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Economic Analysis of Compensating Systems for the Scarcity of Tapping Labour in the Rubber Industry in Côte d'Ivoire

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Labour is the principal constraint in rubber cultivation. To solve this problem a study was conducted at smallholdings in Côte d'Ivoire to assess Low Intensive Tapping System (LITS) in comparison to the traditional High Intensive Tapping System (HITS) on clones PB 260 and GT 1. Analyses were based on profitability of LITS and efficiency of agronomic and physiological parameters of rubber trees. Results showed that the more profitable LITS were S/4U d4 ET10% 12/y (GT 1), S/2 d4 ET5% 4/y (PB 260) and S/2 d5 ET5% 10/y (GT 1). Using these systems, the tapper requirement was reduced by 25 to 40% and the land-man ratio increased from 3 to 4 or 5 ha per man. Rubber yield was increased by 22% only for upward tapping of GT 1. In downward tapping of PB 260 and GT 1, rubber yield was of the same order. The impact on production due to the reduction of labour and the increase in stimulation was optimal when the tapper was remunerated by tapping days. Agronomic performance, physiological profiles and TPD incidence were similar or lower compared to HITS. These three tapping systems turned out to be the best alternatives to LITS for these clones.

Keywords: *Hevea brasiliensis*; Low Intensive Tapping System; labour factor; stimulation; profitability; Côte d'Ivoire

Latex from rubber trees (*Hevea brasiliensis*) is harvested by tapping and various tapping systems have evolved, leading to increased productivity while maintaining health of the tree and the capacity to prolong its productive lifespan[1]. Among several factors *i.e.* terrain, soil fertility, clones, age of trees, fertilisers, weather conditions, tapping systems, levels of mechanisation, skills and quality of labour, which affect productivity of rubber trees in the plantation industry, the labour factor is most important[1]. According to Navamukundan[1], higher productivity can be achieved either by producing more with the same input or by producing the same output with less input. According to Othman[2],

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stimulation practices judiciously applied boosts latex production, improves productivity of the tapper and subsequently, his income. In Cote d'Ivoire, the significance of tappers creates the labour factor, a principal constraint in tapping systems of rubber trees without taking into account effects on production costs[3]. In view of the high level of labour factor cost in smallholdings at Cote d'Ivoire, a study was conducted by the national agronomic research centre from 2008 to 2010 in order to reduce labour demand in tapping systems. New exploitation systems, which are less labour intensive and highly stimulated were compared to the traditional exploitation systems, which are more labour intensive and less stimulated[3–6]. This study aims to identify new, less labour intensive tapping systems to replace traditional tapping systems which are generally high labour intensive[4–6]. This economic study should determine profitably of less labour intensive tapping systems that could be used by producers to compensate for the scarcity of tappers in smallholdings[5,6]. Through a multidisciplinary approach based on the evaluation of agronomic and economic indices (latex production, vegetative growth and the physiological status of rubber trees, dryness sensibility and the profitability of systems), new low intensive tapping systems were selected for clones GT 1 and PB 260 in Cote d'Ivoire.

EXPERIMENTAL

The first step in transfer of technology (TOT) is to identify tapping and stimulation techniques suitable to increase yield without deleterious effects on tree health[2]. Sufficient data should be collected to indicate that the technology is matured and proven to give the desired impact. In Côte d'Ivoire, three research sites were selected for the study: Divo (5º50'N, 5º21'W) and Gagnoa (6º09'N, 5º52'W) in the Centre West and Bonoua (5º16'N, 3º36'W) in the South East. These two regions are characterised by a sub-equatorial climate with a bimodal regime[7] (two rain seasons from April to July and October to November; and two dry seasons from December to March and August to September). Soils are ferallitics derived from tertiary sand[8] and rainfall varies from 1400 to 1600 mm in the Centre West and from 1800 to 2000 mm in the South East[7].

Agronomic data were collected in Divo, Gagnoa and Bonoua where, 25 upward tapping systems were tested on the *Hevea* clone GT 1, 25 downward tapping systems on PB 260 and GT 1, respectively. The experimental design was blocks of Fisher of 25 treatments for each tapping system tested and three replications per treatment with ten trees per treatment. Only downward tapping is practiced in smallholdings in Côte d'Ivoire, but upward tapping was also tested. According to Obouayeba *et al.*[9], the productivity of downward tapping is satisfactory and upward tapping increased rubber tree productivity.

From the agronomic data, an economic analysis was then undertaken. In each of the three research sites, the profit margins of 24 Low Intensive Tapping Systems (LITS) were compared to the profit margin obtained with the traditional High Intensive Tapping System (HITS). The profit margin (M) is the difference between the return on sales (R) and the cost of fresh latex production (C). The LITS which has profitability equal to or more than HITS, could then be considered as an alternative to HITS for reducing labour factor in tapping systems. In addition to profit margin analysis, the efficiency of the two factors *i.e.* capital (K) and labour (W), affecting productivity was estimated by regression of the Cobb Douglas model of production. This model is widely used and well adapted for estimating production function of agricultural products in view of its good statistical quality and operational characteristics. In the case of fish products, the Cobb Douglas model was used by Koffi[10] to estimate the function of production in small inland waters in the north of Côte d'Ivoire. In this study, fish production was expressed as a Cobb Douglas log linear function of fish stock (K) available in water and the fishing effort (L). Finally, the method for selecting new LITS as an alternative to HITS in smallholdings was based on profit margins and the efficiency of factors of production as well as on agronomic and physiological profiles of the rubber trees tapped.

Estimation of Return on Sales

The return on sales (R), expressed in F CFA per hectare per year, was calculated using *Equation 1*.

$$R = Q_{fl} \times P_{fl} \text{ With } Q_{fl} = Q_{dl}/0.625 \qquad \ldots 1$$

With,
Q_{fl} = quantity of fresh rubber (kg/ha/year)
Q_{dl} = quantity of dry rubber (kg/ha/year)
P_{fl} = price of fresh rubber (F CFA/kg)

Estimation of the Price of Fresh Rubber

From annual data of the purchase prices of fresh rubber with producers for the period of 23 years (1989 to 2011) obtained through APROMAC in Cote d'Ivoire, prices were actualised in 2001 considering an actualised rate, *i* of 3 percent. In this study, an average actualised price was calculated considering the post devaluation period of 18 years (1994 to 2011) under the principle that 1 F CFA available *n* years ago is *y* F CFA today according to *Equation 2*.

$$y = 1 \times (1 + i)^n \qquad \ldots 2$$

Estimation of the Cost of Production

The cost of latex production (C) is principally affected by the cost of stimulation product (K) and the labour cost (W), under *ceteris paribus* conditions, expressed as any other variables of the cost of production being presumed to be constant.

$$C = K + W \qquad \ldots 3$$

Variables linked to the cost of stimulation product (K) are the type of product used (Ethrel product mixed with palm oil or a ready stimulation product mixed with water), the concentration of Ethephon (ET) product (2.5, 5 or 10%) and the frequency of stimulation (4, 6, 8, 10 or 12 stimulations per tree per year). In this study, K_1 is considered as the cost of stimulation product by using Ethrel mixed with palm oil and K_2, the cost of stimulation by using a ready stimulation product mixed with water. K_1 and K_2 are expressed in F CFA per hectare per year and are calculated using *Equation 4*.

Estimation of K_1

$$K_1 = (Q_{Ethrel} \times C_{Ethrel}) + (Q_{Palmoil} \times C_{Palmoil}) \qquad \ldots 4$$

with,
$Q_{EthrelX\%}$ (g/ha/year) = quantity of ethrel with x% ET concentration
C_{Ethrel} (F CFA/ha/year) = cost of ethrel with x% ET concentration
$Q_{PalmoilX\%}$ (g/ha/year) = quantity of palm oil with x% ET concentration
$C_{Palmoil}$ (F CFA/ha/year) = cost of palm oil with x% ET concentration
$Q_{Ethrel10\%}$ = 0.25g/tree × NbStimulation/tree/year × Nbtrees/ha/year
$Q_{Ethrel5\%}$ = 0.125g/tree × NbStimulation/tree/year × Nbtrees/ha/year
$Q_{Ethrel2.5\%}$ = 0.0625g/tree × NbStimulation/tree/year × Nbtrees/ha/year

$Q_{Palmoil10\%}$ = 0.75g/tree × NbStimulation/tree/year × Nbtrees/ha/year

$Q_{Palmoil5\%}$ = 0.875g/tree × NbStimulation/tree/year × Nbtrees/ha/year

$Q_{Palmoil2.5\%}$ = 0.9375g/tree × NbStimulation/tree/year × Nbtrees/ha/year

$$C_{ethrel} = Q_{EthrelX\%} \times \frac{7000 \text{ F CFA}}{1200\text{g}}$$

$$C_{Palmoil} = Q_{PalmoilX\%} \times \frac{1250 \text{ F CFA}}{900\text{g}}$$

Estimation of K_2

K_2 = 2000 F CFA × k × NbStimulation/ha/year …5

with,
k = 1 for concentration of ET at the level of 10%
k = 1/2 for concentration of ET at the level of 5%
k = 1/4 for concentration of ET at the level of 2.5%

Variables linked to the labour cost (W) are the tapping method, upward or downward tapping at half cut (S/2), quarter cut (S/4) or eighth spiral cut (S/8), and the tapping frequency (d_k) namely d_3 (every 3 days), d_4 (every 4 days), d_5 (every 5 days) or d_6 (once a week). From the tapping frequency (d_k), the number of tapping days (Wd_k) is determined, considering that one hectare is tapped by one tapper per day. W depends on the method of payment of the tapper chosen by the entrepreneur. The first method consists of remunerating the tapper by quantity of fresh rubber produced on a basis of 62 F CFA/kg. The second one is the remuneration by tapping day on a basis of 2 250 F CFA/day/hectare. W_1 is the labour cost based on the first method and W_2, the labour cost based on the second one. W_1 and W_2 are expressed in F CFA per hectare per year and calculated using *Equations 6* and *7*.

Estimation of W_1

$W_1 = Q_{fl}$/ha/year × 62F CFA/kg …6

Estimation of W_2

$W_2 = Wd_k$ × 2250F CFA/day/ha …7
Wd_k = number of tapping days/ha/year
with Wd_3 = 104, Wd_4 = 78; Wd_5 = 62 and Wd_6 = 52 days/ha/year

Estimation of Profit Margins

Profit margins were estimated for each of the 25 tapping systems of exploitation tested in each of the three research sites considering four scenarios in calculating the cost of production (C). The first is M_1, with the cost of production C_1, when the entrepreneur uses Ethrel with palm oil (K_1) product to stimulate rubber trees and remunerate the tapper per quantity produced (W_1). The second is M_2, with C_2, the cost when Ethrel (K_1) is used with palm oil to stimulate rubber trees and the tapper is paid per day (W_2). The third scenario is M_3, with C_3, the cost when the entrepreneur uses a ready stimulation product with water (K_2) and remunerates the tapper based on per quantity produced (W_1). The last one is M_4 and C_4 the cost when a ready stimulation product is used with water (K_2) and the tapper is paid per day (W_2). Profit margins are expressed in F CFA/ha/year and are calculated using *Equation 8* to *11* below.

$M_1 = R - C_1$, with $C_1 = K_1 + W_1$ …8

$M_2 = R - C_2$, with $C_2 = K_1 + W_2$ …9

$M_3 = R - C_3$, with $C_3 = K_2 + W_1$ …10

$M_4 = R - C_4$, with $C_4 = K_2 + W_2$ …11

Efficiency of K and L

In this study, the inputs considered for latex production are labour (W) and capital (K) factors. The efficiency (or productivity) of these two factors was determined by regression of the model of Cobb Douglas expressed in *Equation 12*.

$$Y = K^{\alpha} + W^{\beta} \qquad \ldots 12$$

with,

$Y = Q_{fl}$ (quantity of fresh rubber)

$K = K_1$ or K_2 (cost of stimulation product)

$W = Wd_k$ (number of tapping days)

A logarithm transformation of variables was necessary to analyse the impact of the two factors K and W on latex production. The log linear model of Cobb Douglas is expressed as follows taking into account the two types of stimulation products used:

$$\ln Y = \alpha \ln K + \beta \ln W \qquad \ldots 13$$

with,

$\ln Y = \alpha \ln K_1 + \beta \ln Wd_k$, when rubber trees are stimulated with Ethrel and palm oil
$\ln Y = \alpha \ln K_2 + \beta \ln Wd_k$, when rubber trees are stimulated with a product ready for use

$$\alpha = \frac{\Delta Y/Y}{\Delta K/K} \qquad \ldots 14$$

$$\beta = \frac{\Delta Y/Y}{\Delta Wd_k/Wd_k} \qquad \ldots 15$$

Coefficients α and β are estimated by multiple regression of log linear Cobb Douglas function. Coefficient α measures the impact or elasticity of the cost of stimulation (capital factor) and coefficient β, the impact or elasticity of the number of tapping days (labour factor) on the fresh latex production. The impact is measured by the percentage of variation of production when a variation of 1% of factors occurred. The LITS which has the lowest impact on production when the labour factor is reduced and has the highest impact on production when the capital factor is augmented is preferred.

RESULTS

Evolution of Prices

Figure 1 presents the evolution of actualised prices of fresh rubber from 1989 to 2011 in Côte d'Ivoire.

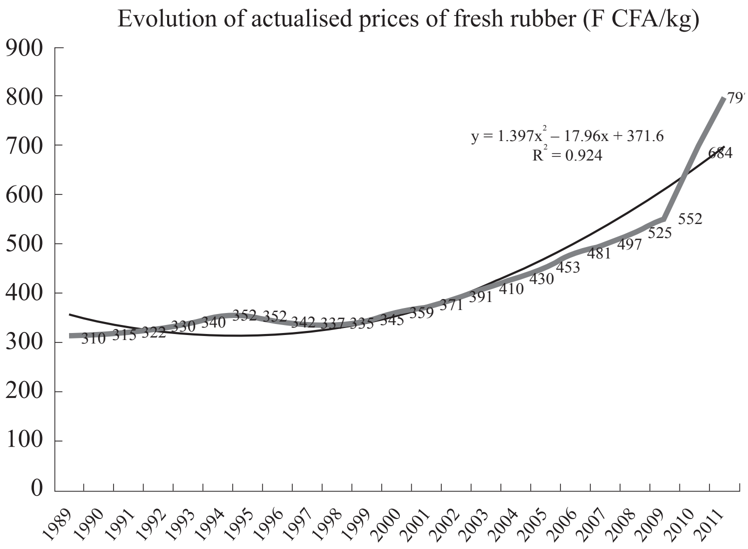
The evolution of fresh rubber prices in Cote d'Ivoire fit a polynomial function with two degrees expressed in *Equation 16*.

$$y = 1.397x^2 - 17.96x + 371.6 \text{ with } R^2 = 0.94 \qquad \ldots 16$$

The price tendency of fresh rubber is positive. The average actualised prices used for calculating profit margins was 352 F CFA/kg considering the post devaluation period (1994 to 2011).

Profit Margins

Table 1 presents the three more profitable systems tested for upward tapping of *Hevea* clone GT 1, downward tapping of PB 260 and GT 1 in Côte d'Ivoire. For upward tapping of the clone GT 1, in comparison with the traditional system (upward quarter spiral cut (S/4), every three days (d_3) with eight stimulations/tree/year at 5% ET), three more profitable systems were identified. These tapping systems are treatments T7 (upward quarter spiral cut (S/4), every four days (d_4) with 12 stimulations/tree/year at 10% ET), T6 (upward quarter spiral cut (S/4), every four



Legend:
500 F CFA = 1 Dollar US

Figure 1. Evolution of fresh rubber prices from 1989 to 2011 in Côte d'Ivoire

days (d_4) with 10 stimulations/tree/year at 10% ET) and T13 (upward quarter spiral cut (S/4), every five days (d_5) with 12 stimulations/tree/year at 10% ET). The highest profit margin is M2 (1 512 418 F CFA/ha/year) obtained with treatment T7 when rubber trees are stimulated with Ethrel and palm oil and the tapper is paid per day.

As for downward tapping of PB 260, in comparison with the traditional system (downward half spiral cut (S/2), every three days (d_3) with four stimulations/tree/year at 2.5% ET), two more profitable systems were identified. They include treatments T5 (downward half spiral cut (S/2), every four days (d_4) with four stimulations/tree/year at 5% ET) and T6 (downward half spiral cut (S/2), every four days (d_4) with six stimulations/tree/year at 5% ET). The highest profit margin is M_2 (1 089 341 F CFA/ha/year) obtained with the treatment T5 when rubber trees are stimulated with Ethrel and palm oil and the tapper is paid per day.

Concerning downward tapping of GT 1, in comparison with the traditional system (downward half spiral cut (S/2), every three days (d_3) with six stimulations/tree/year at 2.5% ET), two more profitable systems were identified. They are treatments T13 (downward half of spiral (S/2), every five days (d_5) with ten stimulations/tree/year at 5% ET) and T6 (downward half spiral cut (S/2), every four days (d_4) with eight stimulations/tree/year at 5% ET). The highest profit margin is M_2 (709 612 F CFA/ha/year) obtained with the treatment T13 when rubber trees are stimulated with Ethrel and palm oil and the tapper is paid per day.

Overall, three most profitable LITS of rubber trees were identified in Cote d'Ivoire. For upward tapping of clone GT 1, the most

TABLE 1. PROFIT MARGINS OF TAPPING SYSTEMS TESTED ON *HEVEA* CLONES GT 1 AND PB 260 IN COTE D'IVOIRE

Profit Margins (F CFA/ha) Tapping Systems	M_1	M_2	M_3	M_4
Upward tapping of GT 1				
T7 S/4U d_4 6d/7 12m/12 ET10% Pa1(1) 12/y (3w)	1,197,518	1,512,418	1,185,518	1,500,418
T6 S/4U d_4 6d/7 12m/12 ET10% Pa1(1) 10/y (m)	1,168,786	1,471,486	1,158,786	1,461,486
T13 S/4U d_5 6d/7 12m/12 ET10% Pa1(1) 12/y (3w)	1,163,511	1,500,911	1,151,511	1,488,911
T1 S/4U d_3 6d/7 12m/12 ET5% Pa1(1) 8/y (m) (T)	929,732	1,077,532	927,954	1,075,754
Downward tapping of PB 260				
T5 S/2 d_4 6d/7 12m/12 ET5% Pa1(1) 4/y(2m)	897,193	1,089,341	896,304	1,088,452
T6 S/2 d_4 6d/7 12m/12 ET5% Pa1(1) 6/y(6w)	872,559	1,055,544	871,225	1,054,211
T1 S/2 d_3 6d/7 12m/12 ET2.5% Pa1(1) 4/y (2m) (T)	898,288	1,032,194	898,955	1,032,861
Downward tapping of GT 1				
T13 S/2 d_5 6d/7 12m/12 ET5% Pa1(1) 10/y(m)	598,277	709,612	596,054	707,390
T6 S/2 d_4 6d/7 12m/12 ET5% Pa1(1) 8/y(m)	612,613	693,022	610,835	691,244
T1 S/2 d_3 6d/7 12m/12 ET2.5% Pa1(1) 6/y (6w) (T)	626,468	652,995	627,468	653,995

Legend:
M_1 = profit when rubber trees are stimulated with Ethrel + palm oil and the tapper is remunerated per quantity produced
M_2 = profit when rubber trees are stimulated with Ethrel + palm oil and the tapper is remunerated per day
M_3 = profit when rubber trees are stimulated with a ready product and the tapper is remunerated per quantity produced
M_4 = profit value when rubber trees are stimulated with a ready product and the tapper is remunerated per day
500 F CFA = 1 Dollar US

profitable system is upward quarter spiral cut (S/4), every four days (d_4) with 12 stimulations per tree per year at 10% ET. For downward tapping of clone PB 260, the most profitable system is downward half spiral cut (S/2), every four days (d_4) with four stimulations per tree per year at 5% ET. Concerning downward tapping on GT 1, the most profitable system is downward half spiral cut (S/2), every five days (d_5) with ten stimulations per tree per year at 5% ET. For each of the three LITS identified, the highest profit margins were obtained when rubber trees were stimulated with Ethrel and palm oil product and the tapper was paid per day.

Efficiency of Factors of Production

Table 2 presents results of the regression of the Cobb Douglas model applied to fresh rubber production in Côte d'Ivoire. The upward tapping of GT 1 using Ethrel and palm oil as stimulation product induces an increase of latex production by 0.85% after an augmentation of 1% of the cost of stimulation and a decrease of 0.22% after a reduction of 1% of the number of tapping days. Using a ready stimulation product, latex production is increased by 0.67% and decreased by 0.51%, respectively. In downward tapping of PB 260 using Ethrel and palm oil product, latex

TABLE 2. PRODUCTIVITY OF CAPITAL AND LABOUR FACTORS IN PRODUCING FRESH RUBBER IN COTE D'IVOIRE

	Upward tapping of GT 1			Downward tapping of PB 260			Downward tapping of GT 1		
	Coef.	s. e	T test	Coef.	s. e	T test	Coef.	s. e	T test
Model 1									
Elasticity of capital K_1 (α)	0.85	0.047	17.93	0.69	0.087	7.9	0.77	0.067	11.44
Elasticity of labour (β)	0.22	0.1	2.23	0.63	0.17	3.71	0.34	0.135	2.51
Model 2									
Elasticity of capital K_2 (α)	0.67	0.063	10.76	0.53	0.093	5.75	0.59	0.08	7.41
Elasticity of labour (β)	0.51	0.14	3.69	0.94	0.18	5.23	0.69	0.16	4.26

production is increased by 0.69% after an augmentation of 1% of the cost of stimulation and decreased by 0.63% after a reduction of 1% of the number of tapping days. Using a ready stimulation product, latex production is increased by 0.53% and decreased by 0.94%, respectively. Concerning downward tapping of GT 1, when Ethrel and palm oil product is used as stimulation product, latex production is 0.77% increased after an augmentation of 1% of the cost of stimulation and 0.34% decreased after a reduction of 1% of the number of tapping days. Using a ready stimulation product, latex production is increased by 0.59% and decreased by 0.69%, respectively. For all *Hevea* clones tested, with reduction of the frequency of tapping, the loss of latex production was greater when rubber trees were stimulated by a product ready for use compared with the case of stimulation with Ethrel and palm oil. The best tapping system is one which minimises the loss of production after reducing tapping days.

Agronomic and Physiological Profiles of Rubber Trees

In upward tapping of clone GT 1, the alternative system identified was S/4 cut tapped on d_4 frequency with 12 stimulations per tree per year at 10% ET. In comparison with the traditional control tapping system, namely S/4 cut tapped on d_3 frequency with eight stimulations per tree per year at 5% ET, the low frequency of tapping system reduced the need of tappers by 25%, increased land-man ratio at 4 ha per man and increased rubber yield by 22% (from 3 818 to 4 904 kg/ha/year). Concerning physiological profiles, vegetative growth were similar (2.7 cm/year for the alternative tapping system and 2.8 cm/year for the control), no percentage of dry trees (TPD) and no occurrence of dry cut length (DCL). The bark consumption (B_c) in a year of tapping for the alternative system (14.8 cm/year) was lower than the traditional system (18.7 cm/year).

For downward tapping of PB 260, the alternative system identified was S/2 cut tapped on d_4 frequency with four stimulations per tree per year at 5% ET. Compared to the traditional control tapping system, namely S/2 cut tapped on d_3 frequency with four stimulations per tree per year at 2.5% ET, the low frequency of tapping system reduced the need of tappers by 25%, increased land-man ratio at 4 ha per man and induced a similar rubber yield (3 676 kg/ha/year) to the traditional system (3 679 kg/ha/year). Concerning the physiological profiles, vegetative growth were also identical

(4.5 cm/year for the alternative system and 4.2 cm/year for the control). No percentage of TPD occurred but the percentage of DCL of the alternative system (5%) was superior to the traditional (0%). This value of DCL is acceptable[9]. Bark consumptions (B_c) in a year of tapping were the same, 13.4 cm/year for the alternative system and 14.0 cm/year for the control.

Regarding the downward tapping of GT 1, the alternative system identified was S/2 cut, tapped on d_5 frequency with eight stimulations per tree per year at 5% ET. In comparison with the traditional control tapping system, namely S/2 cut tapped on d_3 frequency with six stimulations per tree per year at 2.5% ET, the low frequency of tapping system reduced the need of tappers by 40%, increased land-man ratio at 5 ha per man and induced similar rubber yields of 2 508 kg/ha/year for the alternative system and 2 605 kg/ha/year for the control. The decrease of 3.7% in production was not significant. Concerning the physiological profile, vegetative growth was also identical, of 5.0 cm/year for the alternative system and 4.9 cm/year for the control. No percentage of dry trees (%TPD) occurred for the alternative system but an occurrence of 5% was recorded for the control system. The percentage of DCL of the alternative system (8%) was inferior to the traditional system (13%). Bark consumption (B_c) in a year of tapping for the alternative system (12.6 cm / year) was lower than that of the control (16.8 cm/year).

DISCUSSION

The results obtained by Chong *et al.*[11] indicated that for most clones tested, there was a progressive increase in yield as the frequency of tapping decreased from d_2 to d_3, d_4 or d_6 representing 20 to 126 % gain over the d_2 control. In this study, the low intensive tapping systems (LITS) selected as alternatives to traditional high intensive tapping systems (HITS) indicated a decrease from d_3 to d_4 for upward tapping of GT 1 and downward tapping of PB 260 as well as a decrease from d_3 to d_5 for downward tapping of GT 1. The increase in rubber yield represented a 22 % gain over the d_3 control for upward tapping of GT 1 but in downward tapping systems of PB 260 and GT 1, the increase in rubber yield was not significant.

According to Johari *et al.*[12], the LIT d_6 is a promising system in terms of both a reduction of labour and increasing labour productivity, yet the increase in tree productivity due to stimulation is insufficient to offset the loss in tapping days. This study in Côte d'Ivoire indicated that LITS selected as alternatives to the d_3 control are LIT d_4 system, respectively for upward tapping of GT 1 and downward tapping of PB 260 and the LIT d_5 system for downward tapping of GT 1. Profitable frequencies of tapping were therefore, limited to d_4 (for upward tapping of GT 1 and downward tapping of PB 260) or d_5 (for downward tapping of GT 1). Our study confirmed the results obtained by Johari *et al.*[12] which mentioned that a more intensive frequency of tapping up to d_5 is not profitable.

In reference to the study by Koffi[8] relative to the fishing systems used in inland waters in the north of Côte d'Ivoire, profitability was not attractive for the native population whose opportunity costs of labour were greater. Similarly, with the reduction of the frequency of tapping and the increase of the frequency of stimulation and/or the ET concentration in stimulation products used in tapping systems, the productivity of labour and capital increased for systems where rubber trees were stimulated by Ethrel and palm oil and the tapper was remunerated per tapping day. Any other systems of combination of factors of production were less attractive in smallholdings, in view of the high opportunity for cost of labour and capital factors.

CONCLUSION

The most profitable low intensive tapping systems identified in smallholdings in Côte d'Ivoire were namely S/4 upward cut tapped of GT 1 every four days (d_4) with 12 stimulations per tree per year at 10% ET; S/2 downward cut tapped of PB 260 every four days (d_4) with four stimulations per tree per year at 5% ET and S/2 downward cut tapped of GT 1 every five days (d_5) frequency with 10 stimulations per tree per year at 5% ET. These LITS reduced the need of tappers by 25 to 40% and increased land-man ratio from 3 to 4 or 5 ha per man. Taking into account the good agronomical performance and physiological profiles of rubber trees tapped, these LITS turned out to be the best alternatives tapping systems in smallholdings for the clones GT 1 and PB 260 in Côte d'Ivoire.

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REFERENCES

1. NAVAMUKUNDAN, A. (1994) Higher Productivity – Workers' Perspective in the *Proceedings of Workshop on Exploitation Technologies to Address Current Labour Problems in the Rubber Industry. 5–6 December 1994, Crown Princess Hotel, Kuala Lumpur*, 3 – 14.

2. OTHMAN, H. (2008) Transfer of Exploitation Technology, IRRDB Workshop on Latex Harvesting Technologies. *5-8 May 2008,* Sungai Buloh, Malaysia.

3. SOUMAHIN, E.F. (2003) Systèmes d'exploitation compensateurs de la rareté et/ou de la cherté de la main-d'œuvre appliqués au clone PR 107 d'*Hevea brasiliensis*. DEA de Physiologie Végétale, Université de Cocody, Abidjan, Côte d'Ivoire, 62.

4. ANON (1998) Proceedings of Seminar on Low Intensity Tapping Systems (LITS). *10 August 1998,* Sungai Buloh, Malaysia, 165.

5. OBOUAYEBA, S., SOUMAHIN, E.F., BOKO, A.M.C., GNAGNE, Y.M. AND DIAN, K. (2006a) Compensatory Tapping Systems to Tappers Rarity Applied to the Clone PR 107 of *Hevea brasiliensis* (Muell. ARG.) : I. Assessment of 21 years of exploitation. In: *Proc. Int. Nat. Rubb. Conf., Ho Chi Minh City, Vietnam*, 36–46.

6. OBOUAYEBA, S., SOUMAHIN, E.F., BOKO, A.M.C., GNAGNE, Y.M. AND DIAN, K. (2006b) Compensatory Tapping Systems to Tappers Rarity Applied to the Clone PR 107 of *Hevea brasiliensis* (Muell. ARG.) : II, Effect of the Nature of the Exploitation Bark and the Position of Tapping Panel. *Proc. Int. Nat. Rubb. Conf., Ho Chi Minh City, Vietnam*, 47–62.

7. BROU, Y.T. (2005) Climat, mutations socio-économiques et paysages en Côte d'Ivoire. Mémoire de synthèse des activités scientifiques présenté en vue de l'obtention de l'Habilitation à Diriger des Recherches. Universités des Sciences et Technologies de Lille, 213.

8. KELI, J. Z., OBOUAYEBA, S. AND ZEHI, B. (1992) Influence de quelques systèmes vivriers sur le comportement des jeunes hévéas en basse Côte d'Ivoire, Systèmes Agricoles en Afrique, **2 (1)**, 41– 48.

9. OBOUAYEBA, S., SOUMAHIN, E.F., BOKO, A.M.C., DEA, G.B., DIAN, K. AND GNAGNE, Y.M. (2008) Improvement of Productivity of Rubber Trees in Small-holdings by the Introduction of Upward Tapping in the South East of Cote d'Ivoire. *J. Rubb. Res.*, **11(3)**, 163–170.

10. KOFFI, C. (2000) Aspects économiques de l'exploitation des ressources halieutiques des petits barrages du nord de la Cote d'Ivoire. *Agronomie Africaine*, **12(1)**, 33–49.

11. CHONG, K. AND SIVAKUMARAN, S. (1994) Performance of Low-Frequency Tapping Systems. *Proceedings of Workshop on Exploitation Technologies to Address Current Labour Problems in the Rubber Industry. 5–6 December 1994, Crown Princess Hotel, Kuala Lumpur*, 47–67.

12. JOHARI, H.S., SIVAKUMARAN AND MOHD, A.S. (1998) Economics of Low Intensity Tapping Systems. *Proceedings of Seminar on Low Intensity Tapping Systems (LITS). 10 August 1998, Training Complex, Sungai Buloh, Selangor Darul Ehsan*, 103–118.