

Original Research Article

Effect of the Stimulating Paste Conservation Period and Economic Benefit of Ethrel-Palm oil Mixture in Rubber Tree Plantations in South-Eastern Côte d'Ivoire

Abstract

To maintain and increase sustainable productivity and natural rubber yield, the hormonal stimulation management of rubber yield should be controlled from operation centers. During two years, a study was conducted to determine the type of prepared stimulant paste and the maximum efficiency period of this paste in southeastern Côte d'Ivoire. The study was conducted on the clone GT 1, according to one tree plot design of 15 treatments of 30 trees per treatment, corresponding to different conservation periods of the prepared stimulant paste. Two stimulant products, one, marketed under the name of Ethrel used mixed with palm oil and the other one, ready-to-use (Almephon), have been kept at ambient temperature and cold. The stimulant paste was kept for 0, 3, 7, 14, 21, 28, 42 and 56 days, after its preparation. The results showed that rubber yield, radial vegetative growth, physiological profile and health of rubber trees haven't been influenced either by the mode of conservation of the stimulant paste or either by the different conservation periods. Prepared stimulant paste can, therefore, be kept up to 56 days, at ambient temperature as well as in cold, without losing their efficiency. These important results help predict the management of hormonal stimulation of rubber yield, without electrical power, from centers which will ensure distribution to different plantations. Better, the stimulant paste Ethrel-palm oil substantially cheaper, with an important local and profitable product to the bark of the best choice *Hevea brasiliensis* would be the best choice.

Keywords: *Hevea brasiliensis*, Hormonal stimulation, Conservation periods, Rubber yield, Côte d'Ivoire.

28 1. INTRODUCTION

29 The tapping of trees from a plantation enables certainly to yield rubber, but this
30 production is limited. It can't be adjusted to the needs of users and especially the
31 tapping cannot alone enable the recovery of the tree yield potential [1]. Today,
32 systematically, hormonal stimulation of the yield is added to the tapping system [2-4].
33 This consists in preparing the stimulant paste or by diluting the stimulant product ready
34 for use, or mixing Ethrel (containing the Ethephon which is the active matter (a. m.)) to
35 palm oil in order to obtain concentrations in a. m. Ethephon, of 2.5 or 5 % [5-8] and
36 then to apply to the tree in order to improve its productivity rubber [5,9]. Unfortunately
37 in Africa and particularly in Côte d'Ivoire, where rubber cultivation is dominated by
38 smallholders, including villagers [10], the practice of stimulation of the production is
39 very little controlled [11] or even in disorder. Indeed, in hope of substantially increasing
40 rubber yield, the tapper and/or farmer practices, repeatedly and excessively hormonal
41 stimulation, concern frequency of application as well as the concentration in m. a.
42 (Ethephon) during the preparation of the stimulant paste. But, this practice can cause in
43 the long-term the stopping of latex flow (tapping panel dryness) and cause a yield
44 reduction [3,11,12]. The distribution of stimulant pastes correctly prepared to rubber
45 plantations of smallholders' sector, especially villagers, from management centers of
46 plantation stimulation operations (preparation and distribution) is a plausible solution to
47 the control of this operation. The option of controlling hormonal stimulation of rubber
48 yield of smallholders, by centralizing the preparation of the stimulant paste and its
49 distribution from center operation, is certainly a good initiative but remains subjected to
50 the stimulant power of this paste prepared at the time of application. Since, the time
51 between the preparations of the stimulant paste and its application can vary and be long
52 according to distance from the center to the appropriate plantation and the necessary
53 logistics. This period may reasonably exceed one week and raise thus the problem of the
54 efficiency of this stimulant paste at the time of application. This, especially since the
55 common usage, efficient and recommended is the preparation of the stimulant paste on
56 the day of stimulation of the tree although some works have also shown that once
57 prepared, the stimulant can be kept for about one week at room temperature without
58 losing its efficiency [5].

59 The period between the preparations of the stimulant paste and its application may also
60 vary due to the nature of the stimulant paste (ready to use or Ethrel and palm oil

mixture) even though their effect on rubber productivity is similar [7,13,14]. Moreover, by the different nature of the two types of stimulant products, they will not necessarily have the same market value. Thus, in the interests of efficiency and lower cost, it would be appropriate to make the choice of the best of these two stimulants in order to recommend its use to rubber industries especially those of smallholders.

In order to deal with these concerns of national rubber industries, a study on the effect of conservation periods and cost of the stimulant paste on rubber productivity of rubber trees was conducted during two years in southeastern of Côte d'Ivoire. This article reports on the major results.

2. MATERIALS AND METHODS

2.1. Materials

Plant Material. The experiment was carried out on the experimental Research Station of CNRA-Bimbresso, located in Anguédédou, southeastern of Côte d'Ivoire. The plant material consisted of clone GT 1 of *Hevea brasiliensis*, belonging to the class of moderate vegetative growth and also moderate metabolic activity [15,16]. Clone GT 1 (*Gondang Tappen* or GT) originates from Malaysia. Its yield per tree isn't very high but is largely compensated by the good homogeneity and good secondary characteristics such as physiological parameters with the exception of moderate inorganic phosphorus content expressing an average activity metabolism. These physiological characteristics are favorable to the yield [17]. This clone is moderately sensitive to tapping panel dryness (TPD) with the conventional system of tapping d2 6d/7 and 6 to 8 stimulations on panel [17]. It is less sensitive to wind breakage. This clone was planted on a monoclinal plot with an area of 6.25 hectares at a density of 555 trees/ha (6 m x 3 m).

Stimulant products. The stimulant products used were marketed under the names of Ethrel and Almephon. They were applied 48 hours before tapping. The concentration of active ingredient (Ethepon) for each of the stimulant products used in this experiment was 2.5 %. The Almephon, dosed at 5 % Ethepon at delivery, is a ready to use product. As for the Almephon, Ethrel is dosed at 480 g of active matter (Ethepon) per liter (g.a.m.l⁻¹). The density of product was 1.2 and it titles 400 g of active matter per kilogram (g.a.m.kg⁻¹).

91

2.2. Experimental design

The experimental design adopted was a " *one tree plot design* " where each rubber constituted a repetition. The trees selected were distributed into 15 treatments corresponding to different modes of conditioning and conservation periods of the stimulant paste prepared, on a basis of 30 trees or repetitions per treatment. All the trees were tapped in half spiral downward every four days, with one day rest (Sunday) in the week, 12 months on 12 (S/2 d4 6d/7 12 m/12). The dilution of these stimulant products marketed (Ethrel and Almephon) respectively with oil palm and clean water, permitted to obtain stimulant pastes used to stimulate selected trees. These pastes were conserved according to table 1, before being applied to the trees. Trees stimulated with the Ethrel whose stimulant paste was prepared and conserved at ambient temperature during 7 days, made up the control 1 (ETH-air 7). Similarly, trees stimulated with Almephon whose stimulant paste was prepared the day of the stimulation of the trees, made up the control 2 (ALM-air-Jj).

Table 1. Listing of different treatments applied to trees of clone GT 1

ETHREL	ALMEPHON
ETH-air-Dd : stimulant paste prepared from Ethrel on the day of use	ALM-air-Dd : stimulant paste prepared from Almephon on the day of use
ETH-air-3 : stimulant paste prepared from Ethrel and conserved at room temperature during 3 days	ALM-air-3 : stimulant paste prepared from Almephon and conserved at cold during 3 days
ETH-air-7 : stimulant paste prepared from Ethrel and conserved at room temperature during 7 days (Control 1)	ALM-air-7 : stimulant paste prepared from Almephon and conserved at cold during 7 days (Control 2)
ETH-air-14 : stimulant paste prepared from Ethrel and conserved at room temperature during 14 days	ALM-air-14 : stimulant paste prepared from Almephon and conserved at cold during 14 days
ETH-air-21 : stimulant paste prepared from Ethrel and conserved at room temperature during 21 days	ALM-air-21 : stimulant paste prepared from Almephon and conserved at cold during 21 days
ETH-air-28 : stimulant paste prepared from Ethrel and conserved at room temperature during 28 days	ALM-air-28 : stimulant paste prepared from Almephon and conserved at cold during 28 days
ETH-air-42 : stimulant paste prepared from Ethrel and conserved at room temperature during	ALM-air-42 : stimulant paste prepared from Almephon and conserved at cold during 42 days
ETH-air-56 : stimulant paste prepared from Ethrel and conserved at room temperature during	ALM-air-56 : stimulant paste prepared from Almephon and conserved at cold during 56 days
ETH-cold-3 : stimulant paste prepared from Ethrel and conserved at room temperature during 3 days	ALM-cold-3 : stimulant paste prepared from Almephon and conserved at cold during 3 days
ETH-cold-7 : stimulant paste prepared based Ethrel and	ALM-cold-7 : stimulant paste prepared from

conserved at room temperature during 7 days	Almephon and conserved at cold during 7 days
ETH-cold-14 : stimulant paste prepared from Ethrel and conserved at room temperature during 14 days	ALM-cold-14 : stimulant paste prepared from Almephon and conserved at cold during 14 days
ETH-cold-21 : stimulant paste prepared from Ethrel and conserved at room temperature during 21 days	ALM-cold-21 : stimulant paste prepared from Almephon and conserved at cold during 21 days
ETH-cold-28 : stimulant paste prepared from Ethrel and conserved at room temperature during 28 days	ALM-cold-28 : stimulant paste prepared from Almephon and conserved at cold during 28 days
ETH-cold-42 : stimulant paste prepared from Ethrel and conserved at room temperature during 42 days	ALM-cold-42 : stimulant paste prepared from Almephon and conserved at cold during 42 days
ETH-cold-56 : stimulant paste prepared from Ethrel and conserved at room temperature during 56 days	ALM-cold-56 : stimulant paste prepared from Almephon and conserved at cold during 56 days

ETH: Ethrel, ALM: Almephon, 0...56: During of stimulant paste after its preparation (days),

Dd: 0 day

2.3. Preparation and application of stimulant paste

The two types of stimulant paste were respectively obtained by adding water to the Almephon (v/v) and oil palm to the Ethrel then the product was mixed until complete homogenization.

For the application of stimulant paste based on Almephon, measuring in the preparation of 5 % in this experiment, the same volume of water as that of Almephon so as to bring its concentration in Ethephon 2.5 %. Thus, for 1 g of stimulant paste 2.5 % Ethephon, 0.5 g of water was mixed with 0.5 g of Almephon.

In the case of Ethrel, the quantities of Ethrel and of oil palm to be mixed to obtain the required concentration are such that for 1 g of stimulant paste of concentration 2.5 % Ethephon, mixed 0.0625 g of Ethrel to 0.9375 g of palm oil. This mixture, the same as that of Almephon was applied per tree per stimulation. The stimulation was made in our study, on a band of 1 cm wide on the tapping cut and parallel to and above thereof in an amount of 0.7 g of stimulant paste per tree per application [6,7,18]. Exception of stimulant pastes used on the day of their preparations, other pastes were conserved at different times or in cold, or in the open air as shown in table 1.

127 2.4. Measurements and data processing

128 **Yield.** Each tree latex yield collected in the field, was measured by weighing the
129 cumulative coagulated rubber every for weeks. The transformation coefficient (CT),
130 which is the rate of dry matter of a given sample of fresh rubber, was used to calculate
131 the yield of dry rubber in grams per tree (g.t^{-1}).

132 **Latex Micro Diagnosis.** Some collected latex helped determine annually, by the method
133 of Latex Micro Diagnosis (LMD), the value of dry rubber content (DRC (%)) and dose
134 the sucrose (Suc), inorganic phosphorus (iP) and thiol groups (R-SH) contents of the
135 latex, expressed in mmol.l^{-1} . In practice, the dry matter content of the latex was
136 determined by weighing 1 ml of latex into a pillbox of 10 ml, before and after drying in
137 oven at 80 °C during 24 h. But long before, the vacuum out of the pillbox was
138 determined. Then the difference in weight expressed in percentage shows the rate of dry
139 content. Inorganic phosphorus, sucrose and thiol groups were determined from the
140 trichloroacetic acid serum (TCA-serum) obtained by mixing 1 ml of latex and 9 ml of
141 2.5 % TCA. Using a wand, the coagulated rubber was squeezed out and separated from
142 2.5 % TCA. Finally, the different dosages were applied:

- 143 ➤ sucrose (Suc) was assayed by the method of [19] based on anthrone that in the
144 presence of concentrated acid, hexoses dehydrate to give a furfural reacting with
145 anthrone giving a blue-green coloring whose optical density (OD) is read at the
146 wavelength of 627 nm ;
- 147 ➤ inorganic phosphorus (Pi) was assayed by the method of [20] method using
148 molybdate ammonium : phosphorus is complexed with an excess of molybdate
149 ammonium. The complex formed is then reduced by ferrous sulfate, a blue
150 color, whose absorbance value is read at the wavelength 680 nm ;
- 151 ➤ thiol groups (R-SH) was performed by the method described by [21] using
152 dinitro-2,2'-dithio-5-5'-dibenzoic acid (BTNB) thiol groups react with the acid to
153 give the thio-nitro-benzoic acid (TNB) high-absorbency at 412 nm. TNB is
154 revealed by Tris buffer (yellow coloration).

155 Thus, for each treatment, the characteristics of different clones were determined using
156 the latex micro diagnosis.

157 **Radial vegetative growth.** The radial growth was measured at 1.70 m above the ground
158 on each tree treated at the beginning and the end of the experiment. The average annual
159 girth increment (cm.year⁻¹) was determined by the following relation :

$$160 \quad \text{Girth}_{\text{inc}} = (\text{Girth}_{\text{beginning}} - \text{Girth}_{\text{end}}) / i$$

161 With **Girth_{inc}** : Girth increment; **Girth_{end}**: tree girth at the end of the experiment ;
162 **Girth_{beginning}**: initial girth of trees at the beginning of experiment ; **i** : number of years
163 of experiment.

164 **Visual estimation of the tapping panel dryness.** The method of quick survey by visual
165 assessment helped to account for the onset and progress of tapping panel dryness. For
166 each tree tapped, it was assigned a number between 0 and 6.

167 The specific account of trees' condition was performed and the rate of length of dry cut
168 (LDC (%)) for each treatment was calculated as follows:

$$169 \quad \text{LDC (\%)} = (0.1 n_1 + 0.3 n_2 + 0.5 n_3 + 0.7 n_4 + 0.9 n_5 + n_6 + \text{DT}) \times N^{-1}$$

170 **N** : Total number of trees ; **n_i** : Number of trees per tapping panel dryness class ; **DT** :
171 Number of trees whose tapping has already been stopped because of full tapping panel
172 dryness.

173 2.5. Determination of the best stimulant product

174 **Evaluation of agrophysiological parameters.** The rubber yield in gram per tree (g.t⁻¹),
175 the average annual increase in girth, as well as the physiological parameters of latex
176 micro diagnosis of two types of stimulants will be assessed so as to determine the best
177 stimulant product, based on these parameters.

178 **Evaluation of Economical parameters.** The cost of stimulation per hectare with each
179 type of stimulant product will be the only assessment criterion. The number of trees per
180 hectare is about 500. This cost of stimulation will be obtained as follows:

$$181 \quad \text{Cost}_{\text{HaStimET}} = \text{Cost}_{\text{ET}} + \text{Cost}_{\text{HP}} \quad (1)$$

$$182 \quad \text{Cost}_{\text{HaStimAlm}} = \text{Nb}_{\text{Tree/ha}} \times 0.7 \text{ g/tree} \times 5 \text{ USD} \times 500 \text{ g}^{-1} \quad (2)$$

183 With:

$$184 \quad \text{Cost}_{\text{ET}} = V_{\text{ET}} (\text{L}) \times 13 \text{ USD.L}^{-1}$$

$$185 \quad V_{\text{ET}} (\text{L}) = \text{Nb}_{\text{Tree/ha}} \times 0.7 \text{ g/tree} \times 0.0625/1200 \text{ g} \times \text{L}$$

$$186 \quad \text{Cost}_{\text{HP}} = V_{\text{HP}} (\text{L}) \times 1 \text{ USD. L}^{-1}$$

187 $V_{HP} (L) = Nb_{Tree/ha} \times 0.7 \text{ g/tree} \times 0.9375/900 \text{ g} \times L$

188 **2.6. Statistical analysis**

189 Rubber yield data were performed using the software XL-STAT, Pro 6.1.9. The level of
190 significance of differences between averages was estimated by the Duncan test at 5 %
191 threshold.

192 **3. RESULTS AND DISCUSSION**

193 **3.1. Effects of the conservation period of the stimulant products on their efficiency**

194 *Agrophysiological parameters.* Relatively to rubber yield, the latex yield of the rubber
195 trees treated with the stimulant pastes prepared and based on Ethrel and subject to
196 different conservation periods are expressed in gram per tree (g t^{-1}) and presented in
197 table 2. The analysis of this table shows that the rubber yield of different conservation
198 periods of stimulant paste varies significantly. The rubber yield of the control 1
199 (927.215 g t^{-1}) was statistically identical to those of all other periods except those of
200 periods ETH- cold-21 (685.625 g t^{-1}) and ETH-cold-56 ($1139.744 \text{ g t}^{-1}$). Indeed, the
201 control trees had a significantly higher rubber yield than that of ETH-cold-21 treatment
202 and significantly lower than that of ETH-cold-56 treatment.

203 Regarding the physiological profile, rubber yield of rubber trees treated with stimulant
204 pastes prepared with Almephon and also subject to different conservation periods are
205 expressed in g.t^{-1} and presented in table 3. These results  shows that rubber yields of
206 control 2 ($1153.947 \text{ g t}^{-1}$) have been statistically similar to those of the other treatments
207 except those of treatments ALM-cold-3 ($1382.911 \text{ g t}^{-1}$) and ALM-cold-56 (984.615 g t^{-1}).
208 The yields of control 2 have been, in fact, significantly higher than those of ALM-
209 cold-56 treatment and lower than those of ALM-cold-3 treatment.

210 Whatever the stimulant paste used, the rubber yield haven't been influenced either by
211 the mode of conservation of the stimulant paste or either by the different conservation
212 periods.

213 As for latex micro diagnosis results which are also consigned in table 2 they showed
214 that the dry rubber content (DRC) and the sucrose and inorganic phosphorus contents
215 are statistically equivalent for all the trees of the different treatments of stimulant paste
216 based on Ethrel. The trees of the different treatments had on average very high DRC

(54.98 %) and average sucrose contents (7.23 mmol.l^{-1}) and inorganic phosphorus ($16.63 \text{ mmol.l}^{-1}$). Concerning thiol contents, they varied from 0.10 to 1.45 mmol.l^{-1} . The control presented contents statistically equivalent to those of the other treatments except those of treatments ETH-air Dd (1.38 mmol.l^{-1}) and ETH-cold-56 (1.45 mmol.l^{-1}) whose contents were the highest.

The results of physiological parameters of the rubber trees treated with the stimulant pastes prepared and based on Almephon are shown in table 3. The values of dry rubber content (DRC) and those of sucrose and inorganic phosphorus contents are statistically equivalent for all the trees of the different treatments. The trees of the different treatments had on average very high rates of DRC (55.83 %) and average sucrose contents (6.88 mmol.l^{-1}) and inorganic phosphorus ($16.74 \text{ mmol.l}^{-1}$). Regarding the thiols contents, they have fluctuated between 0.11 and 1.64 mmol.l^{-1} . The thiol contents of the control have been statistically identical to those of the other treatments and significantly higher than those of treatments ALM-air-56 (0.12 mmol.l^{-1}), ALM-cold-42 (0.13 mmol.l^{-1}) and ALM-cold-56 (0.11 mmol.l^{-1}). The highest contents were recorded by the treatments ALM-air-Dd (0.70 mmol.l^{-1}), ALM-air-3 (1.64 mmol.l^{-1}), ALM-air-14 (0.66 mmol.l^{-1}) and ALM-cold-3 (1.02 mmol.l^{-1}).

The results of the latex micro diagnosis have helped characterize the trees subjected to different conservation periods and conditioning methods. Thus, inorganic phosphorus contents of the trees of clone GT 1 were $16.63 \text{ mmol.l}^{-1}$ and $16.74 \text{ mmol.l}^{-1}$ on average and corresponded respectively to the trees treated with Ethrel and those treated with Almephon. This is related to the metabolic functioning of this clone with moderate metabolism as shown by several authors such as [13,17,22-25].

The rates of dry rubber content (DRC) of trees of the different treatments were all equivalent and very high. They were 54.98 and 55.83 % on average, corresponding respectively to the trees treated with Ethrel and those treated with Almephon. This high rate of DRC is the expression of a very good regeneration of latex exported during tapping [26]. This is consecutive to stimulation as shown by [22,25,24]. The high contents in thiol groups of trees subjected to different treatments were favorable to yield [17], as there are positive correlations between thiol contents and yield [22].

Furthermore, the evolution in thiol group contents of the different treatment groups was independent of the conservation periods of stimulant pastes. The significant variations

249 of the different thiol groups contents might be due to their degradation, related to the
250 conservation period of the serum-TCA intended to their dosage, as shown by [1].

251 The sucrose content of the latex of all the trees treated was average, because the use of
252 sucrose for the biosynthesis of rubber [27] is important [11]. Indeed, the ethylene
253 stimulation highly activates the metabolism of the clones and the result is a high
254 transformation of the sucrose present in latex vessels, into rubber [11,28,29]. Thus, a
255 strong response to the stimulation of a clone makes predict that there is a good
256 availability of sucrose within latex vessels, reflecting a good supply [23]. Overall, the
257 characteristics of physiological parameters of the latex of trees of the different
258 treatments were all similar to each other. This is the sign that the various periods and
259 conservation methods of the stimulant pastes were statistically equivalent and do not
260 affect negatively the physiological parameters of the latex of trees. These characteristics
261 are favorable for rubber yield of clone GT 1 [17], and are corroborated by a very good
262 average annual girth increment, absolutely above the national average of this clone (> 2
263 $\text{cm}\cdot\text{year}^{-1}$) in Côte d'Ivoire.

264 Regarding the isodiametric growth of the trunk of trees treated with Ethrel, no
265 significant differences were observed in terms of annual increases of trees, regardless of
266 the treatments (Table 2). These girth increments varied between 3.38 and 5.67 $\text{cm}\cdot\text{year}^{-1}$.
267

268 Concerning isodiametric growth of trees treated with Almephon, like the trees treated
269 with Ethrel, no significant differences were observed in terms of annual girth increment
270 in the trees treated with Almephon, regardless of the treatment (Table 3).

271 Rubber trees tapping commencement creates competition for assimilates and energy
272 between radial vegetative growth and latex yield, resulting in a decrease of one of the
273 parameters at the expense of the other as shown by [15,25,28,30,31]. Our results, in
274 relation to the isodiametric vegetative growth, were all equivalent and indicated average
275 significant increase of 4.37 $\text{cm}\cdot\text{year}^{-1}$ and 4.43 $\text{cm}\cdot\text{year}^{-1}$ respectively corresponding to
276 the trees treated with Ethrel and those treated with Almephon. These results are in
277 accordance with those of other studies [17]. Our results on the isodiametric vegetative
278 growth are therefore independent of periods and conservation methods of the stimulant
279 pastes to which the trees have been submitted.

280 *Sensitivity to tapping panel dryness (TPD).* In terms of sensitivity to tapping panel
 281 dryness, the average values of the rates of dry tapping cut length (LDC (%)) and dry
 282 trees (%) of the trees of clone GT 1 treated with Ethrel are also presented in table 2. The
 283 results showed that except for the trees of treatment ETH-air-21 which showed a
 284 significantly high rate of dry tapping cut length (7.0 %); all the trees had rates of
 285 tapping panel dryness statistically identical to each other. These rates varied from 0 to 2
 286 %. As for the trees, except for those being treated with ETH-air-21 which recorded a
 287 rate of dry trees by 5 % significantly highest, all trees treated with stimulant pastes
 288 prepared with Ethrel were free from dry trees regardless of the conservation time and
 289 conditioning mode of the stimulant paste prepared.

290 Relating to the sensitivity to tapping panel dryness, the average values of the rate of dry
 291 tapping cut length (LDC (%)) and dry trees (%) of the trees of clone GT 1 treated with
 292 Almephon are also shown in table 3. The results indicate that all treatments with
 293 Almephon are statistically identical relating to the rates of dry tapping cut length of the
 294 trees of clone GT 1. These rates also varied from 0 to 2 % as was the case for trees
 295 treated with Ethrel. Concerning dry trees, no cases have been observed in trees treated
 296 with stimulant pastes prepared and based on Almephon regardless of the conservation
 297 time and the conditioning method.

298 The rates of dry tapping cut length, all treatments included, except for ETH-air-21,
 299 which showed a high rate of dry-cut length (7.0 %) were low, confirming that clone GT
 300 1 expresses a moderate sensitivity to this syndrome [17]. The conservation period of the
 301 stimulant paste corresponding to treatment ETH-air-21 is neither the shortest nor the
 302 longest. This sensitivity to tapping panel dryness expressed by the trees submitted to
 303 treatment ETH-air-21 would be independent of periods and conservation methods of
 304 stimulant pastes. It would be due to edaphic factors¹¹

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Table 2. Average values for rubber yield, physiological parameters, growth, percentages of dry-cut lenght (LDC) and dry trees of rubber trees treated with ETHREL

Treatments	Yield (g t ⁻¹)	Physiological parameters				Isodiametric increase (cm year ⁻¹)	LDC (%)	Dry trees (%)
		DRC (%)	Suc (mmol.l ⁻¹)	Pi (mmol.l ⁻¹)	R-SH (mmol.l ⁻¹)			
ETH-air-Dd	894.737 cd	54.96 a	8.29 a	13.49 a	1.38 a	4.17 a	1.5 b	0.0 b
ETH-air-3	997.5 bcd	57.72 a	6.15 a	14.60 a	0.62 bc	4.45 a	1.0 b	0.0 b
ETH-air-7 (Control 1)	927.215 bcd	52.85 a	7.37 a	13.97 a	0.23 cd	5.67 a	1.0 b	0.0 b
ETH-air-14	934.375 bcd	59.84 a	6.79 a	16.45 a	0.61 bc	5.10 a	2.0 b	0.0 b
ETH-air-21	901.875 cd	54.50 a	9.04 a	17.24 a	0.27 cd	4.74 a	7.0 a	5.0 a
ETH-air-28	1015 abc	56.08 a	7.36 a	14.91 a	0.77 bc	4.34 a	0.5 b	0.0 b
ETH-air-42	900 cd	57.23 a	9.18 a	16.01 a	0.09 d	3.76 a	1.0 b	0.0 b
ETH-air-56	1058.442 ab	50.05 a	5.84 a	18.78 a	0.20 cd	4.63 a	0.0 b	0.0 b
ETH-cold-3	886.25 cd	56.02 a	6.11 a	16.84 a	0.60 bc	3.48 a	0.0 b	0.0 b
ETH-cold-7	887.821 cd	54.36 a	5.49 a	18.25 a	0.15 cd	4.80 a	0.0 b	0.0 b
ETH-cold-14	865.625 d	53.01 a	7.62 a	18.12 a	0.10 d	3.86 a	2.0 b	0.0 b
ETH-cold-21	685.625 e	55.96 a	9.25 a	18.07 a	0.23 cd	4.11 a	0.5 b	0.0 b
ETH-cold-28	1006.25 abcd	57.46 a	6.84 a	15.88a	0.19 cd	5.28 a	0.0 b	0.0 b
ETH-cold-42	975.796 bcd	49.30 a	7.37 a	17.50 a	0.16 cd	3.61 a	1.0 b	0.0 b
ETH-cold-56	1139.744 a	54.98 a	5.81 a	19.42 a	1.45 a	3.58 a	0.0 b	0.0 b
Means	938.417	54.98	7.23	16.63	0.47	4.37	1.16	0.33

In each column, the values followed by the same letter are not significantly different (test of DUNCAN at 5 %)
g/t: gram per tree, DRC: dry rubber content, Suc: sucrose, iP: inorganic phosphorus, R-SH: thiol components, LDC: dry tapping cut length

Table 3. Average values for rubber yield, physiological parameters, growth, percentages of dry-cut lenght (LDC) and dry trees of rubber trees treated with ALMEPHON

Treatments	Production (g t ⁻¹)	Physiological parameters				Isodiametric increase (cm.year ⁻¹)	LDC (%)	Dry trees (%)
		DRC (%)	Suc (mmol l ⁻¹)	Pi (mmol l ⁻¹)	R-SH (mmol l ⁻¹)			
ALM-air Dd (Control 2)	1153.947 bcd	53.87 a	8.12 a	14.60 a	0.70 abc	3.84 a	1.0 a	0.0 a
ALM-air-3	1307.692 ab	56.52 a	7.18 a	18.16 a	1.64 a	3.58 a	1.0 a	0.0 a
ALM-air-7	1161.333 bcd	54.66 a	6.24 a	15.48 a	0.48 bc	5.15 a	1.0 a	0.0 a
ALM-air-14	1231.646 abc	55.80 a	5.23 a	16.54 a	0.66 abc	3.79 a	1.5 a	0.0 a
ALM-air-21	1205.625 bc	56.21 a	5.94 a	15.00 a	0.41 bc	4.92 a	1.0 a	0.0 a
ALM-air-28	1089.873 cd	53.76 a	8.24 a	17.99 a	0.20 bcd	3.61 a	0.0 a	0.0 a
ALM-air-42	1245.625 abc	56.82 a	5.16 b	17.15 a	0.25 bcd	3.88 a	0.0 a	0.0 a
ALM-air-56	1112.5 cd	57.33 a	8.95 a	19.35 a	0.12 d	4.93 a	0.0 a	0.0 a
ALM-cold-3	1382.911 a	55.88 a	6.51 a	15.74 a	1.02 a	5.22 a	0.0 a	0.0 a
ALM-cold-7	1162.987 bcd	58.91 a	6.67 a	13.06 a	0.40 bc	4.27 a	0.5 a	0.0 a
ALM-cold-14	1068.59 cd	54.27 a	5.31 a	17.85a	0.41 bc	4.03 a	2.0 a	0.0 a
ALM-cold-21	1097.5 cd	57.05 a	6.63 a	17.24 a	0.39 bc	5.19 a	1.5 a	0.0 a
ALM-cold-28	1085.333 cd	54.03 a	8.17 a	18.47 a	0.26 bcd	4.91 a	2.0 a	0.0 a
ALM-cold-42	1137.013 bcd	56.01 a	7.16 a	17.77 a	0.13 d	4.74 a	0.0 a	0.0 a
ALM-cold-56	984.615 d	56.37 a	7.70 a	16.71 a	0.11 d	4.46 a	1.0 a	0.0 a
Means	1161.81	55.83	6.88	16.74	0.48	4.43	0.83	0

In each column, the values followed by the same letter are not significantly different (test of DUNCAN at 5 %)

g/t: gram per tree, DRC: dry rubber content, Suc: sucrose, iP: inorganic phosphorus, R-SH: thiol components, LDC: dry tapping cut length

3.2. Comparative effects of cold and ambient air on the efficiency of Ethrel and of Almephon

Tables 4 and 5 show the values of the agrophysiological parameters and rates of dry-cut length of trees stimulated respectively with the Ethrel and with the Almephon. The analysis of these two tables showed that the two conditionally methods are statistically equivalent relative to agrophysiological and health parameters. In fact, regardless of the conservation periods and the type of stimulant products, no significant difference between treatments had been observed, for values of agrophysiological and health parameters.

The action of stimulant treatment is limited in time [32]. Thus, once prepared, the Ethrel-based stimulant paste can be kept for one week at ambient temperature without the stimulant losing its effect [33], while Almephon-based stimulant paste can be maintained one day without the stimulant losing its effect [33]. To this end, our results are not in accordance with the foregoing. Indeed, the results of the different treatments in relation to their rubber yields were not influenced either by stimulant paste conditioning, or by the different conservation periods to which these treatments were submitted. The conservation periods and the conditioning of the stimulant paste would therefore not, in this work, be limiting factors for the efficiency of the stimulant products. Regarding the independence of the efficiency of stimulant products vis-a-vis the conservation periods and the conditioning of stimulant pastes, our results are in accordance with those of the works of [34] which showed that the amplitude of the response to the stimulation may be limited by climatic factors causing a water deficit and a reduction in the internal turgor pressure. Thus, it is recommended to avoid stimulating the trees during periods of frequent rain and during periods of low luminosities [9]. Indeed, frequent rain water washes the stimulant paste applied to the tree sometime after the rain fell, while low light conditions are unfavorable to the synthesis of photosynthetic assimilates a fraction of which is diverted to a regeneration metabolism of the latex [9,11]. To this end, stimulation is expressed *in fine* by a significant latex export but also by a strong activation of cellular metabolism and an increased consumption of carbohydrate matters resulting from the photosynthetic activity [27,32].

358 Furthermore, most commercial products used in the stimulation of rubber in Côte
 359 d'Ivoire, including Ethrel and Almephon have the same active ingredient chloro-2-
 360 ethylphosphonic acid (Ethephon), in very acid solution ($\text{pH} = 1$). Stable with very acid
 361 pH, Ethephon decomposes and releases ethylene if the pH of the solution becomes
 362 greater than 4.5, which is occurs actually inside the bark tissues: this account for the fact
 363 that the stimulant treatments leads to a release of ethylene in the bark tissue [32]. The
 364 stimulant product would be active and efficient if its center of action becomes less acid.
 365 Thus, on the biochemical and metabolic level, there are also significant and intrinsic
 366 modifications of rubber trees. The pH of the latex shows a tendency to alkalization
 367 which has a significant impact on certain enzyme activities, especially on the glycolysis,
 368 which is accelerated sharply [35,36]. Therefore, the efficiency of the stimulant product
 369 would not be primarily dependent of the conservation period or conditioning of the
 370 stimulant paste but the pH of its environment for action: this could explain the results of
 371 the different treatments in terms of their rubber yield. Our results do not fundamentally
 372 undermine those of previous studies that have shown short periods in relation to ours.
 373 To some extent, these results confirm the first but indicate that the period is probably
 374 longer. Our results are comforting because they provide a clear response to the concerns
 375 of national rubber industries to provide the means to control hormonal stimulation of the
 376 latex yield of smallholders. Technically, this activity can be managed from a stimulant
 377 preparation center in any way whatsoever and distribute to all the plantations under such
 378 center.

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Table 4. Average values for rubber yield, physiological parameters, growth, percentages of dry-cut lenght (LDC) and dry trees of rubber trees treated with ETHREL in function of the conditioning of stimulant pastes

Treatments	Yield (g t ⁻¹)	Physiological parameters				Isodiametric increase (cm.year ⁻¹)	LDC (%)	Dry trees (%)
		DRC (%)	Suc (mmol l ⁻¹)	Pi (mmol l ⁻¹)	R-SH (mmol l ⁻¹)			
ETH-air	953.64 a	55.4 a	7.50 a	15.68 a	0.12 a	4.55 a	1.75 a	0.62 a
ETH-cold	906.81 a	54.5 a	6.93 a	17.72 a	0.09 a	4.02 a	0.50 b	0.00 a

In each column, the values followed by the same letter are not significantly different (test of DUNCAN at 5 %)
g/t: gram per tree, DRC: dry rubber content, Suc: sucrose, iP: inorganic phosphorus, R-SH: thiol components, LDC: dry tapping cut length

Table 5. Average values for rubber yield, physiological parameters, growth, gercentages of dry-cut lenght (LDC) and dry trees of rubber trees treated with ALMEPHON in function of the conditioning of stimulant pastes

Treatment s	yield (g t ⁻¹)	Physiological parameters				Isodiametric increase (cm year ⁻¹)	LDC (%)	Dry trees (%)
		DRC (%)	Suc (mmol l ⁻¹)	Pi (mmol l ⁻¹)	R-SH (mmol l ⁻¹)			
ALM-air	1188.53 a	55.62 a	6.88 a	16.78 a	0.13 a	4.21 a	0.69 a	0.0 a
ALM-cold	1131.28 a	56.07 a	6.89 a	16.69 a	0.10 a	4.43 a	1.00 a	0.0 a

In each column, the values followed by the same letter are not significantly different (test of DUNCAN at 5 %)
g/t: gram per tree, DRC: dry rubber content, Suc: sucrose, iP: inorganic phosphorus, R-SH: thiol components, LDC: dry tapping cut length

410 **3.3. Cost of stimulation of a hectare plantation in downward tapping about**
 411 **stimulant paste based on Ethrel and Almephon and determination of the best**
 412 **stimulant**

413 The report $\text{CostHa}_{\text{StimAlph}}/\text{CostHa}_{\text{StimET}}$ gives 5.843, which signifies that the stimulant
 414 product ready for use, especially the Almephon is at least 5 times more expensive than
 415 based on the Ethrel (Table 6).

416 In our experimental setting, all the other parameters being equal, the ratio
 417 $\text{CostHa}_{\text{StimAlm}}/\text{CostHa}_{\text{StimET}}$ giving 5.843, enables us to assert that hormonal stimulation
 418 with the stimulant product ready for use, Almephon, at least 5 times more expensive
 419 than the Ethrel-based one is significantly less expensive than the latter. In addition, the
 420 works of (Obouayeba personnal communication) have shown that the bark stimulated
 421 with an Ethrel-based stimulant paste is softer than the one stimulated with the stimulant
 422 product (LES 50) ready-to-use. These two results in favor of the Ethrel-based stimulant
 423 paste, reinforces in us the idea that the best stimulant product is Ethrel.

424 **Table 6. Cost of Stimulation of hectare plantation in downward tapping about**
 425 **stimulant paste based on EHTREL and ALMEPHON**

426

Stimulant product	Cost/Ha (USD)
Ethrel	0.599
Almephon	3.500

427

428 **4 ONCLUSION**

429 The conservation of stimulant pastes prepared with stimulant products marketed under
 430 the names of Ethrel and Almephon enabled to note that the efficiency of the stimulant
 431 has been influenced neither by the conditioning of stimulant pastes previously prepared,
 432 nor by the different conservation periods to which these pastes were submitted. The
 433 response to stimulation could be due either to climate factors or the tendency to latex
 434 alkalization which has a particularly significant impact on latex glycolysis.
 435 Conservation recommendations for one day or one week of the stimulant pastes
 436 prepared previously are now obsolete. The stimulant pastes prepared already can thus be

437 conserved for more than one week, specifically up to 56 days, at room temperature as
 438 well as in cold, without the stimulant losing its efficiency.
 439 The ratio $\text{CostHa}_{\text{StimAlm}}/\text{CostHa}_{\text{StimET}}$ worth 5.843, is an illustration of the fact that the
 440 stimulant product ready to use, Almephon, is more expensive than the Ethrel-based one.
 441 It is therefore the best stimulant for natural rubber yield.

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