Sustainable Agriculture Research; Vol. 2, No. 4; 2013
ISSN 1927-050X E-ISSN 1927-0518
Published by Canadian Center of Science and Education

Assessment of Sap Production Parameters From Spathes of Four Coconut (*Cocos nucifera* L.) Cultivars in Côte d'Ivoire

Ysidor N'guessan Konan[1, 2], Jean Louis Konan Konan[1], Rebecca Rachel Assa[2], Brou Roger Konan[3], Joelle Muriel Djeya Okoma[1,2], Kouassi Allou[1] & Henri Marius Godi Biego[2]

[1] Marc Delorme Research Station, Centre National de Recherche Agronomique, Abidjan, Côte d'Ivoire

[2] Laboratory of Biochemistry and Food Sciences, UFR Biosciences, University Felix Houphouët Boigny, Abidjan, Côte d'Ivoire

[3] UFR Sciences and Food Technology, University Nangui Abrogoua, Abidjan, Côte d'Ivoire

Correspondence: N'guessan Ysidor Konan, Laboratory of Biochemistry and Food Sciences, UFR Biosciences, University Felix Houphouët Boigny, 22 BP 582 Abidjan 22, Côte d'Ivoire. Tel: 225-2244-3724. E-mail: haizykonan@yahoo.fr

Received: July 27, 2013 Accepted: August 15, 2013 Online Published: August 28, 2013

doi:10.5539/sar.v2n4p87 URL: http://dx.doi.org/10.5539/sar.v2n4p87

Abstract

Several palm plants have social and economic roles worldwide by providing drinks from their sap. In Côte d'Ivoire, management of the coconut sap is not yet practiced. In this study, parameters related to production of sap have been assessed from four coconut cultivars namely PB 113^+ and PB 121^+ hybrids and WAT and MYD varieties. From all the unopened inflorescences (spathes) studied into the coconut crown, whose ranks varied from 7 to 9, that of rank 8 yielded the highest volume of sap. From this spathe, the PB113^+ hybrid provided the best yield of sap (61.81 ± 20.41 l). Most important proportion of that sap volume was recorded at the morning harvesting. The sap production duration of a spathe varied from 24 ± 1.87 days (MYD) to 46.78 ± 1.86 days (PB 113^+). That duration depended on the length of spathes and regular sap flow allowed by them. Furthermore, the PB 113^+ had the highest number of fruits (NBF = 174.33 ± 78.45 fruits). The results showed that volume of sap available is closely related to the length of production ($r = 0.78$) and the cultivar's nut yield ($r = 0.82$). The use of PB 113^+ hybrid which provided highest quantity of sap is recommended for promoting the production of coconut sap in Côte d'Ivoire in order to improve the benefits derived from this plant.

Keywords: coconut, cultivars, spathe, sap production, Côte d'Ivoire

1. Introduction

Coconut (*Cocos nucifera* L.) is a perennial crop common to tropical lands. It covers 12 millions of ha worldwide (Gunn, Baudouin, & Olsen, 2011). In Côte d'Ivoire, the coconut is cultivated on 50, 000 ha (Konan, Allou, N'goran, Diarassouba, & Ballo, 2006) mainly located on the coastline. It constitutes one of the main cash crops for the farmers of this area. Indeed, coconut products remain source of the main incomes for more than 12, 500 families (Assa et al., 2006). A lot of research works have been carried out to improve the profitability of this palm plant. Some of them resulted to the creation of hybrids with high yields of nuts and coprah. Among these hybrids, the improved PB 121 and PB 113 resulting from Dwarf and Tall crossings (Bourdeix, N'cho, Sangaré, Baudoin, & De Nucé, 1992) are still under large promoting through the world.

The whole coconut plant allows multiple usages (Manisha & Shyamapada, 2011; Batugal, Ramanatha, & Olivier, 2005). However in Côte d'Ivoire, its profitability remains lesser than other perennial cultures such as oil palm, cocoa and hevea. Indeed, valorizations of the Ivorian coconut culture are still mainly concerning trading of the coprah for the oil industry, and immature nuts whose water is a very refreshing drink (Bourdeix, Konan, & N'cho, 2005). Furthermore, competition with other oil crops, such as soya and oil palm, caused a fall in the profitability of coconut and sometimes, led to neglect of the fields by farmers. On the other hand, many countries from South-eastern Asia and Latin America provide varied coconut marketed supplies from all parts of the plant (Borse, Rao, Ramalakshmi, & Raghavan, 2007). Among these products, the coconut inflorescence sap (CIS) records a great interest according to the diversity of its by-products that are the source of high incomes (Cortázar, Rogelio, & Fuentes, 2010; Maravilla & Magat, 1993).

The CIS is naturally a delicious beverage, with 10-15% of carbohydrates content. It is generally whitish and has a nearly neutral pH (Borse et al., 2007). Dehydration of the CIS allows formation of coconut syrup and sugar (Levang, 1988). Besides, it undergoes spontaneous fermentations, leading to a drink with 5-8% of alcohol content (Iwuoha & Eke, 1996); and to an acid raw material containing 4-7% of acetic acid (Gupta, Jain & Shanker, 1980). Thus the CIS is very nutritious (Ezeagu & Fafunso, 2003) and useful for the alcohol and vinegar industries (Van der Vossen & Chipungahelo, 2007).

Many research works are concerned with the coconut sap tapping and its characteristics (Xia et al., 2011; Nakamura et al., 2004). However, there are scanty reports comparing sap production parameters from different cultivars. In addition, production of CIS is not yet practiced in Côte d'Ivoire. The current study aims to investigate the sap production parameters from the most widespread coconut cultivars in Côte d'Ivoire in order to improve the farmer's income.

2. Methods

2.1 Sampling

The plant material was adult coconut trees, more than nine years of age, deriving from four cultivars. Those coconut cultivars were improved hybrids PB 113 (CRD x improved RIT), PB 121 (MYD x improved WAT), and the Malayan Yellow Dwarf (MYD) and West African Tall (WAT) varieties. From these cultivars, unopened inflorescences (spathes), have undergone the sap flow. The study was achieved on three coconut plots of the Marc Delorme research station of the Centre National de Recherche Agronomique at Port-Bouet, Abidjan, Côte d'Ivoire. From each cultivar, three groups (1, 2 and 3) of three coconut trees were randomly considered. They did not have any sign of diseases or ants attack. Thus, 36 coconut trees were assessed from the four cultivars. On each coconut tree, three spathes of ranks 7, 8 and 9 were used for the sap production. At all, 108 spathes (3 spathes x 36 trees) were investigated for the whole work. The sap produced by each spathe was quantified. Therefore 108 volumes of CIS were collected during this assessment. The sap productions from trees of groups 1, 2 and 3 were respectively carried out between November and December 2011, March and April 2012, and from July to August 2012. The CIS was harvested twice a day, at 7 AM and 5 PM.

2.2 Sap Harvesting Process

The harvesting of CIS was from the leaves crown upon the coconut palm. Before harvesting, the spathes were made to undergo four stages consisting of a ligature, inclination, bleeding, and introduction of the section into a cleaned and empty plastic can (Levang, 1988; Cortázar et al., 2010). After reaching the leaves crown with help of a ladder, the spathe was trained to a drooping position by tying and slowly pulling it downward, avoiding breakage at its base, with a twine fastened to the nearby leaf below. Then, a slicing knife permitted the bleeding of the spathe through a transversal cutting and removal of a 15-20 cm length from its tip. The bled part of the spathe was finally introduced into an empty plastic can through a circular opening in order to collect the sap. The can was previously sterilized in hot water at 100 °C. The twine handle of the can was fastened to the spathe, and then both were covered by a plastic cloth against rain and ants. At each harvesting session, the wound was refreshed by removing 3-5 mm thickness from the tip of the spathe to ensure continuous flow of sap (Maravilla & Magat, 1993).

2.3 Assessment of Yield and Duration of Sap Production and Physical Parameters

The sap volume of each harvesting was measured with a measuring cylinder. Comparison of total sap volumes from the three ranks of spathes led to identification of the most suitable development stage for the sap production. The other parameters were assessed with the rank of spathe which allowed the highest yield of sap.

The duration of sap production (DP) or exploitation length of the spathe was the number of days during which it produced the sap. This was assessed by counting days, since the first bleeding until the end of the sap flow from the spathe.

Assessment of the physical parameters consisted in measuring of the length of spathes (LS) and their median circumference (CS) with a measuring tape. Then, the number of fruits (NF) of the whole bunches of the coconut leaves crown at the beginning of sap production was determined.

2.4 Statistical Analysis

The three coconut groups constituted replications of the study. Data was subjected to analysis of variance (ANOVA) at 5% significance level. Means were compared by the tests of Student and Newman-Keuls. Analysed factors were the cultivars and the ranks of spathes. Analysis was performed using a SPSS software package (SPSS 16.0 for windows). The relationship between all traits assessed was valued by the determination of

Pearson index (r).

3. Results

3.1 Production of Sap per Spathe and per Cultivar

Total mean volumes of sap produced per spathe varied from 0.26 l to 61.81 l. They differed spathes of ranks 7, 8 and 9 of the four coconut cultivars ($P < 0.001$). From the whole cultivars studied, spathes of rank 8 produced higher volumes of sap than those of ranks 7 and 9 (Table 1).

Means of sap volumes produced by spathes of rank 8 are 61.81 l, 36.43 l, 14.64 l and 4.54 l respectively for PB 113^+, PB 121^+, WAT and MYD. The lowest sap volumes are recorded from spathes of rank 9, varying from 0.26 l (NJM) to 4.24 l (PB 113^+). Spathes of rank 7 provide intermediate quantities of sap, with volumes of 1.04 l, 5.37 l, 12.68 l and 13.89 l respectively for MYD, WAT, PB 121^+ and PB 113^+.

Table 1. Total sap yield of three ranks of spathes from the 4 coconut cultivars studied

	MEANS ± SD OF SAP VOLUME (L)			
CULTIVARS	Spathe of rank 7	Spathe of rank 8	Spathe of rank 9	P intracultivar
PB 113^+	$13{,}89 \pm 4{,}31^{bA}$	$61{,}81 \pm 20{,}41^{aA}$	$4{,}24 \pm 2{,}54^{cA}$	< 0,001
PB 121^+	$12{,}68 \pm 4{,}38^{bA}$	$36{,}43 \pm 21{,}48^{aB}$	$3{,}26 \pm 2{,}67^{cAB}$	< 0,001
WAT	$5{,}37 \pm 4{,}28^{bB}$	$14{,}64 \pm 12{,}57^{aC}$	$0{,}83 \pm 0{,}62^{bBC}$	< 0,001
MYD	$1{,}04 \pm 0{,}2^{bB}$	$4{,}54 \pm 4{,}00^{aC}$	$0{,}26 \pm 0{,}25^{cC}$	< 0,001
P intercultivar	< 0,05	< 0,05	< 0,05	

Means ± SD (standard deviation), with same minuscule superscript letter (lines) or capital superscript letters (columns), are statistically identical. P, value of probability test; PB 113^+, improved PB 113; PB 121^+, improved PB 121; WAT, West African Tall; MYD, Malayan Yellow Dwarf.

Difference between the four coconut cultivars is also recorded for the three ranks of spathes ($P < 0.05$). Thus, the PB 113^+ hybrid provided highest volumes of sap per spathe, from 4.24 l (rank 9) to 61.81 l (rank 8); followed by PB 121^+ (3.26 L to 36.43 L). WAT (0. 83 L to 14.64 L) and MYD (0.26 L to 4.54 L) produced lowest volumes.

Otherwise, Table 2 shows difference between total sap volumes of rank 8 resulting from the harvestings of 7 AM and 5 PM. Indeed, with PB 113^+ hybrid, harvestings of 7 PM (38.27 ± 13.96 L) recorded higher production of sap than those of 5 PM (23.32 ± 6.80 L). From the PB 121^+ hybrid and its two parents (MYD and WAT), both volumes of sap didn't differ anymore.

Table 2. Total yield of sap provided by spathes of rank 8 of the four coconut cultivars studied according to the period of harvest

CULTIVARS	MEANS ± SD OF SAP VOLUME (L)			
	Morning harvesting (7 AM)	Evening harvesting (5 PM)	t	P intracultivar
PB 113^+	$38{,}27 \pm 13{,}96^{aA}$	$23{,}32 \pm 6{,}81^{bA}$	2,89	0,01
PB 121^+	$23{,}80 \pm 12{,}06^{aB}$	$15{,}64 \pm 6{,}54^{aB}$	1,76	0,09
WAT	$11{,}49 \pm 6{,}41^{aC}$	$7{,}23 \pm 2{,}21^{aC}$	1,36	0,19
MYD	$3{,}79 \pm 1{,}39^{aD}$	$2{,}75 \pm 0{,}64^{aD}$	1,08	0,29
P intracultivar	0,02	0,01		

Means ± SD, with same minuscule superscript letter (rows) or capital superscript letters (columns), are statistically identical. P, value of probability test; t, value of Student statistic test; PB 113^+, improved PB 113; PB 121^+, improved PB 121; WAT, West African Tall; MYD, Malayan Yellow Dwarf.

Daily production of the sap went through four stages (Figure 1). During the initial tapping operation, spathes did not produce a drop of sap throughout the first day (PB 121^+ and PB 113^+) and the second day (MYD and WAT). The second stage lasted 7, 20, 16 and 20 days after the 1st stage, respectively for the MYD, WAT, PB 121^+ and PB 113^+. During this stage, the sap volume that was less than 10 ml at the first day of flow, increased significantly day by day. The 3rd stage was characterized by a maximal and steady daily production. Its extent was 7, 8, 13 and 22 days, respectively for the MYD, WAT, PB 121^+ and PB 113^+. At this stage, the daily main volumes of sap varied between 0.45 l and 0.56 l (MYD); 0.83 L and 1.01 l (WAT); 1.36 l and 1.76 l (PB121^+) and between 1.7 l and 2.50 l (PB113^+). The last stage had continuous decrease of sap exudation, until the end of the spathe exploitation. The sap volumes collected dropped to 0.006 l (MYD), 0.12 l (WAT and PB121^+) and 0.38 l (PB113^+).

3.2 Duration of Sap Production

The duration of production (DP) of the coconut sap from the spathe of rank 8 differed the four coconut cultivars ($P < 0.001$). Considering those cultivars, the DP varied from 24 days to 46.78 days. Spathes of the PB 113^+ hybrid, with a DP of 46.78 days, are exploited longer than those of the three other cultivars. Exploitation of spathes from MYD for sap production lasted the least (24 days). Spathes of PB 121^+ (43.33 days) and WAT (37.78 days) had intermediate duration of sap production (Table 3).

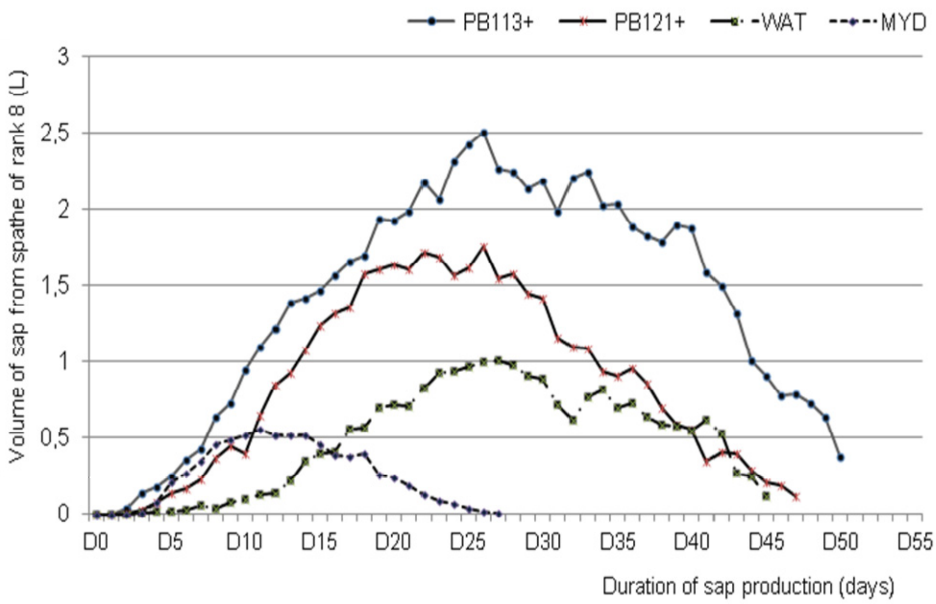

Figure 1. Variation of sap yield from spathes of rank 8 of four coconut cultivars

PB 113^+, improved PB 113; PB 121^+, improved PB 121; WAT, West African Tall; MYD, Malayan Yellow Dwarf.

3.3 Physical Parameters of Coconut Spathes

The physical parameters assessed differed ($P < 0.001$) spathes of rank 8 of the four coconut cultivars (Table 3). The length of spathes varied between 45.48 cm and 79.71 cm. Concerning the spathes circumferences, means differed from 18.22 cm to 24.63 cm. Thus, the length and circumference of spathes of rank 8 from MYD, which were respectively 45.48 cm and 18.22 cm, seemed statistically lower than those of the 3 other cultivars. Otherwise, the longest spathes of rank 8 were provided by the PB 121^+ hybrid (LS = 86.22 cm). The PB 113^+ hybrid and the WAT had intermediate length for spathes of rank 8 (77.44 cm and 79.71 cm respectively). However, the spathes of rank 8 of the PB 113^+ were thicker (24.63 cm) than those of WAT (22.40 cm) and PB 121^+ (22.11 cm). The mean number of fruits on the coconut trees while harvesting the sap differed from 29.44 to 174.33. The PB 113^+ hybrid had higher number (174.33) than the three other cultivars. On the other hand, the coconut trees from MYD provided the lowest number of fruits (29.44).

3.4 Correlations Between Parameters

Significant links between studied parameters were positive at all (Table 4). The length of the spathes of rank 8 was positively linked to their median circumference (r = 0.74) and to their duration of sap production (r = 0.81). Also, yield of sap collected was linked to the DP (r = 0.78). Finally, the sap volume provided by spathes of rank 8 raised as much as the coconut tree seemed able to provide a lot of fruits (r = 0.82).

Table 3. Assessment of some physical parameters from the four cultivars studied

CULTIVARS	MEANS ± SD			
	LS (cm)	CS (cm)	NBF	DP (days)
PB 113$^+$	77,44 ± 8,37^b	24,63 ± 2,22^a	174,33 ± 78,45^a	46,78 ± 1,86^a
PB 121$^+$	86,22 ± 7,41^a	22,11 ± 0,95^b	137,33 ± 32,80^b	43,33 ± 3,04^b
WAT	79,71 ± 8,04^b	22,40 ± 0,43^b	80,67 ± 26,63^c	37,78 ± 7,28^c
MYD	45,48 ± 1,66^c	18,22 ± 0,69^c	29,44 ± 20,99^d	24 ± 1,87^d
P	< 0,001	< 0,001	< 0,001	< 0,001

On the same row, means ± SD (standard deviation) with the same superscript letter are statistically identical. P: value of probability test; LS, length of the spathe, CS, median circumference of the spathe; NBF, number of fruits; DP, duration of sap production per spathe of rank 8; PB 113$^+$, improved PB 113; PB 121$^+$, improved PB 121; WAT, West African Tall; MYD, Malayan Yellow Dwarf.

Table 4. Correlation matrix between five parameters during the production of coconut sap from spathes of rank 8 of the four cultivars studied

	LS	CS	DP	VS	NBF
LS	1				
CS	0,744	1			
DP	0,810	0,750	1		
VS	0,500	0,682	0,783	1	
NBF	0,555	0,627	0,755	0,821	1

LS, length of the spathe; CS, median circumference of the spathe; DP, duration of production of coconut sap per spathe; VS, volume of sap produced per spathe of rank 8; NBF, number of fruits.

4. Discussion

The differed sap productivity of spathes could be attributed to their development stage. Indeed, the sap produced may have resulted from hydro mineral absorption, and photosynthesis and transpiration phenomena (Köstner et al., 2008). It's conducted through the plant vascular tissues, phloem and xylem, toward different organs (Nakamura et al., 2004, Ndon, 2003) according to their needs. Thus, the sap that reaches to the spathes of rank 7, whose inflorescences are still too younger, could contribute primarily for their development. So they couldn't support any more exudation of the sap. On the other hand, the development stage of inflorescences into spathes of rank 8 could allow much sap inside them. One part of this sap ensures maintenance of tissues and the other part flows-out abundantly after cutting the tip of the spathe. From the spathe of rank 9, inflorescences are so mature that they could need little sap for their development. That involves a residual flow of sap into them, and could justify the lowest volumes recorded. Our results of sap yield from spathes of ranks 7, 8 and 9 confirmed the identification of the spathe of rank 8 by Cortázar et al. (2010) for the production of coconut sap.

The ability of the hybrids (PB 113$^+$ and PB 121$^+$) to provide great sap volumes could be due to heterosis phenomenon that occurs from the coconut (De Nucé & Rognon, 1986; Bourdeix, Sangaré, Le Saint & N'cho, 1989). Investigations of B R Konan, J L Konan, Assa, Oulé and Amani (2009) also reported the heterosis effect from PB 121$^+$ hybrid which provides higher yield of nuts and coprah than its two parents MYD and WAT. Thus, yield of sap per coconut tree could be therefore directly related to the potential walnut quantity that it is susceptible to produce. This explains the positive correlation between both parameters. Our results of the daily yield of sap differed from the statements of Cortázar et al. (2010). These authors indicated that the sap production varies from 0.5 to 1 l/spathe/day. The difference could have originated from the type of cultivar. Otherwise, the variation about the daily exudation of sap could result from a progressive involvement of the inflorescence spikelets to the flow of the sap. Thus, the 1st stage corresponds to a latency during which the spikelets inserted onto the inflorescence spine are stimulating to undergo the sap's flow out. After that, these organs allow exudation of the sap, which becomes more intensive, day after day (Sambou, Goudiaby, Ervik, Diallo & Camara, 2002). At the beginning, only the spikelets that appear in the tip part of the spathe undergo the bleeding, and therefore participate to the flow of the sap. The sap exudation increases as more as large number of spikelets are concerned. During the maximum sap yielding stage, the whole spikelets are concerned by the exudation. The delay before this stage and its duration depend on the palm plant. From *Borassus aethiopum*, the maximum sap production occurs after 15 days (Sambou et al., 2002). Close to the end of the sap production from the coconut spathe, a slight number of spikelets remaining at the base of the spathe ensure the sap's flow. The daily yield of coconut sap per spathe is less than the 5 l collected from *Elaeis guineensis* (Lebbie & Guries, 2002), and the 10 l provided by *B. aethiopum* and *Raffia hookeri* (Sambou et al., 2002). Such difference is related to the species of palm plant and the sap tapping process. Indeed, from *E. guineensis*, *B. aethiopum* and *R. hookeri,* sap production often involves incision into the phloem of the plant, leading unfortunately to its death (Karamoko, Djeni, N'guessan, Bouatenin, & Dje, 2012). In this case, the plant's heart is directly bled, and the whole nutrients reserve is engaged. From coconut, sap production implies the spathes only. As a new spathe appears generally monthly, all the spathes can potentially be used when they reach appropriate development stage (Levang, 1988). Other main advantage of the sap production with the coconut spathe lies in the preservation of the plant's life.

The divergence between total volumes of sap recorded at the morning and evening harvestings could result from the exudation length that preceded both sessions. Indeed, harvesting of 7 AM was carried out after 14 hours of sap flow; whereas that of 5 PM was preceded by 10 hours. A lasting sap flow could have ensured high volume of sap. Besides, the biochemical phenomenon of photosynthesis could contribute to this divergence. During this diurnal process, chemical energy (mainly carbohydrates) is synthesized by the plant from sunlight and stored into some organs. Later, it is drained by water through plant tissues toward other organs. The sapflow is linked to the plant's water transpiration (Loustau et al., 1998) happening mostly by night. That justifies greatest debits of sap flow during the night. In addition, from the coconut tree, the respiration activity reaches its lowest level during the night (Anonymous, 1989).

The duration of sap production of spathes is correlated to their length and the regular flow of sap during their exploitation. Indeed, sap harvesting involved removal of a little piece, 3-5 mm thickness, from the spathe at the wounded surface. So, the longer the spathe is the longer the time of exploitation of the sap. This is confirmed by a positive correlation between DP and LS. Our results differed from those of Cortázar et al. (2010) who stated on duration of 20-30 days per spathe. The DP indicated by these authors differed from ours because of differences in coconut plant cultivar and agro-climatic conditions. A positive effect of the DP on the total sap volume was also noticed. Long spathes with regular sap flow were exploited until base of the last spikelets. This improved the probability of much sap record. The duration of coconut sap production per spathe is comparable to that reported from *E. guineensis* and *B. aethiopum* by Sambou et al. (2002).

Assessment of sap production revealed high yield from spathes of rank 8 which appeared therefore more appropriate. Among the four cultivars studied, PB 113^+ hybrid provided the best yield. The main volume of sap derived from spathes of rank 8 of this hybrid exceeded 60 l. The most abundant quantity of sap is recorded during the morning harvesting. Otherwise, analysis of the duration of sap production indicated that the longest spathes had long last exploitation. According to the yield of sap, PB 113^+ hybrid is more recommended for the production of coconut sap for traditional alcoholic drinks. It's followed by the PB 121^+ hybrid which still has large promoting for its high yield of nuts and disease resistance. The WAT variety has also advantages in keeping the genetic pool and providing coconut oil; while MYD could give better sap as regards to nutritious and refreshing water provided by dwarf coconut varieties.

References

Anonymous. (1989). Rapport d'activité. Institut de Recherche sur les Huiles et Oléagineux. *Oléagineux, 44*(4), 220.

Assa, R. R., Konan, J. L., Nemlin, J., Prades, A., Agbo, N., & et SIE, S. R. (2006). Diagnostic de la cocoteraie paysanne du littoral ivoirien. *Sciences et Nature*, 3(2), 113-120.

Batugal, P., Ramanatha, R., & Olivier, J. (2005). Coconut genetic resources, International Plant Genetic Resource Institute- Regional Office for Asia, the Pacific and Oceania (IPGRI-APO), Malaysia. pp. 106-114.

Borse, B. B., Rao, L. J. M., Ramalakshmi, K., & Raghavan, B. (2007). Chemical composition of volatiles from coconut sap (neera) and effect of processing. *Food Chemistry, 101*, 877-880. http://dx.doi.org/10.1016/j.foodchem.2006.02.026

Bourdeix, R., N'cho, Y. P., Sangaré, A., Baudoin, L., et De Nucé, & de Lamothe, M. (1992). L'hybride de cocotier PB121amélioré, croisement du Nain Jaune Malais et de géniteurs Grand Ouest Africain sélectionnés. *Oléagineux, 47*, 619-633.

Bourdeix, R., Sangaré, A., Le Saint, J. P., & et N'cho, Y. P. (1989). Efficacité des tests hybrides d'aptitude individuelle à la combinaison chez le cocotier: premiers résultats. *Oléagineux, 44*, 209-214.

Bourdeix, R., Konan, J. L., & et N'cho, Y. P. (2005). Cocotier, guide des variétés traditionnelles et améliorées, éditions diversiflora, p. 103.

Cortázar, R. M., Rogelio, F. F., & Fuentes del, A. I. M. (2010). Proceso productivo de la "tuba" de coco - una nueva alternativa economica para los cococultores del sureste mexicano, Centro de investigacion regional sureste. *campo experimental chetumal, 1*, 43.

De Nucé de Lamothe M., & et Rognon F. (1986). Cocotiers hybrides ou cocotiers Grands, un choix basé sur des résultats (1), *Oléagineux, 41*, 549-555.

Ezeagu, I. E., & Fafunso, M. A. (2003). Biochemichal constituents of palm wine. *Ecology and Food Nutrition, 42*, 213-222. http://dx.doi.org/10.1080/03670240390226222

Gunn, B. F., Baudouin, L., & Olsen. K. M. (2011). Independent Origins of Cultivated Coconut (*Cocos nucifera* L.) in the Old World Tropics. *PLoS ONE, 6*(6), e21143. http://dx.doi.org/10.1371/journal.pone.0021143

Gupta, R. C., Jain, V. K., & Shanker, G. (1980). Palm sap as a potential starting material for vinegar production. *Research and Industry, 25*, 5-7.

Iwuoha, C. I., & Eke, O. S. (1996). Nigerian indigenous foods: their food traditional operation-inherent problems, improvements and current status. *Food Research International, 29*(5-6), 527-540. http://dx.doi.org/10.1016/0963-9969(95)00045-3

Karamoko, D., Djeni, N. T., N'guessan, K. F., Bouatenin, K. M. J. P., & Dje, K. M. (2012). The biochemical and microbiological quality of palm wine samples produced at different periods during tapping and changes which occurred during their storage. *Food Control, 26*, 504-511. http://dx.doi.org/10.1016/j.foodcont.2012.02.018

Konan, B. R., Konan, J. L., Assa, R. R., Oulé, M., & Amani, G. (2009). The physicochemical characteristics of coconut (Cocos nucifera L.) kernel in germination. *Seed Science and Biotechnology, 3*(1), 1-7.

Konan, J. L., Allou, K., N'goran, A., Diarassouba, L., & et Ballo, K. (2006). Bien cultiver le cocotier en Côte d'Ivoire. Direction des programmes de recherche et de l'appui au développement, CNRA, fiche technique sur le cocotier, p. 4.

Köstner. B., Matyssek, R., Heilmeier, H., Clausnitzer, F., Nunn, A. J., & Wieser, G. (2008). Sap flow measurements as a basis for assessing trace-gas exchange of trees. *Flora, 203*, 14-33. http://dx.doi.org/10.1016/j.flora.2007.09.001

Lebbie, A. R., & Guries. R. P. (2002). The palm wine trade in Freetown, Sierra Leone: production, income, and social construction. *Economic Botany, 56*(3), 246-254. http://dx.doi.org/10.1663/0013-0001(2002)056[0246:TPWTIF]2.0.CO;2

Levang, P. (1988). Le cocotier est aussi une plante sucrière. *Oléagineux, 43*(4), 159-164.

Loustau, D., Domec, J. C., & Bosc, A. (1998). Interpreting the variation in xylem sap flux density within the trunk of maritime pine (*Pinus pinaster* Ait.): application of a model for calculating water flows at tree and stand levels. *Ann. Sci. For., 55*, 29-46. http://dx.doi.org/10.1051/forest:19980103

Manisha, D., & Shyamapada, M. (2011). Coconut (*Cocos nucifera* L.: Arecaceae): In health promotion and disease Prevention. *Asian Pacific Journal of Tropical Medicine, 4*(3), 241-247. http://dx.doi.org/10.1016/S1995-7645(11)60078-3

Maravilla, J. N., & Magat, S. S. (1993). Sequential coconut toddy (sap) and nut production in Laguna tall variety and hybrid coconuts. *Philippine Journal of Crop Science, 18*(3), 143-152.

Nakamura, S. I., Watanabe, A., Chongpraditnum, P., Suzui, N., & Hayashi, H. (2004). Analysis of phloem exudate collected from fruit-bearing stems of coconut palm: Palm trees as a source of molecules circulating in sieve tubes. *Soil Science and Plant Nutrition, 50*(5), 739-745. http://dx.doi.org/10.1080/00380768.2004.10408530

Ndon, B. A., (2003). The Raffia palm. (1st ed.), Concept Publications Ltd, Lagos, Nigeria. p. 16.

Sambou, B., Goudiaby, A., Ervik, F., Diallo, D., & Camara, M. C. (2002). Palm wine harvesting by the Bassari threatens Borassus aethiopum populations in north-western Guinea. *Biodiversity and Conservation, 11*, 1149-1161. http://dx.doi.org/10.1023/A:1016005025090

Van der Vossen, H., & Chipungahelo, G. (2007). Cocos nucifera L., in Van der Vossen H. A. M. and Mkamilo G. S. (Editions), Prota 14: vegetable oils / oléagineux (CD-ROM), Prota, Wageningen, Pays-Bas.

Xia, Q., Li, R., Zhao, S., Chen, W., Chan, H., Xin, B., … Tang, M. (2011). Chemical composition changes of post-harvest coconut inflorescence sap during natural fermentation. *African Journal of Biotechnology, 10*(66), 14999-15005. http://dx.doi.org/10.5897/AJB10.2602