Mediterranean fruit fly (*Ceratitis capitata*) and other fruit flies (*Anastrepha* spp.). Currently, the UNACH (*Universidad Autónoma de Chiapas*), through the Faculty of Agricultural Sciences situated in Huehuetán, Chiapas, is investigating the appropriate choice of commercial cultivars that reach the quality standards of the international market. Moreover, the presence of big competitors in Southeast Asia contributes to the risk. To avoid direct competition with the large producers in Southeast Asia and their low market prices, rambutan production in Mexico needs to be harvested in the months of November to January, which can be achieved with the use of selected cultivars and by improving the agronomic aspects.

2. Materials and methods for studying rambutan quality

2.1. Areas studied in the Soconusco region

Our studies were conducted in the most significant areas of rambutan cultivation, which are located in the Soconusco region (*figure 1*). The Soconusco region is situated in the Southeast of the Chiapas state at lat. 14° 10'–15° 20' N and long. 92° 10'–93° 10' W. Altitude is 0 m at the coast up to more than 2 000 m in the *Vertiente de la Sierra*. This region has varied topographies, which define the climatologic conditions in eight principal sub-regions (*table I*) and determine a high diversity of agro-ecosystems [9, 10]. The studied sites were located in four of these sub-regions: *Inicio de Planicie Sur* (Metapa), *Planicie* (Huehuetán station), *Inicio de Planicie* (Huehuetán station and Tuxtla Chico) and *Ladera Medias* (Cacahoatán). Soils were analysed by the *Universidad Autonoma de Chiapas, Facultad de Ciencias Agrícolas Campus IV* in Metapa, Huehuetán station and Tuxtla Chico (*table II*). The manganese content of the soils is high in Metapa lot 3 (17.08 mg·kg^{-1}), iron is high in Huehuetán left, high values of copper are found in Huehuetán right and Tuxtla Chico is low in phosphorus and high in organic matter.

Among the four sites sampled, a clear division exists between the rainy season and the dry season (*figure 2*). The rainy season is bimodal. Nearly all zones in the region are characterised by high annual precipitation. The

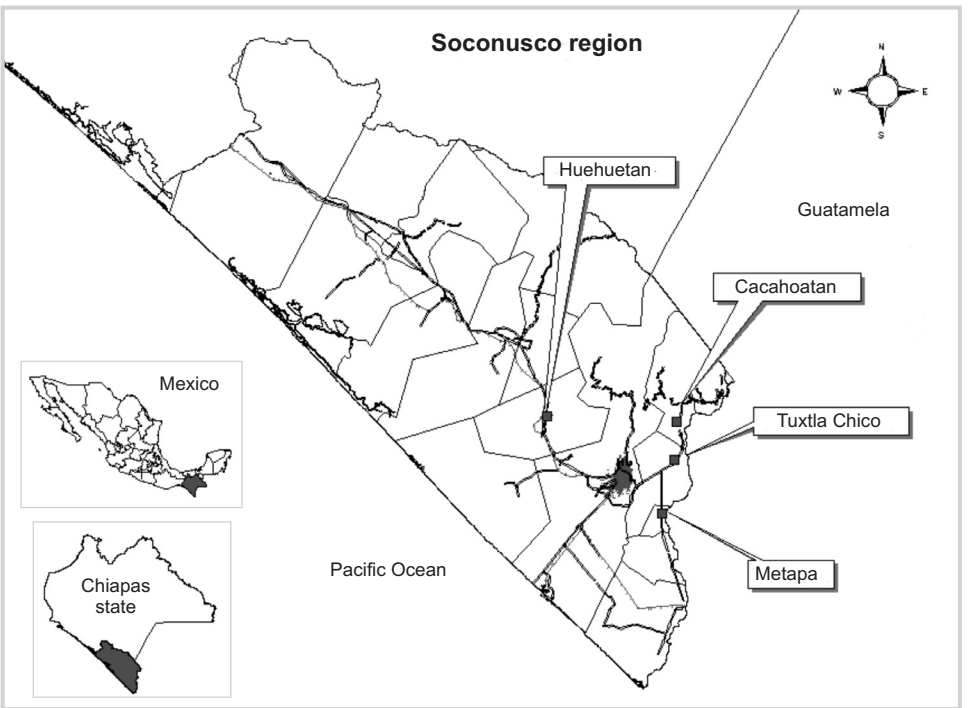

Figure 1.
Location of the Soconusco region (Chiapas state, Mexico) and the situation of the four areas where rambutan trees were observed.

Table I.
Climatologic conditions of the Soconusco region, Chiapas state, Mexico, where rambutan trees were observed.

Sub-regions of the Soconusco region	Type of climate[1]	Annual precipitation (mm)			Average annual temperature (°C)			Evapotranspiration (mm·year^{-1})
		Max.	Med.	Min.	Jan. (min.)	Med.	April (max.)	
Costa	Aw1(w)	1518	1143	784	27.3	28.1	28.8	1653
Planicie	Aw2(w)	1929	1334	850	27.0	28.0	29.2	1588
Inicio de Planicie Sur	Am	2745	2085	1311	26.5	27.2	28.5	1549
Inicio de Planicie	Am(w)	4087	3269	2387	26.6	27.5	28.8	1508
Inicio de Planicie Norte	Am	3101	2395	1775	27.1	27.9	29.3	1639
Ladera Medias	A(C)m(w)	5254	3914	2884	23.4	23.9	24.6	1133
Vertiente de la Sierra	Cw2(w)	1654	1255	832	20.0	21.2	22.2	1270

[1] Classification of Köppen.

origin of the rains is influenced by the topography: the cold fronts descend from the Pacific Ocean and strike *la Sierra Madre*, which is like a south mountain barrier in Chiapas state. The average annual precipitations (*table I*) vary between (1 334 and 3 914) mm·year^{-1} in *Planicie* and *Ladera Medias*, respectively.

The average values of the relative humidity in the zone oscillate between (69 and 79)% (monthly average) during the dry period and (78 up to 84)% during the rainy season. The average monthly temperature shows only slight variation during the year (Cacahoatán 23.9 °C, Huehuetán 28 °C) with (1.5 to 2) °C between the maximum (in April) and the minimum (in January) temperatures. Those temperatures are ideal for the growth of rambutan.

Table II.
Soil analyses for Metapa, Huehuetán station and Tuxtla Chico plantations in the Soconusco region (Mexico). The assumption that the organic C is 58% of the total organic matter is followed here [16].

Plantation studied	Sand	Loam	Clay	Texture	Organic matter	Organic C	[C:N]	N	K	P	Fe	Zn	Cu	Mn	B	pH
	(%)				(%)			(%)	(cmol·kg^{-1})	(mg·kg^{-1})						
Metapa lot 1	49.48	30.36	20.16	Loam	4.37	2.53	12.07	0.21	1.20	25.00	45.17	1.22	2.48	7.11	0.22	5.49
Metapa lot 3	46.48	30.36	23.16	Loam	3.26	1.89	10.50	0.18	1.13	42.00	47.48	2.16	3.24	17.08	0.22	5.63
Huehuetán left	45.48	42.36	12.16	Loam	2.39	1.39	8.76	0.12	0.54	38.00	81.87	1.82	5.05	12.77	0.20	5.63
Huehuetán right	45.48	44.36	10.16	Loam	2.74	1.59	11.55	0.12	0.34	79.00	64.08	2.80	15.53	10.81	0.18	5.26
Tuxtla Chico	52.48	38.36	9.16	Sandy-loam	9.67	5.61	12.46	0.45	0.10	5.00	23.14	2.34	0.68	4.03	0.49	5.45

2.2. Sampling and parameters studied

A series of tree measurements and fruit samples was conducted in different rambutan-growing areas of the Soconusco region (*table III*). In all of the 14 farms sampled, a minimum of ten trees was selected for each treatment. The trees were chosen in such a manner as to have samples of different ages and varieties. From each tree, ten fruits were taken to study fruit internal and external parameters (*table IV*).

The program SPSS, version 10.0, was used for most statistical methods. In the cluster analysis, Ward's method was used so as to join cases into clusters so that the within-cluster variance was minimised.

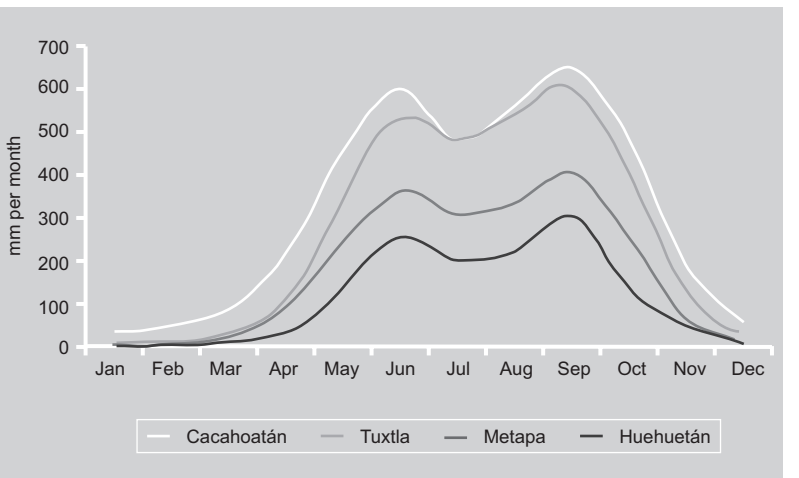

Figure 2.
Average monthly precipitation at Metapa, Huehuetán station, Cacahoatán and Tuxtla Chico, areas of the Soconusco region, Mexico, where the rambutan trees production were analysed.

3. Results

3.1. Fruit characterisation and fruit quality

The fruit quality was dissimilar for the four study areas. The ecosystem and growing management had an important influence on fruit size. Tree size and fruit size are clearly correlated as larger trees gave bigger fruits. Among the different fruit samples collected, it appeared that the environment and cultivation management played an important role in fruit size (*table V*).

The frequency distributions of weight and diameter of fruit and aril (*figures 3, 4*) show that Metapa and Huehuetán locations had a much wider variation available among the fruit samples. Fruit characteristics were more homogeneous in Tuxtla Chico, and particularly in Cacahoatán. All measured criteria show the best values for the Huehuetán fruits. Probably, there exists a good interaction in this location between soil fertility, climate, selected varieties and orchard management. The farm in Metapa presents a more open planting system than in the other places. This improves the ventilation, reduces the appearance of fungi and insect infections and produces more attractive spinterns on the fruits. The fruit colour most liked by the international market is bright red. In Metapa and Huehuetán station, as well as in Cacahoatán, a good number of fruits was of an attractive red colour. Nevertheless, a large number was

Table III.
Experimental places, cultivation parameters and farm owner or field name for the rambutan orchards observed in the Soconusco region (Mexico).

Place	Cultivation parameters	Farm owner or field name
Cacahoatán	Intercropping with *Coffea canephora*	San Alberto
	Home garden	Don Gutiérrez
	Home garden	Don Hernández
	Home garden, original Malaysian material	Don Quilantán
Tuxtla Chico	Home garden	Lot Carretera
Metapa	Orchard with triangular planting system (7.5 × 7.5) m and open soil by tillering	Lot 1
		Lot 3
Huehuetán station	Orchard with planting distance (4 × 6) m, intercropped in the first 3 years with plantain and weed management with slashing by hand	Red round, 5 years old
		Red round, 3 years old
		Orange large, 5 years old
		Orange large, 3 years old
		Orange round, 5 years old
		Orange round, 3 years old
		Esmood Hawaiana, 4 years old

Table IV.
Internal and external fruit parameters analysed to identify varieties of rambutan in the Soconusco region, Chiapas state, Mexico.

Internal fruit parameters	External fruit parameters
Aril diameter (mm), length (mm) and weight (g)	Fruit diameter (mm), length (mm) and weight (number of fruits per kg)
Flavour: the same person tasted 2 fruits out of 10 for each tree sampled with the sweet (1), sweet-sour (2), sour-sweet (3) and sour (4)	Fruit rind colour was classified into yellow (1), yellow-orange (2), orange (3), orange-red (4) and red (5)
Observation of flesh adherence from the seed while eating the fruits regarding the ease of separation: easy (1), easy-medium (2), medium (3), medium-difficult (4) and difficult (5)	Fruits were classified into 7 groups (0 to 6) for spintern colour and dehydration grade: group 0 contains fruits with fresh, firm spinterns without any form of dehydration; group 6 contains fruits with totally dehydrated and black spinterns
Succulence: fruits were classified into juicy (1), juicy-medium (2), medium (3), medium-dry (4) and dry (5)	Presence or absence of fungi
Observation of damage to the flesh caused by insects or rot	Observation of presence or absence of insects
–	Presence of undeveloped fruits

Table V.
Distribution of the number of fruits per kg for rambutan harvested in four sites of the Soconusco region (Mexico).

Classes of fruit weight	Metapa	Huehuetán station	Cacahoatán	Tuxtla Chico
	(%)			
< 33 fruits·kg^{-1}	12	57	19	14
33–40 fruits·kg^{-1}	28	18	56	43
> 40 fruits·kg^{-1}	60	25	25	43

still orange or orange-red. It could be seen that the entire fruit was either red, or red with a yellow part, where it touched another fruit, so that the sun could not reach this part of the fruit.

The international quality standard demands less than 33 fruits per kg [11]. The farm Chinita in Huehuetán station met this requirement for 57% of its fruits. The orchards in Metapa, Cacahoatán and Tuxtla Chico gave a poor result with less than 20% of the fruits

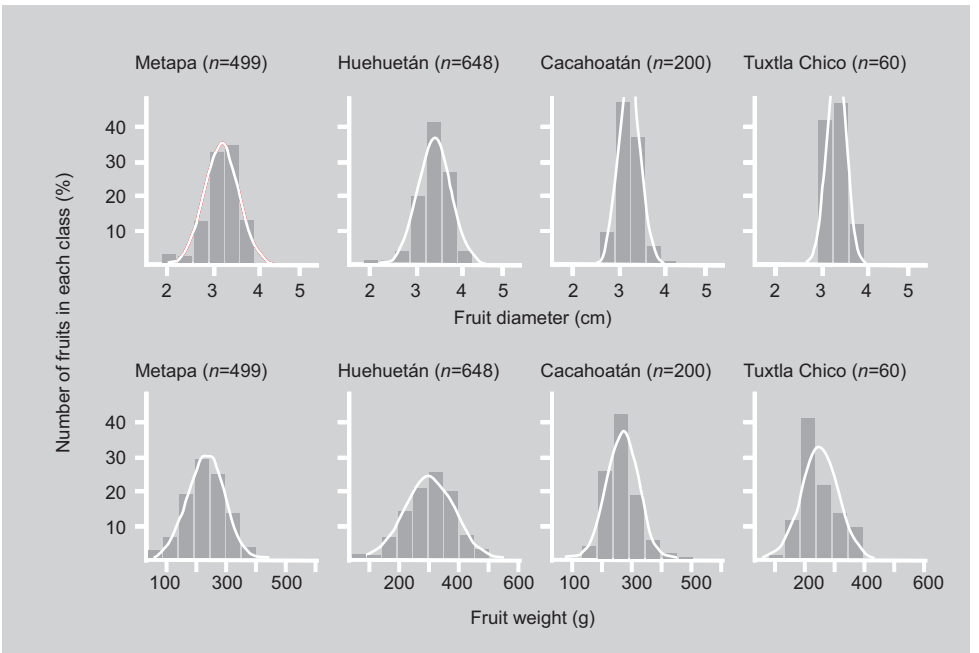

Figure 3.
Fruit diameter and weight classes of rambutan observed in different growing sites of the Soconusco region, Mexico.

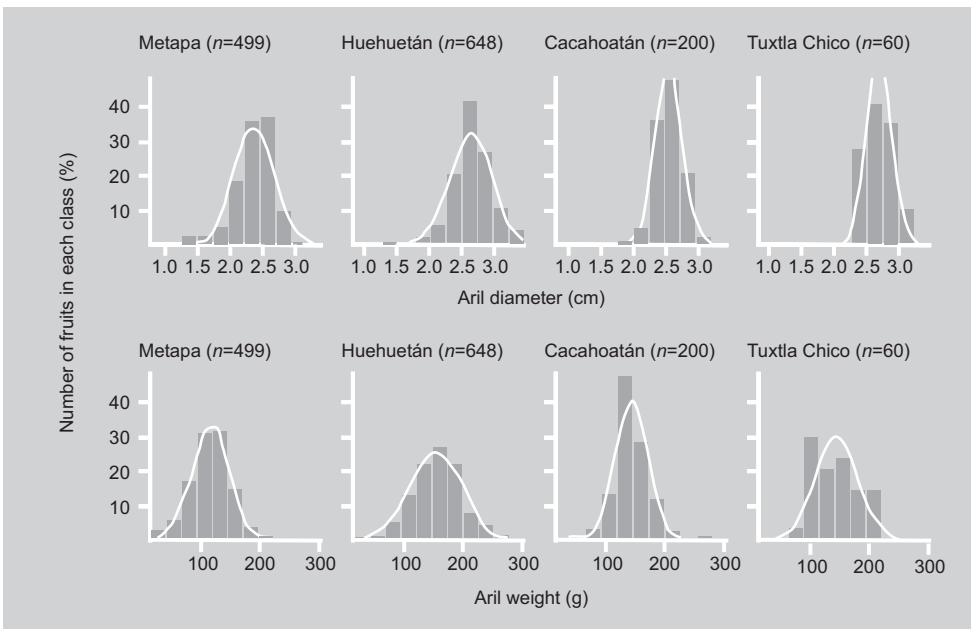

Figure 4.
Aril diameter and weight classes of rambutan in different growing sites of the Soconusco region, Mexico.

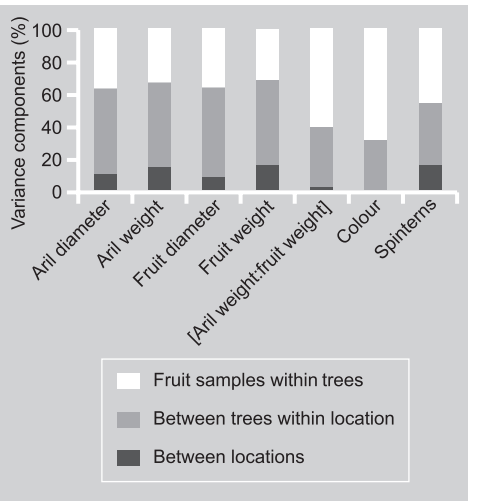

Figure 5.
Variation components for important fruit traits of rambutans from four locations surveyed (the Soconusco region, Mexico).

Table VI.
Characterisation of cluster group centroids from some sampled rambutan fruit (*n* = 139) parameters (Soconusco region, Mexico).

Cluster	Number of trees	Colour unit	Fruit diameter (mm)	Fruit weight (g)	Spintern unit[1]
1	31	2.8	3.5	33	1.4
2	24	2.5	3.2	24	1.1
3	17	4.5	2.7	15	1.9
4	24	4.5	3.2	24	1.0
5	25	4.2	3.3	27	3.4
6	18	3.4	3.7	36	3.9

[1] Fruits were classified into 7 groups (0 to 6) for spintern colour and dehydration grade: group 0 contains fruits with fresh, firm spinterns without any form of dehydration; group 6 contains fruits with totally dehydrated and black spinterns.

with more than 30 g each (*table V*). The internal fruit parameters followed the same characteristics as the external ones. The aril diameter and length and the aril weight were higher than in the other sample sites (*figure 4*). The flavour was sweeter at Metapa and sourer (sweet-sour) at the other places, but this fresh sweet-sour taste is desired. Fruits in Metapa were sweet but often had an off-flavour. Fruits from Huehuetán station and Cacahoatán were juicier than those at Metapa and Tuxtla Chico.

Firm adherence of the pulp to the seed is an undesirable characteristic. For this parameter, fruits from Tuxtla Chico presented the best score, with the flesh quite easily separating from the seed. Metapa had the pulp most strongly attached to the seed. Flavour and succulence were negatively correlated ($r = -0.299$), as seen for all trees. This means that sweet fruits were the driest and sour fruits the juiciest. The correlation between flavour and succulence at the four places separately is not significant. This perhaps indicates a high genetic diversity of the rambutan trees and fruits in the region. Very few rambutan fruits presented a partly rotten aril. This damage was caused by careless harvesting or handling of the fruits. Infection occurred mostly via an opening in the rind.

3.2. Varietal effects

The Huehuetán station is the only site where the different varieties were known. So far, three distinct groups (races) could be identified: red round, orange round and orange large.

For some of the traits, the importance of the location effect was limited, as for colour, fruit diameter or aril to fruit weight (*figure 5*). This means that, for some traits, inherent varietal differences are reflected in tree-to-tree differences which outperform differences between locations. The diversity of varieties planted in the different sites was determined by cluster analysis. Ward's method was used for hierarchical cluster analysis, the dissimilarity measure is the squared Euclidean distance and the variables were standardised. A first, hierarchical cluster analysis of all 139 trees sampled made it possible to divide the trees into six main groups (*table VI*).

When clustering the fruit samples independent of their site of origin, at least six well-defined cluster classes could be identified using the strongly clustering algorithm of Ward on four market-related traits (*table VI*, *figure 6*). A possible market assortment of the six varietal groups can be proposed, using fruit weight as a main criterion and both colour and spinterns as sub-categories (*table VII*).

4. Conclusion

(i) There is an urgent need for further varietal differentiation and characterisation of rambutan in the Soconusco region. Apart from fruit weight, spintern and colour appearances as well as fruit diameter or aril to fruit weight are good indicators. (ii) It is difficult to conclude from the cluster analyses how many varieties, in total, are planted in the Soconusco. Even so, the cluster analyses show that there is a wide range of overlapping varieties to be found in the Soconusco region. Those varieties are in many cases of inferior quality, as the rambutan was multiplied by seed in the first years it was grown in Mexico. (iii) Six major varietal groups (races) were identified.

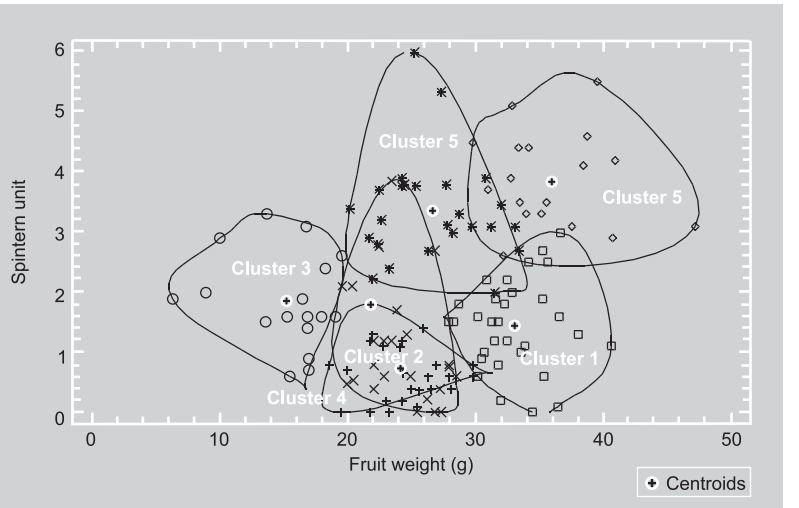

Figure 6.
Scatter plot of 139 trees along six cluster groups of homogeneous rambutan fruit samples based on two important market traits: spinterns and fruit weight. For spintern characterisation, fruits were classified into 7 groups (0 to 6) for spintern colour and dehydration grade: group 0 contains fruits with fresh, firm spinterns without any form of dehydration; group 6 contains fruits with totally dehydrated and black spinterns (the Soconusco region, Mexico).

Table VII.
Assortment of cluster group numbers (1 to 6) according to possible market criteria for rambutan harvested in the Soconusco region (Mexico).

Spintern unit[1]	Colour unit[2]	Fruit weight (g)		
		< 20	20–30	> 30
< 2	< 3	Not applicable	Rambutan group 2	Rambutan group 1
	> 3	Rambutan group 3	Rambutan group 4	Not applicable
> 2	< 3	Not applicable	Not applicable	Not applicable
	> 3	Not applicable	Rambutan group 5	Rambutan group 6

[1] Fruits were classified into 7 groups (0 to 6) for spintern colour and dehydration grade: group 0 contains fruits with fresh, firm spinterns without any form of dehydration; group 6 contains fruits with totally dehydrated and black spinterns.

[2] Fruit rind colour was classified into yellow (1), yellow-orange (2), orange (3), orange-red (4) and red (5).

References

[1] Tindall H.D., Rambutan cultivation, FAO Plant Production and Protection Paper 121, Rome, Italia, 1994, 163 p.

[2] Pohlan J., Borgman J., Memoria diplomado Internacional en fruticultura sostenible, Talleres de Nacional Gráfica,Tapachula, Chiapas, Mexico, 1999, 259 p.

[3] Ramirez T., Alix Ch., Rafie A., Guía para la propagación del rambután en Honduras, FHIA, San Pedro Sula, 2003, 13 p.

[4] Pérez R.A., Pohlan J., La importancia del rambután (*Nephelium lappaceum* L.) en el Soconusco, in: Pohlan J., Borgman J. (Eds.), Memoria Diplomado Internacional en Fruticultura Sostenible, Talleres de Nacional Gráfica, Tapachula, Chiapas, Mexico 1999.

[5] Pérez R.A., El rambután en Mesoamérica, gestación de una realidad empresarial, Ciudad de Guatemala, Editorial IMPRESS, Agri Cultura 3 (35), 2000.

[6] Anon., Anuario Estadístico del Estado de Chiapas, INEGI, Gobierno del Estado de Chiapas, Mexico,1999, 500 p.

[7] Vanderlinden E., Rambutan (*Nephelium lappaceum* L.) cultivation in the Soconusco, Chiapas, Mexico, Hogeschool Gent, Thesis, Belgium, 2003, 105 p.

[8] Nakasone H.Y., Paull R.E., Tropical fruits, Crop Production Science in Horticulture, No. 7, CAB International, Wallingford, UK, 1998.

[9] Anon., El estudio de desarrollo integral de agricultura, ganadería y desarrollo rural de la región del Soconusco (distrito de desarrollo rural no 8, Tapachula) en Chiapas, los estados unidos Mexicanos, Pacific consultants international, Naigai Engineering Co., Ltd., Texto principal y Anexos, Mexico, 1999.

[10] Pohlan J., Borgman J., Eiszner H., Potentials of sustainable agricultural systems in tropical hill regions of Central America, Plant Res. Dev. 45 (1997) 51–60.

[11] Hiranpradit H.P., Paiboonrat S., Chandraparnik S., Jatrajoo S., Quality standardisation of Thai rambutan, *Nephelium lappaceum* L., Acta Hortic. (Wageningen) 2 (321) (1992) 706–712.

Cultivo y calidad del fruto del rambután (*Nephelium lappaceum* L.) cultivado en la región de Soconusco (Estado de Chiapas, México).

Resumen — Introducción. En México, el rambután no es un árbol frutal muy conocido, a pesar de tener un claro potencial de desarrollo en la región de Soconusco, gracias a unas condiciones agroecológicas favorables para la producción de este fruto. Existen actualmente 200 ha de plantaciones en esta región; la adaptación es buena y los rendimientos interesantes. Se estudió la historia del rambután, las prácticas de cultivo, el manejo poscosecha y la comercialización en la región de Soconusco para definir las posibilidades de una extensión del cultivo. En particular, nuestras investigaciones intentaron identificar distintas variedades en las plantaciones frutales de rambután de la zona estudiada. **Material y métodos**. Se estudiaron cuatro zonas a partir de una encuesta efectuada en 14 explotaciones. Se analizaron distintos parámetros de calidad del fruto (diez árboles muestreados por explotación agrícola): diámetro y longitud del fruto, color de la corteza, aspecto de los pelos, longitud y peso del arilo, color de la pulpa, sabor, suculencia, adherencia de la pulpa, presencia de parásitos y enfermedades. **Resultados**. La calidad del fruto fue distinta en cada una de las cuatro zonas estudiadas. Las diferentes muestras de fruta que se tomaron mostraron que el entorno y el manejo del cultivo desempeñaban un papel importante en el tamaño de la fruta. La diversidad de las variedades plantadas en distintos lugares se determinó mediante un análisis tipológico. Independientemente de la situación de los árboles, al menos seis clases fueron identificadas claramente con este método. **Conclusión**. El peso del fruto, el color de la corteza, el aspecto de los pelos, así como el diámetro de la fruta o la relación (peso del arilo / peso del fruto), parecen ser buenos indicadores para evaluar la calidad de la fruta. Los análisis tipológicos evidenciaron que existe una amplia gama de variedades en la región de Soconusco. Se identificaron seis grupos varietales principales. Será necesario proseguir con la tarea de diferenciación y caracterización de rambutanes en Soconusco para un mejor desarrollo de este cultivo en la zona.

México / *Nephelium lappaceum* / localización de la producción / cultivo / frutas / calidad / información situación del mercado / variedades