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Fruit characterization of *Cocos nucifera* L. (ARECACEAE) cultivars from the Pacific coast of Costa Rica and the Philippines

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Abstract

Tall coconut cultivars from the Pacific coast of Costa Rica and the Philippines (San Ramón, Tagnanán, and Laguna), were evaluated for fruit characteristics. Most of the introduced cultivars showed extremely large heterogeneity. A cluster analysis, based on the Ward method, classified the palms into four groups with high internal homogeneity. Some of the evaluated coconut palms from the Costa Rican Pacific area had nut characteristics similar to the San Ramon and Tagnanan palm groups but not to the Laguna group. At the association level used (semipartial R^2 = 0.10), another group which included the remaining palms sampled from the Costa Rican Pacific coast was constituted.

Introduction

In 1981 the National Banana Corporation (CORBANA) of Costa Rica initiated a selection programme of local coconut palms with interesting agronomic characteristics to provide the country with better plants for coconut production. Two years later, seeds of the cultivars San Ramon, Tagnanan and Laguna were imported from the Philippines. This led to the establishment of a germplasm base from which to carry out the evaluation, verification and characterization of the planting materials.

Richardson et al. (1978) showed differences between the cultivars coming from the Pacific coast and those from the Atlantic coast of Costa Rica based on evaluation of fruit components. It further enabled these authors to suggest a possible origin of those materials.

According to Raveendran et al. (1987), nut characteristics provide more reliable criteria for the classification of cultivars than other morphological characters (e.g. plant height, number of functional leaves, trunk thickness, petiole length and number of leaflets). Even though cultivars may differ in a range of morphological traits, differences in fruit characteristics are greater and more informative (Menon & Pandalai, 1958). Additionally, plant (compared to nut) morphological characteristics depend more on plant age, and consequently they need to be evaluated repeatedly (Rao & Pillai, 1982). Climatic and ecological conditions can also influence the expression of these characters (Harries, 1977).

The objective of this study was to characterize the tall populations introduced from the Philippines (cvs. San Ramon, Tagnanan and Laguna) as well as those coming from the Pacific coast of Costa Rica, using variability in fruit characteristics.

Materials and methods

The study was carried out on the germplasm collection located in the Agricultural Research Station '28 Millas', Matina county, province of Limon, from 1991 to 1993. The rainfall during the study years was 3590, 2981 and 2905 mm, for 1991, 1992 and 1993, respectively.

The trial materials consisted of palms coming from the Pacific coast of Costa Rica (P) and the cultivars San Ramon (SR), Tagnanan (T) and Laguna (L), from the Philippines. All of them were 11 years old. The total numbers of individuals per accession at the beginning of the research were 43, 22, 28 and 12 plants, respectively. Of those, six palms of the Pacific population, seven of San Ramon, five of Tagnanan and three of Laguna were selected at random for evaluation. The sample size varied because only plants under full competition were chosen.

During the trial period, 10 samplings from each palm were performed. Two fruits from the middle of the bunch were taken on each sampling date. The fruits were completely or partially dry, and the calyx still had its original immature fruit colour. The harvested fruits were weighed (g), and their components were analyzed: nut weight (g), polar and equatorial diameter of the fruit (cm), weight of endosperm, shell and the water (g), polar and equatorial diameter of the nut (cm). This work was carried out within a 10 day period after harvest. The following relationships of weight and shape were calculated: nut to fruit (%), fruit shape index (polar/equatorial diameter), endosperm to nut (%), shell to nut (%), water to nut (%), dry matter to endosperm copra weight (g), copra to nut (%) and nut shape index (polar/equatorial diameter of the nut). The quantification of fruit components and copra was performed using the methodology described by Wuidart and Rognon (1978).

An analysis of variance (ANOVA) was performed, which prompted the implementation of a new regrouping of the palms, using a cluster analysis, according to the Ward method (SAS Institute Inc.; SAS/STAT, 1989). Finally, a new ANOVA was performed to determine the variables with most differentiation among the groups.

Results

Palms coming from the Pacific coast of Costa Rica (P) differed notably among themselves. This situation is also evident with the San Ramon (SR) and Tagnanan (T) cultivars. Analysis of Variance showed a high variation within cultivars ($P = 0.0001$) for all the variables studied. Differences among cultivars ($\alpha = 0.05$) were only found in six of the sixteen variables: fruit weight, polar diameter of the fruit, polar/equatorial index of the fruit, weight of endosperm, weight of the shell and polar diameter of the nut. At $\alpha = 0.10$, differences were declared in the remaining variables.

The regrouping of the palms in more homogenous clusters is presented in Figure 1. At one R^2 semi-partial of 0.10, the original population was redistributed into four new groups. Group 1 consisted of two palms of the Pacific cultivar (41 and 51), six palms of the San Ramon cultivar (13, 14, 27, 28, 36 and 38) and two palms of the Tagnanan cultivar (2 and 17). Group 2 was formed by three palms from the Pacific coast of Costa Rica (63, 80 and 86). Group 3 comprised three palms of the Laguna cultivar (9, 12 and 13). Group 4 contained one palm of the Pacific cultivar (115), one of the San Ramon (4) and three palms of the Tagnanan cultivar (7, 21 and 33).

The characterization of each of the new groups formed was carried out on the basis of their means of fruit and nut characteristics (Table 1). The differences among the new groups were larger than among the original groups (Table 2), so the *F* values of the Analysis of Variance increased considerably, except for polar diameter and polar-equatorial index.

Group 1 presented rather large and elongated fruits, the polar diameter being the longest of all. The nut was nearly round. The remaining measured variables had intermediate means regarding the other groups.

Group 2 showed small-size and mildly elongated fruits with small-size and nearly round nuts. The weight of nut, endosperm and water, and the nut and water per fruit were the lowest encountered. However, the proportions of endosperm, shell and copra per nut, as well as dry matter were the highest found.

Group 3 displayed rounded and small-size fruits with slightly flattened nuts and the lowest weight values of shell and copra. Meat weight was low, like Group 2. Dry matter, shell and copra per nut were low, like group 4 and opposed to previous groups.

Group 4 offered the heaviest fruit and nuts, as well as the highest percentage of nut per fruit. Fruits of this group were of medium size and rounded. Nuts were the largest, gently flattened and with a high amount of liquid, whose proportion in the nut was the highest found. Similarly, they had the greatest weights of endosperm, shell and copra, nonetheless they exhibited the lowest percentages in these variables. The dry matter content was one of the lowest values.

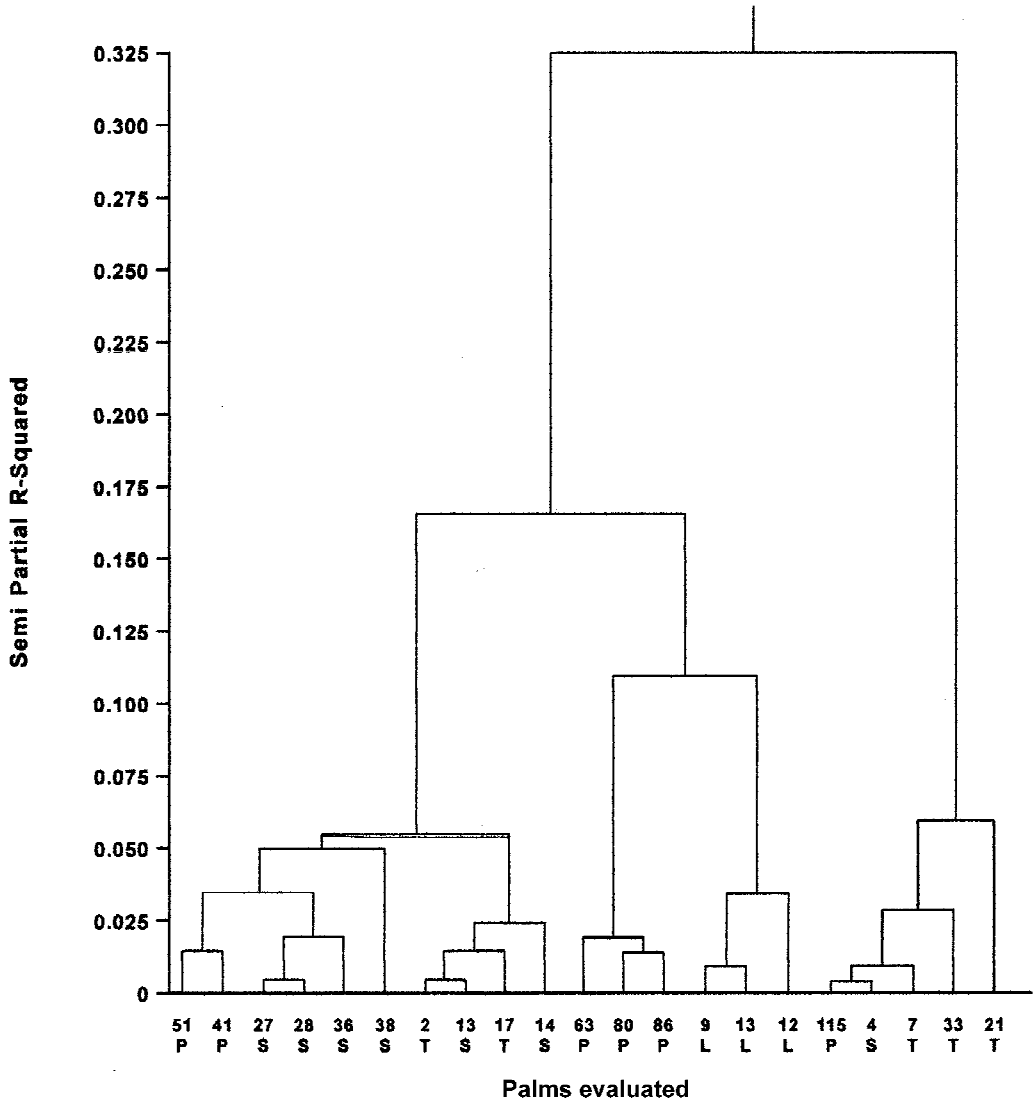

Figure 1. Regrouping of the palms evaluated according to the cluster analysis technique (Ward method).

Discussion

It was possible to identify a series of individuals whose original selection appears to have been inadequate. The redistribution of the original population to groups of greater homogeneity evidenced the high degree of heterogeneity of the coconut palms present in the majority of the cultivars introduced.

Fruit component descriptions showed that the Tagnanan cultivar has a very large nut, high nut/fruit ratio and high values of endosperm, water and copra in absolute and percentage terms (Gemperle & Fremond, 1980). According to Santos (1981), such values are generally of greater magnitude compared to those of the San Ramon cultivar, which also produces large nuts (Menon & Pandalai, 1958; Ohler, 1986). Therefore, it is possible to relate the San Ramon cultivar with Group 1 and the Tagnanan with Group 4.

The inclusion in each of these two groups of a number of palms coming from the Pacific region, and originally identified as belonging to the Pacific cultivar, can be linked, according to Harries (1978), to the trade routes between the Philippines and America which developed in the 16th Century. An additional source could have been via introductions of germplasm from the Far East in 1925 by the interme-

Table 1. Characterization (mean ± SD) of the new groups of palms formed

Variables	Group			
	1	2	3	4
Fruit weight** (kg)	2.09 ± 0.11	1.79 ± 0.11	1.85 ± 0.14	2.47 ± 0.20
Polar fruit diameter** (cm)	24.40 ± 1.32	22.60 ± 1.48	20.60 ± 2.00	22.90 ± 0.51
Polar/equatorial fruit index*	1.25 ± 0.10	1.18 ± 0.04	1.08 ± 0.09	1.10 ± 0.03
Nut weight** (kg)	1.45 ± 0.11	1.16 ± 0.10	1.30 ± 0.08	1.83 ± 0.19
Polar nut diameter** (cm)	14.09 ± 0.6	12.74 ± 0.44	12.43 ± 0.60	14.29 ± 0.64
Polar/equatorial nut index*	0.95 ± 0.05	0.92 ± 0.05	0.85 ± 0.06	0.88 ± 0.03
Nut per fruit** (%)	69.31 ± 3.06	64.33 ± 2.77	70.05 ± 1.42	74.52 ± 1.83
Endosperm weight** (kg)	0.61 ± 0.04	0.53 ± 0.05	0.55 ± 0.04	0.71 ± 0.06
Shell weight** (kg)	0.33 ± 0.02	0.30 ± 0.01	0.28 ± 0.01	0.37 ± 0.03
Water weight** (kg)	0.51 ± 0.07	0.33 ± 0.04	0.46 ± 0.04	0.75 ± 0.12
Endosperm per nut** (%)	42.36 ± 2.53	46.19 ± 0.62	42.58 ± 1.73	39.18 ± 2.22
Shell per nut** (%)	22.64 ± 1.41	25.80 ± 1.75	21.75 ± 0.61	20.47 ± 0.92
Water per nut** (%)	35.03 ± 3.24	27.99 ± 2.14	35.68 ± 2.04	39.64 ± 2.46
Dry matter* (%)	50.13 ± 2.12	53.62 ± 1.76	46.17 ± 3.95	47.75 ± 3.88
Copra weight* (kg)	0.33 ± 0.03	0.30 ± 0.03	0.27 ± 0.03	0.36 ± 0.06
Copra per nut** (%)	22.63 ± 1.87	26.33 ± 0.52	20.97 ± 2.51	19.88 ± 1.95

* = Significant differences among groups at $P < 0.05$.
** = Significant differences among groups at $P < 0.01$.

diary of the banana transnational, United Fruit Company, destined for its research stations in Changuinola, Panama and Lancetilla, Honduras (Harries, 1978). This could account for the presence of this type of coconut palm on the Pacific coast of Costa Rica. Materials with large nuts and high water content, similar to those mentioned in the previous groups, appear sporadically in the coconut growing regions of Costa Rica. They are known as 'chocuanos' by the local people in these areas.

Table 2. F values corresponding to 'among groups' differences. Analysis of Variance was conducted using both 'among original groups' and 'among the new groups resulted from cluster analysis'

Variable	*F* Value	
	Original groups	New groups
Fruit weight	3.50	18.92
Polar fruit diameter	11.08	6.91
Polar/equatorial fruit index	5.73	4.86
Nut weight	2.76	21.27
Polar nut diameter	5.93	10.25
Polar/equatorial nut index	2.52	4.53
Nut per fruit	1.26	9.84
Endosperm weight	4.32	11.14
Shell weight	4.01	13.76
Water weight	1.67	18.47
Endosperm per nut	0.26	6.35
Shell per nut	1.90	11.12
Water per nut	0.53	10.62
Dry matter	2.21	4.23
Copra weight	3.05	3.87
Copra per nut	0.96	7.99

Group 2, consisting of the rest of the plants coming from the Pacific coast, did not present, at the grouping level employed (Semipartial $R^2 = 0.10$), any association with the other cited groups. This finding may be a preliminary indication of different origin.

Group 3 maintained the original identification of the Laguna cultivar, without any change.

The characterization and regrouping of the sample evaluated can contribute, despite the small number of individuals analyzed, to a better knowledge and identification of the different local tall coconut materials present on the Pacific coast of America. These materials, also observed in Mexico (Smith, 1978), Ecuador (Smith, 1974), Colombia and Panama (Romney, 1969) are generally classified as the Panama cultivar. This cultivar, according to Harries (1978), is the equivalent of the Pacific cultivar present in Costa Rica. An ample description of its fruit can be found in Harries (1978) and Vargas (1991). Further research in the identification and characterization of the coconut materials present on the Pacific coast of America would be of benefit to breeding programmes. According to Zizumbo-

Villareal (1996); Zizumbo-Villareal & Piñero (1998) and Zizumbo-Villareal & Quero (1998), the evaluation of the genetic diversity present in Mexico, Costa Rica, Panama, northwest Colombia and Peru could lead to the discovery of genotypes to combat lethal yellowing.

A germplasm survey in Burica (dividing peninsula between Costa Rica and Panama) would be of special interest since the chronicles of the first Spanish explorers (Oviedo and Valdez, 1541) mentioned that coconuts were growing there even at that time. Their presence and origin still continue to be subject of controversy today.

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References

Fernández de Oviedo y Valdez, G., 1959. Historia General y Natural de las Indias, pp. 280–284. Estudio preliminar de Juan Pérez Tudela. Volumen I. Libro IX. Capitulo IV.

Gemperle, E.R. & Y.L. Fremond, 1980. Tagnanán coconut population: A promising breeding material. In: Proceedings International Conference on Cocos and Coconut, pp. 500–510. Kuala Lumpur, Malaysia.

Harries, H.C., 1978. The evolution, dissemination and classification of *Cocos nucifera*. Botanical Rev. 44: 265–320.

Harries, H.C., 1981. Practical identification of coconut varieties. Oleagineux. 36: 63–69.

Menon, L.V. & K.M. Pandalai, 1958. The Coconut Palm. A Monograph, Indian Central Coconut Committee, pp. 86–102. The Times of India Press, Bombay, India.

Ohler, J.G., 1986. El cocotero árbol de la vida. FAO, Roma.

Rao, E.V.V.B. & R.V. Pillai, 1982. Characterization on coconut germplasm based on fruit component analysis. In: Proc. Fifth Symposium of Plantation Crops, pp. 113–124. Kasaragod, India.

Raavendra, T.S., T. Ramanathan, G. Nallathambi & H. Vijayaraghavan, 1987. Metroglyph Analysis in Coconut (*Cocos nucifera* L.). Cocos 5: 32–38.

Richardson, D.L., H.C. Harries & E. Balsevicius, 1978. Variedades de cocoteros en Costa Rica. Turrialba 28: 87–90.

Romney, D.H., 1969. Central America. In: FAO Coconut Breeding, pp. 6–8. Yearly Progress Report.

Santos, G.A., 1981. Coconut varieties and cultivars. The State of Arts on Coconut, pp. 47–66. Philippine Coconut Authority.

SAS Institute Inc.. 1989. User Guide – Version 6. 4th ed. Volume 1. SAS Institute, Inc., Cary, NC, 943 p.

Smith, R.W., 1974. Ecuador. pp: 4. *En*: FAO Coconut Breeding. Yearly Progress Report.

Smith, R.W., 1970. México. pp: 20–21. *En:* Fao Coconut Breeding.

Vargas, A., 1991. Caracterización del fruto de tres variedades y dos híbridos de cocotero (*Cocos nucifera* L.) en Costa Rica. CORBANA. 15: 19–24.

Wuidart, W. & F. Rognon, 1978. Analysis of Nut Components of the Coconut. Method of Copra Determination. Oleagineux. 33: 231–233.

Zizumbo-Villareal, D., 1996. History of coconut (*Cocos nucifera* L.) in Mexico: 1539–1810. Genet. Resour. Crop Evol. 43: 505–515.

Zizumbo-Villareal, D. & D. Piñero D., 1998. Pattern of morphological variation and diversity of *Cocos nucifera* (Arecaceae) in Mexico. Am. J. Botany 85: 855–865.

Zizumbo-Villareal, D. & H. Quero, 1998. Re-evaluation of early observations on coconut in the New World. Economic Botany 52: 68–77.