Influence of Ethephon Stimulation on Latex Physiological Parameters and Consequences on Latex Diagnosis Implementation in Rubber Agro-Industry.

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ABSTRACT

Latex Diagnosis (LD) is currently considered by Cirad and most of its rubber agro-industry partners as a routine physiological tool to optimise, at block level, the rubber yield production of the rubber plantations.

Without using LD, a general stimulation recommendation per clone and per tapping year is generally applied at plantation scale, as a function of tapping cut position and direction, whatever the local and actual yield potential is. Even though this general recommendation is based on clonal physiological latex characteristics, such a global approach does not permit to consider the local specificities of the yield potential, as it avoids considering factors like soil heterogeneity, microclimate variations in larger estates and differential expression of diseases (leaf diseases, root diseases…). In this case, plantations are almost "blind" regarding suitability of the applied stimulation intensities, and uniform application of the same rate of stimulant in all homogenous cultural units may sometimes lead to optimised exploitation but may also lead locally to underexploitation in higher yield potential areas or to overexploitation in lower yield potential areas.

Using LD permits to optimize the stimulation at local level (decrease of stimulation when an overexploitation is detected, increase of stimulation intensity when an underexploitation is detected) and therefore permits the yield optimisation block per block, taking into account the plantations heterogeneities and therefore the actual local yield potential. Of course, LD interpretation depends on former set up LD parameters reference values. These ones are clonal and established for the 4 parameters used in LD: latex sucrose content, latex inorganic phosphorus content, latex reduced thiols content and DRC/TSC. These LD reference values are established for 5 limit levels (very low, low, normal, high and very high), for each LD parameter (Suc, Pi, RSH and DRC/TSC), either at regional scale or, in case of large estates and companies, at plantation scale when local LD parameters database is large enough. To set up correctly these LD reference values, it is required to know what can be the general evolution of the 4 LD parameters depending on exploitation intensity. These evolutions are detailed in the document.

INTRODUCTION

Latex Diagnosis (LD) is currently considered by Cirad and most of its rubber agro-industry partners as a routine physiological tool to optimise, at block level, the rubber yield production of the rubber plantations.

During the peak production period (August to November in Northern Hemisphere, February to May in Southern Hemisphere), the simultaneous comparison of:

- Latex Sucrose content (Suc, indicator representing the possibilities of exploitation intensification),
- Latex Inorganic Phosphorus content (Pi, indicator of the energetic level of latex cells metabolism),
- Latex Reduced Thiols content (RSH, indicators of cell/organite membranes protection against Reactive Oxygen Species (ROS) released during latex metabolic activation),
- latex DRC/TSC (indicator of the balance between water importation to the latex cells and cytoplasmic biosyntheses resulting from latex regeneration,

is a picture of the physiological condition of latex cells at the moment of sampling/analysis and permits to derive a diagnosis of normal, under or over exploitation (Eschbach *et al*, 1984, Jacob *et al*, 1985, 1988a, 1988b, 1995a, 1997, 1998, d'Auzac *et al*. 1997).

Of course, LD interpretation depends on former set up LD parameters reference values. These ones are established for the 4 parameters used in LD: latex sucrose content (Suc, $mM.l^{-1}$), latex inorganic phosphorus content (Pi, $mM.l^{-1}$), latex reduced thiols content (RSH, $mM.l^{-1}$) and DRC/TSC (%). These LD reference values are established for 5 limit levels (very low, low, normal, high and very high), for each LD parameter (Suc, Pi, RSH and DRC/TSC), either at regional scale or, in case of large estates and companies, at plantation scale when local LD parameters database is large enough.

LD reference values are usually set up for each clone, not taking into account panel cut positions or implemented tapping systems. LD interpretation lays in the combination of the levels of each LD parameter (Suc, Pi, RSH and DRC/TSC) in comparison with the corresponding parameter reference values. Therefore, it is exactly the same principle as that used for interpretation of blood analyses in human or veterinarian medicine.

Of course, the method used to establish each LD parameter (Suc, Pi, RSH and DRC/TSC) reference value, as well as interpretation keys of each combination of parameters levels, is strictly confidential and cannot be explained and detailed here, as it represents the expertise of each rubber research institute as well as Intellectual Property Rights (IPR) of the associated industrial partners.

To set up correctly these LD reference values, it is required to know what can be the general evolution of the 4 LD parameters (Suc, Pi, RSH and DRC/TSC) depending on exploitation intensity. In the agro-industry, tapping frequency is usually fixed, as it is mostly determined by manpower availability and cost in regard of the rubber price, as well as housing and social facilities. For these reasons, stimulation intensity is the most often used parameter used in rubber agro industries using reduced tapping frequencies to modulate their exploitation intensity (Gohet *et al*. 1991).

To perform an accurate LD interpretation, it is therefore essential to know and to understand what can be the effect of stimulation on each LD parameter.

INFLUENCE OF ETHEPHON STIMULATION ON LD PARAMETERS (SUC, Pi, RSH and TSC/DRC).

1. Effect on Latex Sucrose content (Suc, mM. l^{-1}): Figure 1

Whatever the tapping frequency, increase in Ethephon stimulation intensity generally results in a hyperbolic decrease of Latex Sucrose content. This decrease (from very high Suc values to very low Suc values) is due to increased sucrose consumption from the latex regeneration metabolism. It is however remarkable that overexploitation, due to excessive stimulation intensity, results in a simultaneous drop of production and Latex Sucrose content (Lacrotte 1991, Gohet 1996, Gohet *et al*.1997).

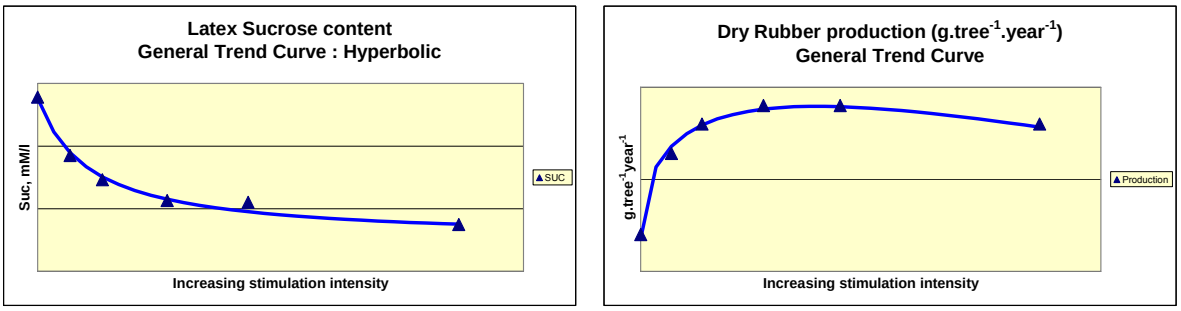

Figure 1: Simultaneous effect of Ethephon stimulation intensity on Latex Sucrose Content (Suc, mM.l^{-1}) and on dry rubber production (g.$tree^{-1}$.$year^{-1}$). Clone GT1 in Côte d'Ivoire. Average values after 7 years of tapping.

2. Effect on Latex Pi content (Pi, mM.l^{-1}): Figure 2

Whatever the tapping frequency, increase in Ethephon stimulation intensity generally results in a parabolic evolution of Latex Pi content. For lower stimulation intensities, increase of stimulation results in metabolic activation (increase of Pi, until reaching a maximum level). It is afterwards followed by a drop of Pi for higher intensities. This drop of Pi is a significant sign of overexploitation and is always associated with a drop of production. (Gohet *et al*. 1995, 1996, Gohet 1996).

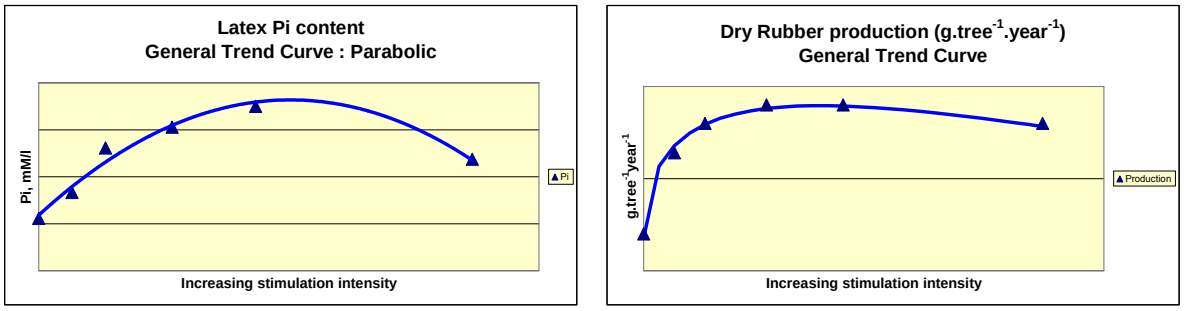

Figure 2: Simultaneous effect of Ethephon stimulation intensity on Latex Pi Content (Pi, mM.l^{-1}) and on dry rubber production (g.$tree^{-1}$.$year^{-1}$). Clone GT1 in Côte d'Ivoire. Average values after 7 years of tapping.

3. Effect on Latex RSH content (RSH, mM.l^{-1}): Figure 3

Whatever the tapping frequency, increase in Ethephon stimulation intensity generally results in a linear decrease of Latex RSH content. This decrease (from very high RSH values to very low RSH values) is due to an enhanced synthesis of reactive oxygen species (ROS) produced during latex cells metabolic activation. These released ROS oxidise RSH groups, leading to the decrease of their content in the latex. Sometimes, for low intensities of stimulation and/or for low metabolism clones, RSH curve may show a slight increase before starting decreasing again. Such a transient increase of RSH shows in such case the effect of metabolic activation on RSH synthesis, as this synthesis requires energy (Gohet 1996).

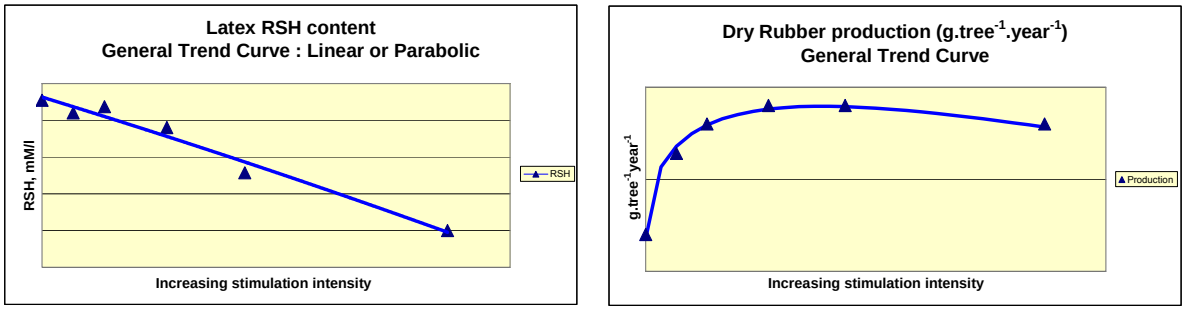

Figure 3: Simultaneous effect of Ethephon stimulation intensity on Latex RSH Content (RSH, mM.l^{-1}) and on dry rubber production (g.tree^{-1}.year^{-1}). Clone GT1 in Côte d'Ivoire. Average values after 7 years of tapping.

4. Effect on TSC/DRC (%): Figure 4

Whatever the tapping frequency, increase in Ethephon stimulation intensity generally results in a linear or hyperbolic decrease of Latex DRC/TSC. This decrease (from very high DRC/TSC values to very low DRC/TSC values) is first due to enhanced water importation to the latex (activation of water transport). Sometimes, for low intensities of stimulation and/or for low metabolism clones, DRC/TSC curve may show a slight increase before starting decreasing again. Such a transient increase of DRC/TSC shows in such case the effect of metabolic activation on total cytoplasm syntheses, permitted by the metabolic activation of latex cells and concurrent release of metabolic energy (Gohet 1996). In fact, DRC and TSC give a global view of the balance between two antagonist effects of stimulation: Enhancement of water importation into the latex (Decrease of DRC/TSC) and enhancement of syntheses following metabolic activation (Increase of DRC/TSC). DRC/TSC is therefore an integrated parameter whose significance is less precise than those of the three other parameters (Suc, Pi and RSH). DRC/TSC is therefore mainly used as a confirmation of LD interpretation derived from combination of Suc, Pi and RSH levels.

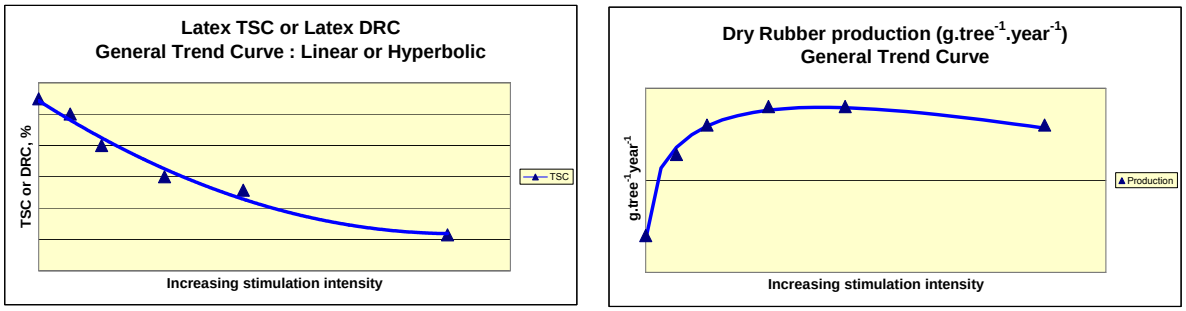

Figure 4: Simultaneous effect of Ethephon stimulation intensity on TSC or DRC (%) and on dry rubber production (g.tree^{-1}.year^{-1}). Clone GT1 in Côte d'Ivoire. Average values after 7 years of tapping.

INDUSTRIAL LATEX DIAGNOSIS: PRINCIPLES AND APPLICATIONS.

In plantations where Cirad has transferred LD and where it has been used as a physiological tool to pilot this exploitation intensity at local (block per block) level, the strategy has been as follows:

1. First step.

At the start and during the first months of the physiological year (For instance in Northern hemisphere: April to End–August / Mid - September, that is 5 months after completed refoliation), a unique tapping frequency and an associated stimulation intensity are applied to every homogenous cultural unit (Same clone, same planting year, same planting material, same date of opening, same tapping panel position and same plantation division).

This implemented stimulation intensity must be as precise as possible. It must take into account the clonal latex physiological characteristics and therefore a latex clonal typology (Jacob *et al*. 1995b, Gohet *et al.* 1997, 2005, Thanh and Thuy 2005), but also factors like year of tapping, tapping panel position, tapping direction (downward tapping, upward tapping, combined upward/downward…), tapping cut length (½S, ⅓S or ¼S) and tapping frequency (d/3, d/4, d/5 or d/6).

The latex clonal typology established by Cirad lays in a classification of *Hevea brasiliensis* clones in a 2 dimensions-matrix (Latex Clonal Typology) containing five different metabolic types (low, low-medium, medium, medium-high and high) and three different latex sugar loading types (low, medium and high). This typology permits in particular to describe the response of any rubber tree clone to ethephon stimulation: stimulation intensity is to be increased when clonal latex metabolic activity decreases and/or when clonal latex sugar loading capacity increases. Conversely, stimulation intensity is to be decreased when clonal latex metabolic activity increases and/or when clonal latex sugar loading capacity decreases. Latex Clonal Typology therefore greatly simplifies stimulation recommendations, as only five different levels of stimulation intensity (very high, high, medium, low and very low) provide accurate stimulation recommendations to all physiological types of clones, depending on their respective position in the matrix (Jacob *et al*. 1995a, Gohet *et al*. 2005).

This physiological modelling thus allows predicting, in case of use of reduced tapping frequencies (d/3, d/4, d/5 and d/6), the recommended ethephon stimulation intensity that will be required for the clonal yield potential expression. In fact, these stimulation

recommendations can be associated to 5 matrix diagonals, limiting to 5 the total number of possible stimulation recommendations for all clones (**Table 1**).

- **Very high stimulation intensity (diagonal 1): classes c2 and c5**
  - Low metabolism x medium sugar loading (c2: AF 261…)
  - Low-medium metabolism x high sugar loading (c5: PB 217…)

- **High stimulation intensity (diagonal 2): classes c1, c4 and c8**
  - Low metabolism x low sugar loading (c1: AV2037…)
  - Low-medium metabolism x medium sugar loading (c4: PR 107…)
  - Medium metabolism x high sugar loading (c8: RRIC 121…)

- **Medium stimulation intensity (diagonal 3): classes c3, c7 and c11**
  - Low-medium metabolism x low sugar loading (c3)
  - Medium metabolism x medium sugar loading (c7: GT1, RRIC 100…)
  - High medium metabolism x high sugar loading (c11: IRCA 41, IRCA 19, RRIM 921…)

- **Low stimulation intensity (diagonal 4): classes c6, c10 and c13**
  - Medium metabolism x low sugar loading (c6)
  - Medium-high metabolism x medium sugar loading (c10: RRIM 600, BPM 24, IRCA 18, PR 255…)
  - High metabolism x high sugar loading (c13: IRCA 230, RRIM 712…)

- **Very Low stimulation intensity (diagonal 5): classes c9 and c12**
  - Medium-high metabolism x low sugar loading (c9)
  - High metabolism x medium sugar loading capacity (c12: PB 235, PB 260, PR 261…)

This modelling is of great importance as it also permits significant reduction of time usually required to introduce newly selected clones into rubber estates. As a matter of fact, a few yield and physiological data obtained from these new clones, compared to those of control clones under same tapping conditions, are sufficient to precise their position in the typology matrix and therefore to perform early and accurate stimulation recommendations for these new clones. Long-lasting tapping system experiments usually set up to optimise stimulation recommendations are therefore less and less necessary.

Table 1: Cirad Clonal Latex Typology, updated in 2008

Clonal Metabolic Typology. CIRAD
Physiological basis for tapping systems recommendations (tapping frequency, stimulation)

	Low Metabolism Met-	Low-Medium Metabolism Met -=	Medium Metabolism Met =	Medium-High Metabolism Met =+	High Metabolism Met +
Low Sugar Loading (Suc -)	***Typology c1*** ***Met -*** ***Suc -*** AVROS 2037 High Stimulation	***Typology c3*** ***Met -=*** ***Suc -*** Medium Stimulation	***Typology c6*** ***Met =*** ***Suc -*** Low Stimulation	***Typology c9*** ***Met =+*** ***Suc -*** Very Low Stimulation	***Low probability***
Medium Sugar Loading (Suc =)	***Typology c2*** ***Met -*** ***Suc =*** AF 261 Very High Stimulation	***Typology c4*** ***Met -=*** ***Suc =*** PB 86 PR 107	***Typology c7*** ***Met =*** ***Suc =*** GT1 PB 254 RRIC 100	***Typology c10*** ***Met =+*** ***Suc =*** RRIM 600 PB 5/51 BPM 1 IRCA18 BPM 24 IRCA 109 RRIC 110 PB 330 PR 255 PM 10	***Typology c12*** ***Met +*** ***Suc =*** PB 235 RRIM 911 PB 260 PR 261 PB 340 IRCA 111 RRIM 901 IRCA 130 PB 312 IRCA 209 PB 314 PB 366
High Sugar Loading (Suc +)	***Low probability***	***Typology c5*** ***Met -=*** ***Suc +*** PB 217	***Typology c8*** ***Met =*** ***Suc +*** RRIC 124	***Typology c11*** ***Met =+*** ***Suc +*** IRCA 19 IRCA 41 RRIM 921	***Typology c13*** ***Met +*** ***Suc +*** IRCA 230 RRIM 712 PB255

Updated 04/2008

Diagonals of the [5,Met x 3,Suc] matrix : Homogenous stimulation recommendations

2. Second step.

At the end of the first period (End August until Mid October in Northern Hemisphere, End February until Mid April in Southern Hemisphere), LD (latex field sampling, analysis of physiological parameters and interpretation) is performed on each homogenous cultural unit of each plantation. For each one, LD is performed to assess the latex physiological status on the cultural unit after at least 5 months of tapping and stimulation under the initial stimulation intensity. After LD interpretation, 5 types of conclusions and decisions may be taken. These conclusions and associated decisions are summed up in the following table (**Table 2**):

A new stimulation rhythm is generally applied from October to January (Northern Hemisphere) or from April to July (Southern Hemisphere), the peak yielding months. This permits the fine local optimisation (block per block) of tapping and stimulation intensities during the peak production period and therefore permits to get a maximum and sustainable rubber yield, balanced with the actual physiological yield potential of each plantation block, creating a safe and significant added value.

Table 2: Recommended modifications of stimulation intensity following LD interpretation.

Latex Diagnosis Interpretation	Decision regarding stimulation intensity	Stimulation planning modification (rounds per year)	Example
Overexploitation status (LD --): VERY LOW YIELD POTENTIAL AREAS	Stimulation to be decreased , depending on clonal typology and risk level strategy	-2/Yor -1/Y	Et2.5% 8/Y ↓ Et2.5% 6/Y or Et2.5% 7/Y
Light overexploitation status (LD -): LOW YIELD POTENTIAL AREAS	Stimulation to be or slightly decreased or maintained, depending on clonal typology and risk level strategy	-1/Y or 0/Y	Et2.5% 8/Y ↓ Et2.5% 7/Y or Et2.5% 8/Y
Optimal physiological status (LD =): AVERAGE YIELD POTENTIAL AREAS	Stimulation to be maintained or slightly increased, depending on clonal typology and risk level strategy	0/Y or +1/Y	ET2.5% 8/Y ↓ Et2.5% 8/Y or Et2.5% 9/Y
Light underexploitation status (LD +): HIGH YIELD POTENTIAL AREAS	Stimulation to be increased, depending on clonal typology and risk level strategy	+1/Y or +2/Y	ET2.5% 8/Y ↓ Et2.5% 9/Y or Et2.5% 10/Y
Underexploitation status (LD ++) VERY HIGH YIELD POTENTIAL AREAS	Stimulation to be increased, depending on clonal typology and risk level strategy	+2/Y or +3/Y	ET2.5% 8/Y ↓ Et2.5% 10/Y or Et2.5% 11/Y

This optimisation of stimulation basis is valid only for the current physiological year, as it depends on the current position of the tapping cut and the process must be restarted every year.

CONCLUSION

Without using LD, a general recommendation per clone and per tapping year is generally applied at plantation scale, as a function of tapping cut position and direction, whatever the local and actual yield potential is. Even though this general recommendation is based on clonal physiological latex characteristics, such a global approach does not permit to consider the local specificities of the yield potential, as it avoids considering factors like soil heterogeneity, microclimate variations in larger estates and differential expression of diseases (leaf diseases, root diseases…). In this case, plantations are almost “blind” regarding suitability of the applied stimulation intensities, and uniform application of the same rate of stimulant in all homogenous cultural units may sometimes lead to optimised exploitation but may also lead locally to underexploitation in higher yield potential areas or to overexploitation in lower yield potential areas.

Using LD permits to optimize the stimulation at local level and therefore permits the yield optimisation block per block, taking into account the plantations heterogeneities and therefore the actual local yield potential.

The agro industrial partners of Cirad applying such local optimisation strategies are at the moment:

- Michelin plantations in Brazil (PEM and PMB)
- SIPH plantations in Côte d'Ivoire, Nigeria and Ghana (SAPH, RENL, GREL)
- SOCFINCO plantations in Indonesia (SOCFINDO) and in Côte d'Ivoire (SOGB)
- Bakrie Sumatera Plantations in Indonesia (BSP).
- Gremial de Huleros de Guatemala.

These plantations represent an approximate total area of 120000 ha to date.

A similar strategy is under development in Yunnan, China (Yunnan Institute of Tropical Crops, General Bureau of State Farms), after a first LD industrial application in Gan Lan Ba rubber state farm in 2007.

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