Original Research Article

Agronomic And Economic Assessment Of A Tapping System Reducing The Shortage Of Tapping Manpower In Rubber Tree Cultivation In Southeastern Côte d'Ivoire

ABSTRACT

Rubber trees are the main source of natural rubber and a source of income for several companies and farmers around the world. However, its exploitation is threatened by the lack of tapping manpower which can cause a considerable drop in rubber yield or even the collapse of this sector. This work aims to evaluate agronomically and economically a tapping system reducing the shortage of tapping manpower. The study was carried out at the Société Africaine de Plantations d'Hévéa (SAPH) of Toupah in southeastern Côte d'Ivoire, during three months (from April to June 2018). Rubber tree clones comprising the three main metabolic activity classes, namely GT 1, RRIC 100, IRCA 230 and PB 217, with different years of operation were selected and subjected to two treatments (normal tapping and tapping system reducing the shortage of tapping manpower) in a completely randomized blocks design with 4 repetitions. This comparative study was carried out on the basis of the agronomical parameters and the profitability of the tapping tested. The results showed that compared to normal tapping, tapping system reducing the shortage of tapping manpower is more productive (+17%) and profitable (+18%). This tapping system reduces the operating expenses and social expenses by 3% and the shortage of tapping manpower by 25%. It is an alternative to reduce the enormous shortage of tapping manpower observed in Côte d'Ivoire and around the world.

Keywords: Profitability, rubber tree, shortage of tapping manpower, tapping, yield.

1. INTRODUCTION

Hevea brasiliensis, commonly known as rubber tree, is a tree with high added value derivatives essentially grown for its latex, which is the only commercially exploited source of natural rubber (Compagnon, 1986). Rubber tree is one of the most important cash crops in the world. Natural rubber is one of the major raw materials in industry with an annual world yield in 2016 of 11.5 million tons. Côte d'Ivoire remains the 1st African producer and the 4th in the world. According to the exhaustive census of independent producers, carried out in 2020 by APROMAC, the surface areas planted would be 700 000 ha (APROMAC, 2021). The Ivorian yield reached 850 000 tons in 2020 (APROMAC, 2021). Rubber tree cultivation is gaining more and more momentum in all continents of the world due to the use of rubber in almost all industries. In view of these figures, it seems obvious that rubber tree is an agricultural enterprise of great economic importance. However, its exploitation faces serious threats. Among them is tapping labor shortage in operating rubber tree plantations (Soumahin et al., 2009, Soumahin, 2010; Mahyao et al., 2014; Soumahin et al., 2018). Indeed, several rubber tree plantations are not tapped worldwide due to the lack of tappers. The scarcity of tapping labor is one of the factors causing a considerable drop in rubber industry production. Moreover, the workload and arduousness of operation work favor the instability of this labor.

Being aware of the danger in which natural rubber is, it is important to carry out investigations on the adoption of other operating methods allowing to curb the problem of labor. Optimization of operating systems by reducing the tapping labor is necessary to reduce operating expenses and increase the profit margin of the holders. This study, which focuses on the agronomic, physiological and economic assessment of a system reducing the shortage of tapping manpower in rubber tree cultivation, fits in this context. The system reducing the shortage of tapping manpower consists, for the tappers, in carrying out tree tapping and the additional work by starting tapping earlier in the morning and increasing the number of trees to be tapped without however harvesting their yield. The latter will be the responsibility of an external subcontracting company.

Thus, the overall aim of our study is to contribute to solving the problem of tapping labor shortage.

Specifically, this will include:

- assessing the effect of system reducing the shortage of tapping manpower on the agronomic parameters of the selected rubber tree clones;
- assessing the effect of system reducing the shortage of tapping manpower on the physiological parameters of the selected rubber tree clones;

carrying out an economic study of system reducing the shortage of tapping manpower.

2. MATERIAL AND METHODS

2.1. Study site

The study took place in Côte d'Ivoire, at the Agroindustrial Unit of the Société Africaine des Plantations d'Hévéa in Toupah, located in the municipality of Dabou. The city of Toupah is located at 22 km from Dabou and 52 km from Abidjan on the Abidjan-Grand-Lahou road. The relief is very uneven with a dominance of plains and low plateaus. Of ferralitic type, the soil has a sandy-clay texture and has a gravelly horizon. This type of loose and airy soil makes it fertile and favorable for agricultural activity. The area has a humid tropical climate characterized by heavy rainfall. Four seasons including two rainy seasons are observed with a large one from April to July and a small one from October to November and two dry seasons with a small one from August to September and a large one from December to March. The annual rainfall varies between 1200 and 1700 mm with a good distribution and an annual average of 1660 mm (Brou, 2005). This area is characterized by dense forest vegetation with mainly rubber tree and oil palm plantations.

2.2. Material

2.2.1. Plant material

The plant material used consisted of four *Hevea brasileinsis* clones spread over a surface area of 177.25 ha. These included clones IRCA 230, GT 1, RRIC 100 and PB 217, which combine all three metabolic activity classes.

Clone IRCA 230 is derived from GT1 x IRCA 229 crossbreeding; it has very high vigor, good sucrose reserves and low dry cut incidence despite low thiol values. It is a slow-metabolism clone.

Clone GT 1 is the control clone in all large-scale trials, it was selected around 1930 and is relatively less susceptible to the different leaf diseases (except Colletotrichum, because of its late defoliation), to dry cut or wind damage. It has a good response to stimulation, an average metabolism. It is a high-producing clone whose yield per tree and per tapping is low (Soumahin, 2010). With the exception of a moderate inorganic phosphorus content, which reflects an average metabolism, its physiological characteristics are all favorable to yield.

Clone PB 217 (Prang Besar), stemming from PB 28 x PB 49 crossbreeding, was created in Malaysia in 1955. Its vegetative growth before tapping is comparable to that of GT 1 (Obouayeba, 2005). Its productivity is about 20% higher than that of GT1 with an intense stimulation regime. Its physiological characteristics are expressed by a slow metabolism, significant carbohydrate reserves. This clone is susceptible to wounds and *Colletotrichum gloeosporioides* (leaf disease).

Clone RRIC 100 originates from Malaysia. It stems from RRIC52 x PB86 crossbreeding. It has a physiological profile limited by low thiol content (RSH). Its productivity is greater than or equal to that of GT1 with average vigor. Its physiological characteristics are expressed by an average metabolism, hence its belonging to the average metabolic activity class.

The selection of these clones is justified by the fact that they combine the three main metabolic classes and are clones with sought-after agronomic characteristics (good productivity with resistance to diseases, stress, harsh climates).

Table 1 provides information on the characteristics of experimental plots.

Table 1: Characteristics of experimental plots

Clones	**Tapping systems**	**Tapping year**	**Number of years of exploitation**
IRCA 230	S/2	2010	3
PB 217	S/2	2010	2
GT1	S/4U	1999	13
RRIC 100	S/4U	1999	14
GT1	S/4U	1996	16

2.2.2. Technical material

The technical material used in this study consisted of field equipment and laboratory equipment for biochemical analysis.

The field equipment consisted mainly of knives (Fauna) and gouges for tapping trees, digital cameras for taking photos, notebooks for reporting the production of each tapper, scales to weigh farm gate yield, personal protective equipment kits for the personal protection of tappers (raincoat, rubber boots, goggles, jumper dress), flashlights for lighting tapping panels during unusual working hours, a cooler containing ice for conserving latex samples.

As for the laboratory equipment, it essentially consisted of micropipettes for pipetting, precision electronic scales for weighing latex samples, a water bath for incubation, pillboxes for packaging the latex, an oven for drying the latex, a spectrophotometer for reading the optical densities of the solutions.

2.3. Methods

2.3.1. Experimental design

The experiment was a comparative study of two types of tapping according to tapping orientation (half-spiral downward tapping (S/2) and quarter-spiral upward tapping (S/4U)). The experimental design was in completely randomized Fisher blocks with two treatments and four repetitions. Each repetition constituted an elementary tapping plot. The trees were tapped every four days (d4) which gave four elementary plots per tapper.

In downward as well as in upward tapping, the treatments were therefore as follows:

T0: Normal or classic tapping (control)

T1: Tapping system reducing the shortage of tapping manpower.

The two treatments were made up of several elementary plots or tapping task. Each tapper tapped an elementary plot or tapping task per day. The plot of T0 and that of T1 had the same surface area (89 ha). The number of trees tapped per tapper and per day was 750 and 950 respectively for treatment T0 and for treatment T1. The larger number of tapped trees for treatment T1 is explained by the fact that for this treatment the tapper did not harvest the rubber yield.

2.3.2. Organization of the trial

The human resource used, was divided into two teams:

- A team of tappers (18 people) headed by a team leader, 10 of whom carried out normal tapping and the other 8 carried out tapping system reducing the shortage of tapping manpower;
- A team from an external company comprising 8 people for harvesting the yield of tapping system reducing the shortage of tapping manpower tappers.

The activities were divided between the tappers and a subcontracting team. The tapping and the stimulation of trees were reserved solely for the tappers. The tappers of the normal tapping harvested their yields while those of the tapping reducing the shortage of tapping manpower were harvested by the staff of the external subcontracting company. These activities were carried out from Monday to Saturday.

2.3.2.1. Normal tapping (T0)

The tapping began at 6:00 a.m. and ended around 11:30 a.m. At the end of the tapping, each tapper went to his plot for tapping the next day to harvest his yield.

2.3.2.2. Tapping system reducing the shortage of tapping manpower (T1)

The tapping began at 4:30 a.m. and also ended around 11:30 a.m. After the tapping, the tapper went to his home. The sub-contracting staff harvested his yield.

2.4. Parameters measured

2.4.1. Rubber yield

The daily yield was harvested per tapper, it was then weighed using a scale. The farm-gate weight at the end of this weighing was converted into dry weight using a coefficient (0.65). The dry rubber yield was expressed as:

- Gram per tree per tapping (g/t/t);
- Kilogram per hectare per day (kg/ha/d);
- Kilogram per tapper per quarter (kg/t/q).

2.4.2. Economic study of the trial

The trial expenses were assessed so as to study the cost-effectiveness of tapping system reducing the shortage of tapping manpower compared to normal tapping. These costs related only to socio-economic expenses, exceptional expenses generated by the tapping system reducing the shortage of tapping manpower and certain operating expenses. For each tapping method, the profitability (R) was calculated and expressed in United States Dollars (USD).

2.5.1. Socio-economic expenses

Socio-economic expenses or personnel expenses are the expenses made by the company on its personnel.

2.5.1.1. Base salary and personnel support

The base salary is the gross salary before any deductions. It includes insurance and other support (housing, medical care, etc.). Tappers have a pretty special salary. In fact, to the base salary is added a performance bonus which depends on their production.

2.5.1.2. Amortizations

Amortization makes it possible to assess the wear or the loss of value of a material. The bicycle is the only amortized material.

2.5.2. Exceptional expenses

2.5.2.1. Subcontractor salary

The subcontractor is the staff of the external company that harvested the tapping yield. It was paid according to the yield of the tappers. The unit price was set at 0.011 USD.

2.5.2.2. Purchase of lighting equipment

The practice of tapping system reducing the shortage of tapping manpower between 4:30 a.m. and 6:00 a.m. in the morning required lighting. To this end, a set of adequate equipment was purchased. This equipment consisted of forehead-mounted flashlights and batteries.

2.5.2.3. Operating expenses

For the operation of the farm, various tapping equipment were purchased. Within the framework of this experiment, only the variable material between both types of tapping was taken into account. These included the number of tapping knives, personal protective equipment (rubber boots, jumper dress, goggles, etc.), harvesting container (bucket), tapping gouge handle.

2.5.3. Profitability of the different types of tapping

The profitability of a farm depends on its yield and the expenses it generates. For each type of tapping tested, the profitability (P) was calculated and expressed in USD, from the following relation:

$$P = Or - Oc$$

With Or: Operating revenue (USD), Oc: Operating cost or expense (USD).

The unit price of dry rubber varied each month, thus the unit prices for the three months of study were 1.478 USD/kg (April 2018), 1.586 USD/kg (May 2018) and 1.554 USD/kg (June 2018).

2.6. Data processing method

The data obtained were subjected to statistical analyses carried out using R software version 3.3.1. The Student's t-test was performed to compare the means of the parameters of two sample groups. A significant difference was observed when the probability (p) value of this test was below 5% threshold.

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Assessment of the agronomic parameters studied

3.1.1.1. Effect of the types of tapping on dry rubber yield (g/t/t) of the different clones studied

Figure 1 shows the effect of normal tapping (T0) and tapping system reducing shortage of tapping manpower (T1) on dry rubber yield expressed in grams/tree/tapping (g/t/t) for each clone studied. The average rubber yield obtained with the tapping system reducing shortage of tapping manpower was 111 g; 101g; 126 g; 130 g and 112 g respectively for clones IRCA 230, PB 217, GT 1 (1996), GT 1 (1999) and RRIC 100 against 87 g; 78 g; 94 g; 101 g and 101 g for normal tapping. The Student's t-test carried out showed that the average rubber yield obtained by tapping system reducing shortage of tapping manpower (T1) was significantly greater than the one obtained with normal tapping (T0) for the clones studied except clone RRIC 100 where the average yield of both methods remained statistically identical.

3.1.1.2. Effect of the types of tapping on dry rubber yield in kg/ha/d of the different clones studied

Table 2 shows the effect of normal tapping (T0) and tapping system reducing the shortage of tapping manpower (T1) on the average dry rubber yield in kilograms/ha/day (kg/ha/d) of the clones studied. Rubber yield of the clones studied was significantly influenced by the tapping methods except in clone RRIC 100. The average rubber yield in kg/ha/d of tapping system reducing the shortage of tapping manpower was significantly higher than that of normal tapping in IRCA 230, PB 217, GT 1 (1996) and GT 1 (1999). This average dry rubber yield of tapping system reducing the shortage of tapping manpower of these clones was 36.17, 20.57, 40.95 and 45.90 kg/ha/d respectively against 24.29, 14.41, 29.90 and 35.87 kg/ha/d for normal tapping.

For clone RRIC 100, this average dry rubber yield was 30.78 kg/ha/d for tapping system reducing the shortage of tapping manpower against 29.49 kg/ha/d for normal tapping.

Table 2: Dry rubber yield depending on the type of tapping

Clone	Treatment	Yield (kg/ha/d)	*t*	*p*
IRCA 230	T0	24,29 ± 0,17	50,64	< 0,001
	T1	36,17 ± 0,37		
PB 217	T0	14,41 ± 0,47	8,24	0,0012
	T1	20,57 ± 1,21		
RRIC 100	T0	29,49 ± 0,26	1,53	0,2008
	T1	30,78 ± 0,18		
GT 1 (1996)	T0	29,90 ± 0,70	16,12	< 0,0001
	T1	40,95 ± 0,96		
GT 1 (1999)	T0	35,87 ± 4,57	3,78	0,01938
	T1	45,90 ± 0,47		

t : student's test value *p : probability associated to student's test*

3.1.1.3. Effect of the types of tapping on dry rubber yield (kg/ha/q) of the different clones studied

Table 3 presents the effect of both tapping methods on the average dry rubber yield in kilograms per hectare per quarter (kg/ha/q) of the clones studied. The dry rubber yield of clones IRCA 230, PB 217, GT 1 (1996) and GT 1 (1999) was influenced by the tapping method. The yield recorded with tapping system reducing the shortage of tapping manpower was significantly higher than that of normal tapping. This average rubber yield obtained with tapping system reducing the shortage of tapping manpower was 597.78; 457.56; 652.88 and 796.87 kg/ha/q respectively for clones IRCA 230, PB 217, GT 1 (1996) and GT 1 (1999). Normal tapping of clones IRCA 230, PB 217, GT 1 (1996) and GT 1 (1999) gave respective yields of 365.67; 234.30; 406.98 and 552.93 kg/ha/q. In contrast, in clone RRIC 100, the yields obtained with both methods were statistically identical (421.73 and 526.47 kg/ha/q respectively for treatments T0 and T1).

Table 3: Dry rubber yield in kg/ha/q depending on the type of tapping of the different clones studied

Clone	Treatment	Yield (kg/ha/q)	t	p
IRCA 230	T0	365,67 ± 9,74	4,14	0,01437
	T1	597,78 ± 96,62		
PB 217	T0	234,30 ± 11,80	11,14	0,00037
	T1	457,56 ± 32,66		
RRIC 100	T0	421,73 ± 59,65	0,86	0,4374
	T1	526,47 ± 201,87		
GT 1 (1996)	T0	406,98 ± 65,76	5,627	0,00491
	T1	652,88 ± 37,51		
GT 1 (1999)	T0	552,93 ± 44,34	7,47	0,0017
	T1	796,87 ± 35,04		

t: student's test value *p: probability associated to student's test*

3.1.2. Profitability of the different types of tapping

The cumulative dry rubber yield in kg of all the clones studied and the unit price of dry rubber for each month of the quarter made it possible to calculate the revenue for each method (Table 4). The revenue from tapping system reducing the shortage of tapping manpower (75,486.46 USD) was higher than that of normal tapping (64,341.54 USD) over the entire study quarter with a difference of 11,144.92 USD, that is, 17.32% increase in revenue.

Table 4: Operating revenue depending on the type of tapping

Treatments	**Month**	**Yield (kg/treatment)**	**Rubber price/kg (USD)**	**Operating revenue (USD)**
T0	April	8,892.39	1.478	13,142.95
	May	17,342.97	1.586	27,505.95
	June	15,246.23	1.554	23,692.64
	Total	**41,481.59**		**64,341.54**
T1	April	10,532.87	1.478	15,567.58
	May	19,306.49	1.586	30,620.09
	June	18,853.79	1.554	29,298.79

Total	**48,693.15**	**75,486.46**

The expenses generated by both tapping methods are recorded in Table 5. The social expenses and operating expenses of normal tapping were higher than those of tapping system reducing the shortage of tapping manpower. Only tapping system reducing the shortage of tapping manpower generated exceptional expenses up to 698.37 USD. The sum of all the expenses showed that the expenses for normal tapping (3,180.32 USD) were higher than those for tapping system reducing the shortage of tapping manpower (3,083.61 USD) with a difference of 96.71 USD, that is, a reduction of 3,04% of expenses with the practice of tapping system reducing the shortage of tapping manpower.

Table 5: Cost of each type of tapping tested

Rubrics	**T0**	**T1**
Social expenses (USD)	2,600	1,950
Operating expenses (USD)	580.32	435.24
Exceptional expenses (USD)	0	698.37
Total (USD)	**3,180.32**	**3,083.61**

The profitability (P) obtained after deduction of expenses from the revenue was higher with tapping system reducing the shortage of tapping manpower (72.402,85 USD) than with normal tapping (61.161,22 USD, Table 6). The difference was 11,241.63 USD, that is, an increase of 18.38% in profits.

Table 6: Profitability of the two types of tapping tested

Treatments	**Operating revenue (USD)**	**Operating cost (USD)**	**Profitability (USD)**
T0	64,341.54	3,180.32	61,161.22
T1	75,486.46	3,083.61	72,402.85

3.2. Discussion

3.2.1. Effect of the types of tapping on dry rubber yield

The average dry rubber yield in grams per tree and per tapping (g/t/t) showed a significant difference between treatments T0 and T1 with an average yield of T1 higher than that of T0 in clones IRCA 230, PB 217 and GT1. This result confirms that treatment T1 is more productive for these clones. This assertion is confirmed by the results of Diarrassouba *et al*., (2012) who obtained an average dry rubber yield of 50 g/t/t in clone PB 217 which is half of the yield (101 g/t/t) obtained with the practice of tapping system reducing the shortage of tapping manpower for the same clone. Coulibaly *et al*., (2017) obtained a dry rubber yield of 73 g/t/t in clone PB 235, lower than that obtained by tapping system reducing the shortage of tapping manpower (111 g/t/t) in this study in clone IRCA 230 belonging to the same metabolic activity class.

For clone RRIC 100, both types of tapping induced statistically identical average dry rubber yields. This result attests that both types of tapping are productive for this clone and that treatment T1 does not influence the yield of this clone.

Concerning the average daily dry rubber yield (in kg/ha/d), the rubber trees subjected to treatment T1 gave significantly higher yields than those of the rubber trees subjected to treatment T0 in the clones studied except clone RRIC 100. For the latter, the average daily dry rubber yield from the trees using both tapping methods were statistically identical.

Similarly, the average quarterly dry rubber yield (in kg/ha) evolved in the same direction as the daily dry rubber yield. The yield of the trees subjected to treatment T1 (tapping system reducing the shortage of tapping manpower) was significantly higher than that of the trees of treatment T0 (normal tapping) in all the clones except clone RRIC 100 where the average dry rubber yields of the trees of both tapping methods were statistically identical.

In view of all these results, it appears that tapping system reducing the shortage of tapping manpower gives better yield than normal tapping. Indeed, the earliest tapping favors a high flow rate and an extension of the latex flow time, thus increasing rubber yield (Compagnon, 1986).

3.2.2. Effect of the types of tapping on farm profitability

The economic gain obtained from tapping system reducing the shortage of tapping manpower was higher (72.402,85 USD) than that from normal tapping (61,161.22 USD) with a difference of 1,1241.63 USD, that is, an increase of 18.38% in profits. This profit margin for tapping system reducing the shortage of tapping manpower was due to the 17% increase in operating revenue and the 3.04% reduction in operating expenses compared to normal tapping.

The 17% increase in operating revenue induced by tapping system reducing the shortage of tapping manpower could be explained by the fact that this practice increased dry rubber production by 17%. Since tapping system reducing the shortage of tapping manpower generated additional (exceptional) expenses compared to normal tapping, it recorded a reduction in expenses by 3.04% compared to normal tapping. This decrease would be essentially linked to social expenses and operating expenses, because tapping system reducing the shortage of tapping manpower reduces the number of staff supported by 25% by increasing the size of tapping task.

4. CONCLUSION

At the end of this comparative study between normal tapping and tapping system reducing the shortage of tapping manpower, with a view to reducing the need for tapping labor, it appears that tapping system reducing the shortage of tapping manpower is more productive and profitable than normal tapping.

In fact, tapping system reducing the shortage of tapping manpower, characterized by an earlier tapping start, an increase in tapping task and the non-collection of latex by the tapper, induces higher rubber production (in g/t/t, kg/ha/day and kg/ha/q) (+17%) than that of normal tapping regardless of the clone (GT1, PB 217, IRCA 230 and RRIC 100).

From an economic point of view, tapping system reducing the shortage of tapping manpower reduces operating expenses and social expenses by 3% and increases profit margins by 18%.

Tapping system reducing the shortage of tapping manpower, makes it possible to reduce the need for tapper by 25%. Tapping system reducing the shortage of tapping manpower therefore appears as an alternative to reduce the enormous need for tappers observed in Côte d'Ivoire and around the world.

This study on tapping system reducing the shortage of tapping manpower is not exhaustive. It would be wise to pursue it in the following areas:

- Assess the effect of tapping system reducing the shortage of tapping manpower on tree growth and dry cut rate;
- Assess the effect of tapping system reducing the shortage of tapping manpower on tapping quality and tappers' health condition;
- Extend this study to other rubber tree clones, in other rubber-growing regions and over the long term.

REFERENCES

APROMAC. The success of the rubber sector in figures. 2021. Accessed 24 June 2022. Available: www.apromac.ci/le-succes-de-la-filiere-hevea-en-chiffre/ French

Brou YT. Climate, socio-economic changes and landscapes in Côte d'Ivoire. Summary report of scientific activities presented with a view to obtaining the authorization to direct research. University of Sciences and Technologies of Lille, 2005: 212 p. French

Companion P. Natural rubber. Paris, France: Coste R.Ed. G.P. Maisonneuve & Larose. 1986: 595 p. English.

Coulibaly FL, Traore SM, Soumahin EF, Obouayeba S and Keli ZJ. Incidence of tapping frequencies d3, d4 and d6, at low hormonal stimulation regimes, on the descending panel of the rubber tree clone PB 235 in Côte d'Ivoire. International Journal of Biological Chem. Science. 2017: 11(4): 1655-1668. English.

Diarrassouba M, Soumahin EF, Coulibaly LF, N'guessan BA. Dick KE, Kouame C, and Obouayeba AS. Latex harvesting technologies adapted to clones PB 217 and PR 107 of Hevea brasiliensis Muell. Arg. of the slow metabolism class and to the socio-economic context of Côte d'Ivoire. International Journal of Biosciences (IJB) 2012: Vol. 2, No. 12, pp 125-138.

Mahyao A, Soumahin EF, Koffi C, Coulibaly LF, N'guessan AEB, Kouame C, Obouayeba S, Economic analysis of compensating systems for the tapping labor in the rubber industry in Côte d'Ivoire. Journal of Rubber Research, 2014: 17(1), 34-44 pp.

Obouayeba S. Contribution to the determination of the physiological maturity of the bark for tapping Hevea brasiliensis Muell. Arg. (Euphorbiaceae): openness standards. University Doctorate Thesis, University of Cocody, Abidjan, Ivory Coast. 2005: 223 p. English.

Soumahin EF. Optimization of operating systems in rubber cultivation by reducing tapping intensities. University Doctorate Thesis, University of Cocody, Abidjan, Ivory Coast. 2010: 94 p. English.

Soumahin EF, Obouayeba S and Anno AP, 2009. Low tapping frequency with hormonal stimulation on Hevea brasiliensis clone PB 217 reduces tapping manpower requirement. Journal of Animal & Plant Sciences. 2009: 2(3): 109-117.

Soumahin EF, Adou BYC, Tonessia DC and Oobouayeba S. Production systems to minimize the latex harvesting cost of rubber. European Scientific Journal. 2018: Vol 14, No 30, 190-205.