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YIELD RESPONSE OF LOW FREQUENCY UPWARD TAPPING BY INCREASING THE TAPPING CUT LENGTH IN *HEVEA BRASILIENSIS* (CLONE GT 1) IN SOUTH-EASTERN CÔTE D'IVOIRE

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Rubber tree cultivation is facing a problem of availability of tapping labour. One way to overcome this constraint is the development of low intensity tapping system with use of yield stimulant (ethephon), reducing the need for tappers. Thus, a study was conducted in Côte d'Ivoire on low frequency tapping system compensated for, not by stimulation, but by an increase in the length of tapping cut. The standard tapping in S/4U d3 6d/7 was compared to the tapping in S/2U d6 6d/7 in clone GT 1. The results showed that although the tapping in S/2U d6 6d/7 causes losses of rubber yield by 13 and 25 per cent per tree and per hectare respectively, it generates gains in yield per tree and per tapping by 75 per cent and in net operational incomes by 3 to 4 per cent. Moreover, the tapping in S/2U d6 6d/7 has no significant impact on the physiological profile and the tapping panel dryness of trees. This technology can therefore be an alternative to the standard upward tapping in order to remedy the problem of availability of tappers and enable to palliate a deficit of 39 per cent of the needs for tappers without increasing the level of stimulation.

Keywords: Côte d'Ivoire, Length of tapping cut, Low frequency tapping, Tapping labour, Yield

INTRODUCTION

The cultivation of *Hevea brasiliensis* (Euphorbiaceae) which started in the Amazon basin, the current Brazil, two centuries ago, has now become an important economic activity around the world, as it generates huge incomes. Main source of natural rubber used in various fields, particularly in the tyre industry (Compagnon 1986; Anonymous 1, 2009), the cultivation of rubber tree faces the problem of availability of tapping labour. Indeed, latex harvesting is done through tapping which requires a large tapping labour thus

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constituting a major investment for the farmer and significantly reducing his net operation income.

The advent of hormonal stimulation has made it possible to reduce the work of tapping (tapping cut length and tapping frequency) therefore the needs for tappers, while maintaining a good level of yield; losses in yield being compensated for by stimulation (Tonnelier, 1981; Hashim, 1988; Xiaodi *et al.*, 2003; Soumahin, 2003; Anonymous 1, 2009; Obouayeba *et al.*, 2010; Soumahin *et al.*, 2010). However, rubber cultivation remains heavily dependent on and consumer of tapping labour which expensiveness and scarcity are increasingly enhanced (Rodrigo *et al.*, 2003). It was therefore necessary to continue the work on latex harvesting technologies which reduce the need for tappers while implementing other ways to compensate for losses in yield due to the reduction of tapping intensity.

On that respect, a study was conducted in the Rubber Tree Programme of the *Centre National de Recherche Agronomique* (CNRA), in South-Eastern Côte d' Ivoire, intending to compensate the yield by adopting low frequency tapping with increase in cut length without increase of stimulation intensity in high panel tapping. This paper provides results of four years of experimentation on the effect of the low frequency tapping accompanied by the increase in the length of tapping cut on the agronomic and physiological parameters as well as the profitability of the rubber trees of clone GT 1.

MATERIALS AND METHODS

Study area

The experiment was conducted on the experimental field of the CNRA, research station of Bimbresso, in Anguededou, in south-eastern Côte d'Ivoire, over an area of 6.25 ha. The clone of rubber tree used in this experiment was the clone GT1 of *H. brasiliensis*. It is a clone originating from Indonesia, specifically from Java (Gondang Tapen). It is the reference clone in Côte d'Ivoire. It is a high yielding clone which sensitivity to tapping panel dryness and its equally acceptable resistance to breakage due to wind. GT 1 is a clone having an intermediary metabolism (Anonymous 2, 1999). The trees were planted in 1966 with a density of 625 trees per hectare. The trees were started being tapped in March 1972. The trial began in March 1988, when the trees were in the first year of upward tapping. This region is characterized by a sub-equatorial climate type with two rainy seasons and two dry seasons. The soils are ferralitic (Keli *et al.*, 1992).

Statistical design

There were four treatments comprising d3 and d6 frequencies of tapping with quarter and half spiral cuts and two concentrations of stimulation. The experiment was laid out in completely randomized blocks with four replications spread over sixteen elementary plots of approximately 238 trees per plot. Yield stimulant was mixed with palm oil at a final concentration of 2.5 and 5 per cent of active ingredient by panel application.

The treatment details (T1 to T2) are given below as per the new tapping notations (Vijayakumar *et al.*, 2009).

T1 – S/4U d3 6d/7. ET5% Pal(1) 10/y* (control)

T2 – S/2U d6 6d/7. ET2.5% Pal(1) 10/y*

T3 – S/2U d6 6d/7. ET5% Pal(1) 10/y*

T4 – S/2U d6 6d/7. ET5% Pa2(1) 10/y*

The trees tapped upward throughout the year, using a tapping knife and the yield was harvested in polythene bag. The yield was estimated by weighing the fresh coagulated rubber of each experimental plot every month. For each treatment, samples of 2 kg fresh coagulated rubber were used to calculate the transformation coefficient, which is used to determine the weight of dry rubber in gram per tree (g tree^{-1}), gram per tree per tapping (g t^{-1} t^{-1}) and the yield in kilogram per hectare (kg ha^{-1}).

Latex analysis

Latex physiological parameters were assessed once in a year between August and December. Latex samples were collected according to the method for microdiagnosis (Jacob *et al*., 1988) and extracted with Trichloroacetic acid. The sucrose, inorganic phosphorus and the reduced thiols were measured in the TCA extract according to the methods described by Ashwell (1957), Taussky and Shorr (1953) and Boyne and Ellman (1972). The results are expressed as mmole per liter of latex (mM). Dry rubber content was determined after acid coagulation of known weight of latex drying in oven at 80 ^{o}C and weighed again and expressed as per cent.

Tapping panel dryness

The tapping panel dryness quick measurement method by visual estimation (Van de Sype, 1984) enables to report on the progress of the "disease". On that respect, the trees tapped were rated from 0 to 6 in proportion to the progress of the "disease". The sensitivity of trees to tapping panel dryness is assessed through the parameters of dry cuts (%) and dry trees (%).

Economic analysis

For each latex harvesting technology, the net operational income (NOI) was calculated expressed in US$, from the following relations:

NOI = GOI – LHC

GOI = Y x SP

LHC = CL + CS

GOI- Gross Operational Income, LHC- Latex Harvesting Cost: Y- Yield in farm gate kg of rubber ha^{-1}, SP- Selling Price of a farm gate kg of rubber, CL- Cost of Labour, CS - Cost of Stimulation.

One payment method of tappers was used. It was the method of payment per workday or per tapping. The tappers were paid according to the number of workdays or of tapping. The costs of tapping labour (CL) were determined by the following relations:

CL = CLT x NTg x NTr

CLT - Cost of labour per tapper and per day NTg - Number of tapping, NTr - Number of tappers,

The calculations of net operational incomes were theoretical calculations made on the basis of a tapping of 400 trees. The cost per kilogram of rubber was 0.5 US$. Concerning the payment of the tapper per workday, the cost was 8 US$ per day and per tapper.

Statistical analysis

An analysis of variance of the data including the rubber yield and latex micro diagnosis was done with SPSS statistical software and the Student-Newman-Keuls test, at $P<0.05$.

RESULTS AND DISCUSSION

Rubber yield

The trees tapped in upward quarter-spiral cut of d3 frequency of tapping stimulated with a concentration of 5 per cent ethephon gave rubber yield per tree significantly higher than those of trees tapped in upward half spiral once a week (Table 1). These low frequency tapping treatments caused losses in yield per tree ranging from 13 to 25 per cent compared to the control. Furthermore, an increase in the concentration from 2.5 to 5 per cent ethephon, caused a significant increase in rubber yield under d6 frequency of tapping. However an increase in the amount of stimulant by 1 to 2 g, did not lead to an increase in rubber yield.

Rubber yield (g t^{-1} t^{-1}) under low frequency tapping (d6) significantly higher than the control (Table 1). The gains in yield resulting from the reduction in tapping frequency ranged from 50 to 75 per cent compared to the control. The increase in the concentration of active ingredient caused a significant increase in rubber yield per tree and per tapping. However, the increase in the amount of stimulant had no effect on the yield of trees tapped upward under weekly tapping.

The control trees tapped in upward quarter-spiral twice a week gave rubber yield per hectare higher than those of low frequency tapping treatments (Table 1). Losses in rubber yield caused by the reduction in tapping frequency varied from 13 to 25 per cent. The increase in the concentration of active matter had a significant effect on the rubber yield (kg ha^{-1}) of trees tapped in upward half spiral under weekly tapping. However, the increase in the amount of stimulant had no significant effect.

The reduction of tapping frequency (from d3 to d6), compensated by an increase in the tapping cut length (from S/4 spiral to S/2 spiral) in upward tapping resulted in a gain in yield per tree and per tapping from 50 to 75 per cent and in losses in yield per tree as well as per hectare respectively from 13 to 25 per cent compared to the control. The increase of the period between two consecutive tappings enables to increase the yield per tree and per tapping (Compagnon, 1986; Soumahin, 2010; Soumahin *et al.*, 2010). Thus, the rubber tree meets the tapping; the latex-producing function is enhanced by tapping. This is the reason for high yields per tree obtained by the control trees (Compagnon, 1986; Soumahin *et al.*, 2010).

It is however important to note that losses in yield are not proportional to the reduction in tapping frequency (Obouayeba *et al.*, 2011). Thus, it is not appropriate to increase the amount of stimulant since the yields obtained are of the same. However, it makes sense to compensate the reduction in tapping frequency by stimulation at 5 per cent instead of 2.5 per cent ethephon. In terms of rubber yield, the best alternative to the standard upward tapping is S/2U d6 6d/7. ET5 % Pa1(1).

Table 1. **Annual mean dry rubber yield of *H. brasiliensis* (clone GT 1) during four years of upward tapping in South-Eastern Côte d'Ivoire**

Treatments	tree ha^{-1}	kg $tree^{-1}$	g t^{-1} t^{-1}	kg ha^{-1}
T1- S/4U d3 6d/7 ET5% Pa1(1) 10/y* (control)	400	8.154a (100)	78.4c (100)	3368a (100)
T2- S/2U d6 6d/7 ET2.5% Pa1(1) 10/y*	400	6. 115c (75)	117.7b (150)	1804b (75)
T3- S/2U d6 6d/7 ET5% Pa1(1) 10/y*	400	7.134b (87)	137.2a (175)	2383b (87)
T4- S/2U d6 6d/7 ET5% Pa2(1) 10/y*	400	7.129b (87)	137.1a (175)	2609b (87)

Mean within columns followed by the same letters are not significantly different from each other ($P < 0.05$).
Values in parenthesis are percentage difference over T1

Physiological profile

Dry rubber content

The dry rubber contents were high at the beginning and end of experiment for all the treatments (Table 2). At the beginning of the experiment, T2 gave a dry rubber content identical to that T4 and higher than those of the other treatments. The control (T1) and T3 and T4 had equivalent dry rubber contents. At the end of experiment, T3 and T4, having low tapping frequency, stimulated at a concentration of 5 per cent ethephon, showed dry rubber contents that were identical to that of the control and superior to that of T2, having low tapping frequency stimulated at a concentration of 2.5 per cent ethephon. The increase in the concentration of active ingredient, by 2.5 to 5 per cent ethephon, resulted in a significant increase in dry rubber contents while the increase in the amount of stimulant by 1 to 2 g, had no significant impact on the dry rubber content.

The dry rubber contents were good and high at the beginning and end of experiment. This reflects a good biosynthetic activity of latex vessels regardless of tapping frequency and tapping cut length. For stimulations at a concentration of 5 per cent ethephon, the reduction in tapping frequency does not have a negative impact on the dry rubber contents (Soumahin, 2010; Soumahin *et al.*, 2010).

Sucrose

The sucrose contents were high on the whole at the beginning as well as at the end of experiment (Table 2). At the beginning of experiment, the sucrose contents in T1 and T2 were identical and superior to those of T3 and T4, which showed similar values. At the end of experiment, treatments (T3 and T4) having low tapping frequency, stimulated at a concentration of 5 per cent ethephon, and the control had identical contents and superior to that of T2, with low tapping frequency with stimulation at 2.5 per cent ethephon. The increase in the concentration of ethephon caused an increase in sucrose contents while the increase in the amount of stimulant had no significant effect on sucrose contents of upward half spiral treatments tapped once in a week.

Sucrose contents were high for all the treatments at the beginning as well as at the end of experiment except for T2 (ET 2.5%), which showed a very low sucrose content. This low rate might be due to a low supply of sugar for latex vessels attributable to low intensity stimulation in upward tapping (ET 2.5%). This may be the reason for the low yields obtained with this pattern. For stimulations at a concentration of 5 per cent ethephon, the reduction in the tapping frequency does not have a negative impact

Table 2. **Physiological status of *H. brasiliensis* (clone GT 1) during four years of upward tapping in the south-eastern Côte d'Ivoire**

Treatments	drc (%)		Sucrose (mM)		Pi (mM)		RSH (mM)	
	Start	End	Start	End	Start	End	Start	End
T1 S/4U d3 6d/7. ET5% Pa1(1) 10/y* (control)	48.9b	52.1a	31.7a	20.1a	18.5c	18.2ab	0.93a	0.55a
T2 S/2U d6 6d/7. ET2.5% Pa1(1) 10/y*	52.9a	44.9b	21.6a	9.7b	15.7c	20.5a	0.78c	0.52a
T3 S/2U d6 6d/7. ET5% Pa1(1) 10/y*	48.5b	54.5a	13.8b	16.9a	24.2a	15.9b	0.87b	0.36b
T4 S/2U d6 6d/7. ET5% Pa2(1) 10/y*	50.2ab	55.3a	15.3b	15.1a	21.3b	15.5b	0.88b	0.38b

Mean within columns followed by the same letters are not significantly different from each other ($P < 0.05$).

on the sucrose contents as shown by Soumahin *et al*. (2010).

Inorganic phosphorus

The inorganic phosphorus contents were optimum at the beginning and end of experiment (Table 2). At the beginning of experiment, T3 showed the highest content followed by T4. T1 and T2 showed the lowest contents. At the end of experiment, T2 showed inorganic phosphorus content identical to that of the control and superior to that of T3 and T4. The inorganic phosphorus contents of the latter are equivalent to each other and to the control. The increase in the concentration of stimulant caused a significant decrease in inorganic phosphorus contents, while the increase in the amount of stimulant did not affect the content.

The inorganic phosphorus contents are optimum on the whole for all treatments, synonyms of a sufficient energy supply for the rubber synthesis (Jacob *et al*., 1988). The reduction of the tapping frequency compensated by the increase in tapping cut length had therefore no negative impact on the inorganic phosphorus content.

Thiol

At the beginning of experiment, the thiol contents were high for all the treatment (Table 2). The control (T1) showed the highest content. A fall in thiol content below normal (0.6 mM) was observed for all the treatments at the end of experiment. The lowest thiol contents were T3 and T4, having low tapping frequency, stimulated at a concentration of 5 per cent ethephon. T1 and T2 stimulated at a concentration of 2.5 per cent ethephon, showed the highest thiol content and identical to each other. An increase in the concentration of stimulant led to a decrease in thiol content while an increase in the amount of stimulant did not affect the content.

The low thiol contents observed at the end of experiment for all treatments reflects a low colloidal stability of the latex (Chrestin *et al*., 1984) and a weakening of the protective system after four years of consecutive upward tapping. These signs may be indicative of the beginning of physiological fatigue identified by low thiol contents and are more visible with T3 and T4 having a high tapping cut length.

The reduction of the tapping frequency compensated by the increase in the tapping cut length had no significant negative impact on the overall physiological profile of trees. The low thiol contents observed at the end of experiment for all the patterns appear to be a sign of physiological fatigue, especially in T3 and T4 having substantial cut length, which could be corrected by a switch over low downward panel after two years of

Table 3. **Tapping panel dryness (TPD) of clone GT 1 of *H. brasiliensis* during four years of upward tapping in south-eastern Côte d'Ivoire**

Treatments	Dry cut (%)		Dry trees (%)	
	Start	End	Start	End
T1- S/4U d3 6d/7. ET5% Pa1(1) 10/y* (control)	6.2	8.9	2.6	3.0
T2- S/2U d6 6d/7. ET2.5% Pa1(1) 10/y*	9.6	12.8	4.7	10.5
T3- S/2U d6 6d/7. ET5% Pa1(1) 10/y*	4.5	11.0	1.3	5.8
T4- S/2U d6 6d/7. ET5% Pa2(1) 10/y*	3.5	10.1	0.0	4.4

upward tapping. T3 is the best of low tapping frequency treatment, is the best alternative to the standard upward quarter spiral cut in case of shortage of tappers.

Tapping panel dryness (TPD)

At the beginning of experiment, the rates of dry cut were low for all the treatments (Table 3). T2 showed the highest rate and lowest rate was observed in T4. At the end of experiment, we noticed an increase in the rate of dry cut for all the treatments. The control showed the lowest rate than other treatments.

At the beginning of experiment, the rates of dry trees were low for all the treatments (Table 3). T2 showed the highest rate of dry trees and T4 showed the lowest rate of dry trees. At the end of experiment, the rates of dry trees experienced an increase but remained low on the whole. The control showed the lowest rate and high rate of dry trees in T3. Treatments having low tapping frequency showed the highest rates.

Except T2 having low frequency tapping (ET2.5%), which rates of dry cut length were more important, T3 and T4 having low frequency tapping (ET5%) showed rates of the same order of magnitude than those of the control. The reduction of the tapping frequency compensated for by the increase in the tapping cut length does not then favour the increase of the rate of tapping panel dryness of the trees in T3 and T4 (Hashim, 1988; Soumahin, 2003; Vijayakumar *et al.*, 2003; Jacob *et al.*, 2006).

Indeed, tapping panel dryness occurs especially during intensive harvesting of rubber trees (higher frequency of tapping and/or over stimulation). The increase of the stimulation regime was therefore unable to induce physiological disorders responsible for the resurgence of the disease.

Profitability

The net operational incomes generated by the control were superior to those of T2 and inferior to those of the T3 and T4 (Table 4). Losses in net operational incomes caused in treatment T2 were 14 per cent.

Table 4. **Annual mean of net operational income (US$ year^{-1}ha^{-1}) of low frequency tapping of *H. brasiliensis* (clone GT 1) during four years of upward tapping in south-eastern Côte d'Ivoire (400 trees for each treatment)**

Treatment	CS	CL	GOI	NOI
T1- S/4U d3 6d/7 ET 5% Pa1(1) 10/y* (control)	16.11	624	2718	1870 (100)
T2- S/2U d6 6d/7 ET 2.5% Pa1(1) 10/y*	12.50	312	2040	1612 (86)
T3- S/2U d6 6d/7 ET 5% Pa1(1) 10/y*	16.11	312	126	1946 (104)
T4- S/2U d6 6d/7 ET 5% Pa2(1) 10/y*	32.22	312	236	1928 (103)
Mean	19.24	390	271	1839

Values in parenthesis are percentage difference over T1
CS – Cost of stimulation (US$ year^{-1}ha^{-1})
CL – Cost of labour (US$ year^{-1}ha^{-1})
GOI – Gross operational income (US$ year^{-1}ha^{-1})
NOI – Net operational income (US$ year^{-1}ha^{-1})
Cost per kilogram of rubber 0.5 US$
Payment of the tapper per workday - 8 US $ per day and per tapper

Profit in net operational incomes caused in T3 and T4 ranged from 3-4 per cent.

The net operational incomes of all the treatments were positive as in the conclusion of several authors (Hashim, 1988; Vijayakumar *et al*., 2003; Soumahin, 2010; Soumahin *et al*., 2009; 2010). The considerable net operational income of the T3 and T4 are due to a lowest cost of labour. The 39 per cent reduction in the size of tapping labour through the reduction of tapping frequency and the increase in tapping cut length enable to compensate in terms of net operational incomes, for losses of production caused by the reduction in tapping frequency (T3 and T4). The slight profit margins in T2 are due to a less yield (Soumahin, 2010; Soumahin *et al*., 2010).

CONCLUSION

The problem of availability of tapping labour can be solved by the adoption of low frequency tapping with yield stimulant compensated notably by an increase in the tapping cut length. Indeed, under S/2U d6 6d/7. ET5 % Pa1(1), although leading to losses of 13 per cent in rubber yield per tree and per hectare favours gains in yield per tree and per tapping by 75 per cent and in net operational incomes by 4 per cent, profitable to tapper and farmer. Moreover, it has no significant impact on the physiological profile and sensitivity to tapping panel dryness. This technology can thus be used to solve the problem of availability of labour to the extent that it enables to palliate a shortage of tappers.

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