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Improvement of Productivity of Rubber Trees in Smallholding by the Introduction of Upward Tapping in the South-East of Côte d'Ivoire

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In smallholdings nine to twelve years of downward tapping was carried out on virgin barks followed by downward tapping on renewed barks, a total period of exploitation not exceeding 20 years. However in industrial plantations, downward and upward tapping of rubber trees resulted up to 36 years of exploitation. The study was conducted to assess the feasibility of upward tapping in smallholding conditions in four locations. Downward tapping on renewed barks (½ S d/3 6d/7 ET 2.5% Pa 1(1) 10/y(m)) was compared to upward tapping on virgin barks: ¼ S ↑ d/3 6d/7 ET 5% Pa 1(1) 10/y(m) and ½ S ↑ d/6 6d/7 ET 2.5% Pa 2(1) 10/y(m). The performance of these tapping systems were assessed for rubber production, vegetative growth, physiological profile and the tapping panel dryness (TPD) susceptibility of rubber trees. The productivity of downward tapping was satisfactory, but significantly lower than that of upward tapping systems. In fact, compared to downward tapping, upward tapping increased the rubber tree productivity by 34% and 36% for the quarter cut and half spiral cut respectively. Generally, the physiological profile of all tested systems were good, with little occurrence of TPD. Thus, in smallholdings, nine years of downward tapping followed by upward tapping, especially the upward quarter spiral, turned out to be the best tapping system in Côte d'Ivoire.

Key words: improvement; Côte d'Ivoire; tapping systems; virgin bark; renewed bark; smallholdings; productivity; physiological profile; tapping panel dryness

In Côte d'Ivoire, the modern way of managing rubber tree plantations include two main periods of tapping systems. In industrial plantations, the standard exploitation period consists of nine years of downward tapping of virgin barks immediately followed by upward tapping. In smallholdings, only downward tapping is practised, during the first nine to twelve years on virgin panel and then followed by tapping on the renewed bark. Then, an anarchical use of reachable panel commences, which leads to the poor state of

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the trees. Indeed, the duration of the bark exploitation is shortened not only by the number of tappable rubber trees, but also by poor tapping skill. As a result, in smallholdings productive period of rubber trees is shorter by about 20 years while in industrial plantations it is about 36 years.

The introduction of upward tapping systems in industrial plantations in 1980 led to a significant improvement in rubber tree production[1] that equalled and even exceeded 2000 kg/ha, and resulted in a longer period of exploitation[2]. Nevertheless, this useful technique that dramatically improved the rubber production, is not well known or used in the smallholders field. Thus, the introduction of upward tapping systems in smallholdings could enhance the productivity and the economic life of the rubber trees. A study on upward tapping was therefore carried out in smallholdings. This paper reports results of these trials and suggests appropriate stimulation with the view of introducing upward tapping system in smallholdings.

MATERIAL AND METHODS

Planting Material

Clone GT 1 planted in 1978–1979 in four smallholdings was used in the trial. The tapping of rubber trees started in 1984.

Methods

The experiment was carried out at four locations in the south-east of Côte d'Ivoire. Three locations were of sandy soil and the fourth on gravel soil. The experiment began in April 1994 and ended in March 1998. The experimental design was a Fisher block with four replications and three treatments; Treatment 1 (½ S d/3 6d/7 ET 2.5% Pa 1(1) 10/y(m) on first the renewal bark (Control)), Treatment 2 (¼ S ↑ d/3 6d/7 ET 5% Pa 1(1) 10/y(m) on virgin bark and Treatment 3 (½ S ↑ d/6 6d/7 ET 2.5% Pa 2(1) 10/y(m) on virgin bark. Each treatment covered 10 064 ± 1561 m^2 with 471 ± 47 tappable trees and each trial by location covered of 3.02 ± 0.48 ha. With respect to treatments applied, trees were tapped as follows: Treatment 1, Monday and Thursday, Treatment 2, Tuesday and Friday, Treatment 3, Wednesday. In all trials, Ethrel (2-chloroethyl phosphonic acid) was the stimulant used. Ethrel was diluted with palm oil to a concentration of 2.5 or 5% active ingredient (a.i.). Except for in January and February, the stimulation was applied every month. Rubber produced was weighed once every four weeks. A sample of coagulated fresh rubber was collected, weighed, dried out and reweighed to determine the amount of dry rubber produced. Dry rubber yield (kg/ha) and dry rubber production per tree a year (g/t/y) were calculated and analysed. The biochemical parameters were analysed, using the methods developed by the French Agricultural Research Centre for International Development (CIRAD) and CNRA[3] and adapted in 1995 by the International Rubber Research Development Board (IRRDB)[4], once a year, during the last quarter of the year in 1995, 1996 and 1997. Girth at 1.70 m above ground was measured once a year, from 1994 to 1998. Bark consumption at the end of the experiment was measured and tapping panel dryness (TPD) was assessed by counting the percentage of dry trees (TPD) and estimating the percentage of dry cut length (% DCL), once a year, during the last quarter, from 1995 to 1998.

RESULTS

Vegetative Growth

At the end of the experiment in 1998, the average girth and increment were 77.4 cm and

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TABLE 1. GIRTH AND GIRTH INCREMENT OF *HEVEA BRASILIENSIS* OF DIFFERENT TAPPING SYSTEMS (1994-1998)

Tapping System	Girth and girth increment (cm)								
	Location 1		Location 2		Location 3		Location 4		
Year	94	98	94	98	94	98	94	98	Mean
Girth	72.0	78.1	71.4	78.5	70.3	76.3	69.3	74.3	76.8
½ S.d/3 ET 2.5% pa 1/1 10/Y Increment	6.1		7.1		6.0		5.0		6.1 b
Girth	72.3	81.1	71.1	78.3	70.2	78.8	65.6	71.8	77.5
¼ S↑ d/3 ET 5% pa 1/1 10/Y Increment	8.8		8.2		8.6		6.2		8.0 a
Girth	70.5	79.8	68.3	78.0	71.6	81.7	64.4	72.3	78.0
½ S↑ d/6 ET 2.5% pa 2/1 10/Y Increment	9.3		9.7		10.1		7.9		9.3 a
Mean girth per site	71.6	79.7	70.0	78.3	70.7	78.9	66.4	72.8	77.4
Mean girth increment per site	8.1 a		8.3 a		8.2 a		6.4 b		7.8

a, b: Mean values with the same letter are not significantly different ($P < 0.05$).

7.8 cm respectively, indicating a reasonable tapping growth, with significant differences between treatments (*Table 1*). The girth increment for the two upward tapping systems was similar and higher than the increment of the downward tapping system. A significant effect of location was noticed. Vegetative growth at location 4 was significantly lower than the three other locations where girths were comparable (*Table 1*). These differences could be related to differences in water availability due not only to rainfall but also to the type of soil. The soil on location 4 was gravel and not very deep whereas at locations 1, 2 and 3 soils were sandy and deep.

Production

Tree productivity (*g/t*). Average rubber production per tree reached 5053 g and was satisfactory, with little variation among different locations (*Table 2*). A significant effect of tapping systems on rubber production per tree appeared after 10 years of tapping. Downward tapping system on renewed bark produced significantly less rubber than the upward tapping systems on virgin bark. On the other hand, the two upward tapping systems (¼ and ½ spirals) produced similar yields.

Land productivity (*kg/ha*). An average yield of 2 369 kg/ha was obtained for all locations (*Table 2*). Rubber yield did not vary significantly with locations but varied significantly with treatments. Upward tapping systems regardless of the length of tapping cut yielded significantly more than the downward tapping system on renewed bark (*Table 2*). The two upward tapping systems (¼ and ½ spirals) produced similar yields.

Bark Consumption

The bark consumption (B_c) in a year of tapping was excessive with ($B_c \geq 25$ cm) as

TABLE 2. MEAN ANNUAL RUBBER PRODUCTION (G/T AND KG/HA) OF DIFFERENT TAPPING SYSTEMS AND LOCATIONS

Tapping System		Production of rubber				
		Location 1	Location 2	Location 3	Location 4	Mean*
½ S d/3 ET 2.5% Pa 1(1) 10/y(m)	g/t	3963	5131	3634	3974	4176 b
	kg/ha	1918	2352	1762	1657	1922 ii
¼ S ↑ d/3 ET 5% Pa 1(1) 10/y(m)	g/t	5942	5821	5295	4748	5452 a
	kg/ha	2448	2538	3002	2317	2576 i
½ S ↑ d/6 ET 2.5% Pa 2(1) 10/y(m)	g/t	5568	5994	6135	4427	5531 a
	kg/ha	2472	2589	3018	2351	2608 i
Mean per location	g/t	5158 ab	5649 a	5021 ab	4383 b	5053
	kg/ha	2279	2493	2594	2108	2369

Mean*: Mean of g/t, kg/ha per treatment or tapping system
a, b: Mean values with the same letter are not significantly different ($p < 0.05$).
i, ii: Mean values with the same letter are not significantly different ($p < 0.05$).

shown in *Table 3* in all tapping systems and locations as compared to the recommended consumption of bark of $11.1 \leq B_c$ (cm) ≥ 12.2, $14.0 \leq B_c$ (cm) ≥ 16.1 and $14.5 \leq B_c$ (cm) ≥ 19.7 for upward tapping once a week, downward tapping twice a week, and upward tapping twice a week, respectively.

Biochemical Characteristics of the Latex

Dry rubber content (*D.R.C.*). The average dry rubber content, for all treatments, locations and years of exploitation was 55.5% and 42.6% at the beginning and end of the experiments

TABLE 3. MEAN ANNUAL CONSUMPTION OF BARK UNDER DIFFERENT TAPPING SYSTEMS AND LOCATIONS

Tapping system	Mean consumption of bark				
	Location 1	Location 2	Location 3	Location 4	MCTS*
½ S d/3 ET 2.5% Pa 1(1) 10/y(m)	18.6	23.2	15.9	32.4	22.5 b
¼ S ↑ d/3 ET 5% Pa 1(1) 10/y(m)	27.0	44.1	30.3	37.0	34.6 a
½ S ↑ d/6 ET 2.5% Pa 2(1) 10/y(m)	15.1	22.4	17.4	21.1	19.0 bc
Mean consumption per site	20.2 b	29.9 a	21.2 b	30.3 a	25.4

MCTS*: Mean consumption per tapping system (treatment)
a, b: Values with the same letter are not significantly different ($p < 0.05$).

respectively (*Table 4*). There was significant effect of treatments on DRC. There was a significant decrease in dry rubber content over the trial period in treatments with upward tapping systems (*Table 4*).

Sucrose (*SUC*). Mean sucrose content in latices were 19.0 mM and 11.0 mM. (*Table 4*) at the beginning and of experiment respectively, with a significant decrease at the end. Sucrose content in latex was significantly affected by treatments. With downward tapping systems on renewed bark, sucrose content in latex was significantly lower than in upward tapping systems at the beginning. This tendency was inversed at the end when, the sucrose content in latex of the downward tapping system was significantly higher than that of the upward tapping system.

Inorganic phosphorus content (Pi). Inorganic phosphorus content (Pi) in latices (*Table 4*), was 14.0 mM, on average, with little variation over the years and treatments.

Thiols Grouping Content (RSH). Mean thiols content in latex was 0.45 mM at the end of the trial, with no significant variation among treatments (*Table 4*).

Tapping Panel Dryness (TPD)

An average of 13.2% of trees suffered from partial dryness, in all locations, treatments and over the years (*Table 4*). However, unlike the locations and treatments, this average rate varied significantly between treatments. Downward tapping on renewed bark was more susceptible to dryness than upward tapping. Within upward tapping systems, quarter spiral was less harmful than half spiral. Generally, the occurrence of partially dry tapping panel was evident in all treatments (*Table 4*). The same trend was

TABLE 4. MEAN BIOCHEMICAL PARAMETERS AND INCIDENCE OF TAPPING PANEL DRYNESS UNDER DIFFERENT TAPPING SYSTEMS

Treatments	DRC		SUC		Pi		RSH	DCL		Dry tree	
	94	98	94	98	94	98	98	94	98	94	98
Treatment 1	55.2µ	51.8 a	15.0 c	15.5 a	14.0	11.0 c	0.46*	4.2	19.6 a	0	14.8 a
Treatment 2	253.9	38.8 b	19.6 b	6.0 c	14.4	14.9 ab	0.46	3.4	7.0 c	0	11.4 b
Treatment 3	351.5	37.3 b	22.4 a	11.5 b	13.4	16.1 a	0.43	4.0	13.1 b	0	11.6 b
Mean	55.5	42.6	19.0	11.0	13.9	14.0	0.45	3.9	13.2	0	12.6

Treatment 1 : ½ S d/3 ET 2.5% Pa 1(1) 10/y(m)
Treatment 2 : ¼ S ↑ d/3 ET 5% Pa 1(1) 10/y(m)
Treatment 3 : ½ S ↑ d/6 ET 2.5% Pa 2(1) 10/y(m)
µ: mean values obtained at beginning (1994) and end (1998) of the experiment (all trials or locations)
*: mean values obtained at the end of experiment (1998)
Mean values with the same letter are not significantly different ($p < 0.05$).
D.R.C. : Dry Rubber Content (%)
SUC : Sucrose (mM)
Pi : Inorganic phosphorus (mM)
RSH : Thiols grouping (mM)
DCL : Dry Cut Length

observed for totally dried cut, or dry trees. As for the means of TPD on Treatments 2 and 3, the rates were comparable but less significantly affected than treatment 1.

DISCUSSION

In smallholding conditions, the average production per tree per year and yield amounted to 5053 g and 2369 kg/ha, respectively. Such productions are very interesting and could be explained by availability of sucrose and inorganic phosphorus which are involved in the biosynthesis of cis-polyisoprene (natural rubber)[5]. Despite these high levels of production, a well-balanced physiological profile[6,7] revealed a satisfactory physiological state of the trees. Sucrose and inorganic phosphorus contents in latex varied from intermediate to high and thiol contents were intermediate. The good physiological status was translated into an acceptable level of tapping panel dryness and satisfactory tree growth[8,9].

It should be noted that in upward tapping systems, quarter spiral tapping cut led to lower sucrose content than half spiral tapping cut[10]. In the quarter spiral tapping cut of the upward tapping system, the sucrose content in latex, was even lower than that excepted for GT1 clones unlike in the two other tapping systems.

The consistency of results within the four locations gave further evidence that modern rubber tree's exploitation practices can be successfully practised in smallholding conditions[6,11].

The average tree and land productivity were influenced by the tapping systems applied (treatments). Downward tapping on first renewed bark was less productive than upward tapping on virgin bark, regardless of the length of tapping cut (half or quarter spiral). Satisfactory production from the renewed bark confirmed the fact that renewed bark needs at least ten years to mature and to be tapped again without damaging the physiological state of trees. The low tree dryness incidence obtained and the good physiological profiles, similar to that of PR 107 clone provided further evidence. The two upward tapping systems tested produced similar productivity in a year. However, upward tapping in quarter spiral (¼ S) confers greater advantage over upward tapping in half spiral (½ S) with regards to the lasting quality, since the tappable bark area is definite[6,12,13]. Indeed, in many cases, the ¼ S enables 8 years of upward tapping whereas the ½ S only offers 4 to 6 years.

On the other hand, bark consumption is influenced by tapping skill. Tappers in locations 2 and 4 consumed twice more bark than recommended, while tappers in locations 1 and 3 over consumed by only 30%. Heavy consumption of bark is essentially related to the tappers' tapping skills and a strict monitoring of the tapping quality. Resulting from guidance and frequent monitoring of the tapping quality, tappers in locations 1 and 3 obtained lower bark consumption unlike those in locations 2 and 4. Smallholders would greatly benefit from some tapping training.

Giving the slight yield advantage of ½ S ↑ over the ¼ S ↑ and the healthy physiological state of trees, upward tapping in quarter spiral constitutes the best alternative[6,14] for smallholders at the end of the downward tapping. Smallholders could benefit from upward tapping systems provided that they start tapping trees at 1.20 m above ground level at the opening of tapping of trees. In this way, the high panel could be exploited for 10 to 12 years instead of 8 years when the opening takes place at 1.50 m as in this experiment.

The stimulation has proven to be very useful. It is well established that in smallholdings, rubber production hardly reached 1 tonne (1000 kg/ha). Thus the high yield obtained, greater than the tonne national (Côte d'Ivoire) average (1700 kg/ha) and the best in the world, could be explained by the higher concentration of Ethephon in the stimulating paste (ET 5%)[15]. The more the concentration of the active ingredient in the stimulating paste, the greater the water content in latex.

This experimentation confirms the maturity of a ten year renewed bark but also gives evidence that smallholders could handle upward tapping effectively[6]. With this, smallholders could exploit their plantations for at least 25 years *i.e*. about 18 years of downward tapping on virgin and renewed bark and 8 years of upward tapping system on virgin bark.

CONCLUSION

Upward tapping in smallholding conditions produced more economical satisfactory results, since great rubber production was obtained without undermining the trees' physiological state. When compared to downward tapping on renewed bark, upward tapping on virgin bark increased the productivity of the rubber tree by about 34% for the quarter spiral cut and 36% for the half spiral cut. Upward tapping systems yielded on average 2 592 kg/ha per year, with small occurrence of tapping panel dryness and hence confirmed their great productive potential already proven in industrial plantations. They significantly outperformed the downward tapping on first renewed bark, which produced 1 922 kg/ha more than the national average yield of 1 700 kg/ha. In smallholding conditions, upward tapping in quarter-spiral would be a better practice than half-spiral tapping. This upward tapping system at d/6 frequency can be adopted without yield reduction, to address the problem of labour shortage and unskilled tappers.

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