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Effect of mineral fertilization on agrophysiological parameters and economic viability of clone PB 235 of *Hevea brasiliensis* in the region of GO in south western Côte d'Ivoire

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1 ABSTRACT

In order to determine the significance of mineral fertilization on rubber trees, a twenty-year study on both agrophysiological and economic viability aspects was conducted in a plantation of clone PB 235 of *Hevea brasiliensis*, in south western Côte d'Ivoire. The effects of six treatments at different doses (Control 0D, ½ D, 1D, 2D, 4DT and 4DP) of nitrogenous, phosphatic and potassic fertilizer on yield were assessed. The experimental design was completely randomized blocks (CRB) with four repetitions. Mineral fertilization significantly improved the radial vegetative growth of the trees at immature and mature stages. It thus enabled tapping to start early and to have a number of tappable rubber trees, statistically higher than that of the control. It was also probably responsible for the significant loss of tapped trees compared to the control. Mineral fertilization at immature stage, for 5 years, followed by a dozen years of potassic fertilizer at ½ D, 1D and 2D doses, had a positive effect on the productivity of the rubber ($g.t^{-1}.t^{-1}$, $g.t^{-1}$) of rubber trees. This effect is strongly influenced by the density of tapped trees, limiting to 5.3 % the productivity gain in rubber ($kg.ha^{-1}$) of the half-dose compared to the control. Only the application of the half-dose of fertilizer gave convincing agrophysiological results and a positive profit margin. The latter, with a yield gain of 1240 $USD.ha^{-1}$ and a productivity gain of 779 $USD.ha^{-1}$, is profitable and likely to be recommended in rubber tree plantations.

2 INTRODUCTION

Rubber tree, the world's leading source of natural rubber (Rajagopal et *al*., 2003; Sekhar, 1989) is mainly grown for its latex, which is obtained by tapping which consists in making a cut or incision in the bark and expelling the contents of cut latex vessels (Thomas et *al*., 1995; Obouayeba *et al*., 2000; Obouayeba, 2005). The treatment of latex gives natural rubber, which is valued for its various qualities of elasticity and plasticity

(Compagnon, 1986). Natural rubber is used in various fields, especially in the tyre industry (Compagnon, 1986). Numerous studies on genetic selection and latex harvesting systems of clones contributed to the improvement and sustainability of rubber productivity. Thus, the works of Lacrotte (1991) and Obouayeba (2005) in particular have helped to substantially increase the yield of trees and hence that of plantations (Eschbach et Tonnelier, 1984; Obouayeba, 2005). Despite these profitable results, the stabilization of productivity at a high level during the exploitation period of trees remains a concern, particularly for Côte d'Ivoire whose yield is one of the best in the world (1650 kg.ha^{-1}). The solution to this problem should help double the national yield, switching from 300,000 T currently to more than 600,000 T over 400,000 ha by the 2025s. Mineral fertilization could increase and maintain sustainably rubber productivity (Sivanadyan 1983 ; Pushparajah *et al*, 1983). Even if all the formulae of fertilizer do not systematically produce the desired effect, and that the different results are noticeable only after a minimum period of 4 years of application (Sivanadyan, 1983), the profits of fertilization may, however, be additional to the good performance of clones and latex harvesting technologies (Obouayeba *et al*, 2008, 2009; Coulibaly *et al*, 2011; Soumahin *et al*, 2014). Indeed, as the high yield results in a significant export of minerals during tapping, a compensatory correction by fertilization should be done to maintain the balance, and thus the shape of the trees This explains the fact that in Malaysia, the input of mineral fertilizer is systematic and gradual from a yield equal to 1400 kg.ha^{-1} (MRB, 2009). The objective of the study was to analyze the agrophysiological behaviour of clone PB 235 of *Hevea Brasiliensis* under different doses of nitrogenous, phosphatic and potassic fertilizer, to determine the optimum dose for this plant and assess the production cost in the southwest area of Côte d'Ivoire.

3 MATERIALS AND METHODS

3.1. Description of the study environment: The study was conducted on the research and experimental station of Go located in the southwest (5°40' North, 6°43' West) of Côte d'Ivoire. The soils in that area are gravelly, ferralitic , highly desaturated and with good water retention capacity, but have migmatite and schist origins (Keli *et al.*, 1997). They have a low organo-mineral potential and are poor in available phosphorus (DRC, 1968; Gabla, 1998). The climate is sub-equatorial with low amplitudes of temperature (25-30°8C) and high humidity (80-90%). The average annual rainfall in that area is superior to 1600 mm and is characterized by a bimodal regime; two rainy seasons, from April to July and October to November, and two dry seasons from December to February-March and August to September (Keli *et al.*, 1992). The land on which crops were set was originally occupied by a secondary forest and cocoa trees.

3.2. Material

3.2.1. Plant Material: Clone PB 235 of *Hevea brasiliensis* served as plant material. The preparation of the land was done mechanically by a 350 hp Bulldozer. *Pueraria phaseoloides* (Tropical kudzu) was planted as a cover crop after burning of the felled trees.

3.2.2. Fertilizers used: The fertilization of plots was performed with nitrogen (urea: 46 % N), phosphorus (tricalcium phosphate: 33 % P_2O_5) and potassium (potassium chloride: KCl 60 %).

3.3. Methods

3.3.1. Experimental design: The experimental design was completely randomized blocks with six treatments and four repetitions. The total area covered was about 4,14 ha planted according to the density of 510 trees/ha (7m x 2.80m). Each elementary plot contained 130 trees.

3.3.2. Fertilization plan: The different treatments applied as well as the doses input (0D, 1/2D, 1D, 2D, 4DT and 4DP) are shown in Table 1. The composition and amount of the different fertilizers tested were compared to those of the currently recommended dose in industrial plantations of the study area (Table 2). The fertilizer (with nitrogen phosphorus and potash) was use for the first three years. The immature period lasted 5 years, while the harvest of latex spread over 12 years during which the potassium fertilizer (KCl) was input.

Table 1: Different doses of fertilizer spread on plantation of clone PB 235 during the experiment

Treatments	Doses of KCl (kg.ha^{-1}.yr^{-1})	Dose of fertilizer
1. 0D	0	Control, without fertilizer
2. ½ D	20	Half dose of fertilizer spread on industrial plantation
3. 1D	40	Normal dose of fertilizer spread on industrial plantation
4. 2D	80	Double dose of fertilizer spread on industrial plantation
5. 4DT	160	Quadruple dose of fertilizer spread on industrial plantation
6. 4DP	160	Quadruple dose of fertilizer spread permanently on industrial plantation

Table 2: Doses (kg.ha^{-1}.yr^{-1}) and type of fertilizer applied on clone PB 235 of *Hevea brasiliensis* on south west ecological condition of Côte d'Ivoire during the experiment

Applied period	Year	0 D			½ D			1 D			2 D			4 DT			4 DP		
		Urea	PCa3	KCl	Urea	PCa3	KCl	Urea	PCa3	KCl	Urea	PCa3	KCl	Urea	PCa3	KCl	Urea	PCa3	KCl
Immaturity	Planting year 0	0	0	0	17.5	75	35	35	150	50	70	300	100	140	600	200	140	600	200
	Year 1 (1990-91)	0	0	0	17.5	40	0	35	80	0	70	160	0	140	320	0	140	320	0
	Year 2 (1991-92)	0	0	0	17.5	40	0	35	80	0	70	160	0	140	320	0	140	320	0
	Year 3 (1992-93)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	140	320	0
	Year 4 (1993-94)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	140	320	0
Tapping	Year 1-12	KCl			KCl			KCl			KCl			KCl			KCl		
	1994-2006	0			20			40			80			160			160		

0D. Control, without fertilizer
½ D. Half dose of fertilizer spread on industrial plantation
1D. Normal dose of fertilizer spread on industrial plantation
2D. Double dose of fertilizer spread on industrial plantation
4DT. Quadruple dose of fertilizer spread on industrial plantation
4DP. Quadruple dose of fertilizer spread permanently on industrial plantation

3.3.3. Agrophysiological monitoring of clone PB 235

3.3.3.1. Agrometric parameters of rubber trees: Early in the second year after planting, the radial growth of the trunk of rubber trees was measured with a tape measure at 1 m above the ground throughout the immature period, and 1.70 m above the ground during the exploitation period between January and March each year. The rubber trees were tapped in S/2 d4 6d/7 and stimulated with Ethephon at 2.5 % at 1 g/tree according to the annual frequencies of 3 and 6, respectively the first 3 and from the 4th years of latex harvesting. The yield of rubber trees in coagulated rubber (cup film) is weighed every 28 days for each elementary plot, and a rate of dry trees is calculated concerning treatment.

3.3.3.2. Biochemical parameters of the latex: The technique of latex micro diagnosis (Jacob *et al.*, 1995) conducted over some years in October-November, helped monitor the physiological state of the rubber. This technique takes into account the evaluation of the content of rubber that constitutes the dry matter. It also incorporates the of sucrose, inorganic phosphorus and thiol groups contents (expressed as 1-m.mol.L) determined in serum obtained after coagulation of the latex by the trichloroacetic acid. For these last measurements, the methods used were respectively those of Ashwell (1957) of Taussky et Shorr (1953), Boyne et Ellman (1972).

3.3.3. Assessment of production costs: The assessment of production costs was made based on economic calculations that enabled to examine the profitability of rubber fertilization. Thus, for each treatment, the profit margin (M.B.) was calculated and expressed in US dollars, using the following equation:

M. B. = V. R.- C.T.F

with CTF = CMO + CAE + CTE + CME.

- M. B.: Profit Margin
- VR: Income Variation between the control and that of each treatment
- R. : Income: Yield (P) × Purchase Price at farm gate (PA) = USD 0.704/Kg, corresponding to the average value of the discounted prices over 18 years (1994-2011) (Mahyao et *al*, 2014)
- CMO : Labour Costs = USD 3/man-day
- CAE : Fertilizer Purchase Cost = Urea Cost (USD 24.7/50 Kg) + PCa3 Cost (USD 16/50 kg) + KCl Cost (USD 27.1/50 kg) (STPEC Data, October 2013)
- CTE : Fertilizer Transportation Cost) = 30 USD / 1000 Kg
- C.M.E : Fertilizer Spreading Equipment Cost

3.3.4. Statistical Analysis: Data concerning rubber tree density, radial vegetative growth, rubber yield and dry cut were subjected to analysis of variance using the software StatG. The ranking of averages was carried out according to the Newman-Keuls test at the threshold of 5 %.

4 RESULTS

4.1. Effect of mineral fertilization on the agrophysiological parameters of clone PB 235 of *Hevea brasiliensis*

4.1.1. Number of tapped rubber trees : The average number of tapped rubber trees of clone PB 235 at start of tapping was 403, five years after planting. It varied depending on the treatment. Indeed, its value was lower in the control, which had not received fertilizer (0D) than in all fertilized treatments (Table 3). Similarly, for treatments with doses 1/2D and 1D, the values, which were identical, proved however to be statistically higher than for 4DT and 4DP. After 12 years of latex harvesting, the average number of tapped trees (374) experienced a significant variation. The largest numbers were observed, in the same way, with treatments OD and 1/2D. The lowest were from treatments 4DT and 4DP. Thus, at the rubber tree start of tapping (5 years after planting) as well as at the end of the experiment (after 12 years of exploitation), the number of tapped trees decreased with the dose of fertilizers spread.

4.1.2. Rubber trees trunk girth and average annual growth: The girth of trees trunk, observed at start of start of tapping was equal to 52.40 cm, and 82.12 cm after a dozen years of latex harvesting. During that period, the increase was 2.71 $cm.year^{-1}$ (Table 3). Moreover, the values of the girth and growth of trees from the control treatment without fertilizer (0D) were statistically lower than those of fertilized rubber trees were. In the latter, the increase in doses of fertilizer had no impact on the girth. However, concerning growth, the values increased, but not significantly, depending on the spread dose

Table 3: Annual average number, girth and girth increase of tappable trees during the experiment

Treatment	Annual average number of tappable trees.ha^{-1}			Girth (cm) of tappable trees		Girth increase (cm/year) during tapping
	Start	End	During experiment	Start	End	
1. 0D	296 ± 24 d	424 ± 09 a	464 ± 63 a	51.1 ± 5.6 b	75.7 ± 7.6 b	2.24 c
2. ½D	452 ± 09 a	400 ± 15 ab	456 ± 56 b	53.0 ± 4.6 a	82.1 ± 7.3 a	2.65 b
3. 1D	444 ± 12 a	372 ± 15 bc	433 ± 54 c	53.1 ± 4.5 a	82.8 ± 7.9 a	2.70 b
4. 2D	432 ± 12 ab	360 ± 19 bc	419 ± 60 d	52.9 ± 4.8 a	84.1 ± 7.8 a	2.84 ab
5. 4DT	408 ± 11 bc	348 ± 14 c	406 ± 61 e	52.4 ± 6.2 a	85.0 ± 8.8 a	2.96 a
6. 4DP	388 ± 17 c	340 ± 18 c	413 ± 62 de	51.7 ± 5.9 a	83.0 ± 8.7 a	2.85 ab
Average	**403 ±14**	**374 ± 15**	**432 ± 68**	**52.40 ± 5.7**	**82.12 ± 7.5**	**2.71**

On the row, the values assigned with the same letter are not significantly different (Scheffe 5%)

0D. Control, without fertilizer
½ D. Half dose of fertilizer spread on industrial plantation
1D. Normal dose of fertilizer spread on industrial plantation
2D. Double dose of fertilizer spread on industrial plantation
4DT. Quadruple dose of fertilizer spread on industrial plantation
4DP. Quadruple dose of fertilizer spread permanently on industrial plantation

4.1.3. Rubber yield of rubber trees: The average rubber yield expressed in grams per tree per tapping (g.t^{-1}.t^{-1}) obtained during the experiment was 62 and the average annual yield in grams per tree (g.t^{-1}) reached 4819 (Table 4). The average annual yield reached 1868. The yield, expressed in kg.ha^{-1} of the fertilized treatment at half-dose (½ D), statistically similar to that of the unfertilized control, was significantly superior to that of all the other treatments (3-1D, 4-2D, 5-4DT and 6-4DP). The best results were due to the application of the ½ D dose. The average yield after treatment with ½ D, 1D and 2D statistically equivalent, were superior to those of unfertilized rubber trees (OD) or those treated with the 4DT and 4DP doses whose values were similar. Thus, we note that the high doses (4DT, 4DP) as well as the lack of fertilizers, influenced identically the yields, but less efficiently than treatments ½ D, D and 2D, among which the most favourable was the half dose. However, in terms of yield, the absence of fertilization (OD) and especially fertilizer ½ D, were the most productive treatments.

Table 4. Annual average yield (g.t^{-1}.t^{-1}, g.t^{-1}, kg.ha^{-1}) according to fertilizer treatment during the experiment

Treatment	Average g.t^{-1}.t^{-1}	Average g.t^{-1}	Average Yield (kg.ha^{-1})
1. 0D	58 ± 33 d	4541 ± 2579 d	1974 ± 1102 ab
2. ½ D	66 ± 38 a	5126 ± 2951 a	2079 ± 1103 a
3. 1D	62 ± 35 abc	4869 ± 2748 abc	1873 ± 993 bc
4. 2D	64 ± 37 ab	4958 ± 2868 ab	1830 ± 980 cd
5. 4DT	61 ± 36 bcd	4784 ± 2788 bcd	1722 ± 931 d
6. 4DP	59 ± 33 cd	4637 ± 2552 cd	1729 ± 910 d
Mean	**62 ± 35**	**4819 ± 2738**	**1868 ± 1013**

On the row, the values assigned with the same letter are not significantly different (Scheffe 5%)

0D. Control, without fertilizer
½ D. Half dose of fertilizer spread on industrial plantation
1D. Normal dose of fertilizer spread on industrial plantation
2D. Double dose of fertilizer spread on industrial plantation
4DT. Quadruple dose of fertilizer spread on industrial plantation
4DP. Quadruple dose of fertilizer spread permanently on industrial plantation

4.1.4. Biochemical parameters: The results of biochemical parameters shown in Table 5 indicate that at the start of tapping as well as at the end of the experiment, the average dry rubber content (DRC = 50.78 and 55.72 %, respectively) was high as being superior to the threshold of 35 %. It has experienced an increase over time and was less influenced by the dose of fertilizer spread. The average annual concentration of sucrose in the latex was average but in accordance with that of clone PB 235. It has experienced a decrease during the experiment 6.50 to 5.43 m.mol.L^{-1}). The average content of inorganic phosphorus in the latex, being 19.4 m.mol.L^{-1} at rubber tree start of tapping, increased approximately by 16 % to reach 22.97 m.mol.L^{-1} at the end of the experiment. It was consistent with that of PB 235 but with a lower value (16 m.mol.L^{-1}) in the absence of fertilization. Similarly, the concentration of thiol groups in the latex (0.70 m.mol.L^{-1}) being good at tapping start, decreased to average at the end of the experiment (0.54 m.mol.L^{-1}). These results show that the input of fertilizer increases more the possibility of activation parameters of latex cells for a good rubber yield.

Table 5: Average biochemical parameters at the start and end under different fertilizer doses applied to clone PB 235 during the experiment

Treatment	DRC (%)		Suc (m.mol.L^{-1})		Pi (m.mol.L^{-1})		RSH (m.mol.L^{-1})		TPD (%)
	Experiment		Experiment		Experiment		Experiment		
	Start	End	Start	End	Start	End	Start	End	End
1. 0D	54.0 a	56.7 a	5.8 bc	4.8 bc	16.0 cd	16.3 d	0.68 a	0.46 b	2.80 a
2. ½ D	51.0 a	56.1 a	5.7 bc	5.8 ab	18.0 bc	22.6 bc	0.65 a	0.57 a	1.97 a
3. 1D	50.0 a	57.0 a	6.0 bc	4.5 c	19.5 ab	20.3 c	0.69 a	0.51 ab	2.77 a
4. 2D	50.8 a	54.6 a	8.2 a	5.4 ab	19.8 ab	26.5 a	0.75 a	0.55 ab	5.25 a
5. 4DT	50.2 a	55.0 a	6.5 b	6.2 a	20.5 ab	25.2 ab	0.68 a	0.56 a	4.43 a
6. 4DP	48.7 a	54.9 a	6.6 b	5.9 ab	22.5 a	26.9 a	0.67 a	0.56 a	6.05 a
Mean	**50.78**	**55.72**	**6.50**	**5.43**	**19.40**	**22.97**	**0.70**	**0.54**	**3.88**

On the row, the values assigned with the same letter are not significantly different (Scheffe 5%)

0D. Control, without fertilizer
½D. Half dose of fertilizer spread on industrial plantation
1D. Normal dose of fertilizer spread on industrial plantation
2D. Double dose of fertilizer spread on industrial plantation
4DT. Quadruple dose of fertilizer spread on industrial plantation
4DP. Quadruple dose of fertilizer spread permanently on industrial plantation

DRC: dry rubber content (%), Suc: sucrose (m.mol.L^{-1}), Pi : inorganic phosphorus (m.mol.L^{-1})
RSH: thiol (m.mol.L^{-1}), TPD : tapping panel dryness (%)

4.1.5. Rate of tapping panel dryness: At the beginning of the experiment, the rubber trees of all the treatments were selected as being safe, that is to say without dry cut. At the end of the works, the average rate of tapping panel dryness, all treatments combined, reached 3.88 %. This rate was low as a whole, acceptable and suggests that the tapping panel dryness has not been a limiting factor in the expression of treatments. The treatment fertilized with half dose gave the lowest rate of tapping panel dryness (1.97 %) while the treatment fertilized with quadruple doses permanently practiced in industrial plantation, showed the highest rate (6.05 %). Compared to fertilized treatments, we noted, except for the case of treatment 5, a relative increase in the rate of tapping panel dryness with the dose of fertilizer spread.

4.1.6. Relations between the dose of fertilizer and the agrophysiological parameters: The study of correlations between the input of fertilizers at different doses and the agrophysiological parameters of clone PB 235, enabled to note:

• a strong correlation between the dose of fertilizer spread and the number of tapped trees with $R^2 = 0.972$ analytical expression $y = 0.003\ x^2 + 0.841\ x + 466.05$ (Figure 1);

• a good correlation between the doses of fertilizer spread and the average growth rate of the trees; $R^2 = 0.896$ analytical expression $y = 05.10^{-5}\ x^2 + 0.010\ x + 2.326$ (Figure 2);

• a very strong negative correlation between the dose of fertilizer input and the yield in $kg.ha^{-1}$ coefficient of determination $R^2 = 0.818$ and equation $y = -\ 1.814\ x + 2006.9$ (Figure 3);

• A strong correlation between the doses of fertilizer spread and the rate of dry trees, with $R^2 = 0.717$, analytical expression $y = 0.0001\ x^2 + 0.039\ x + 2.034$ (Figure 4).

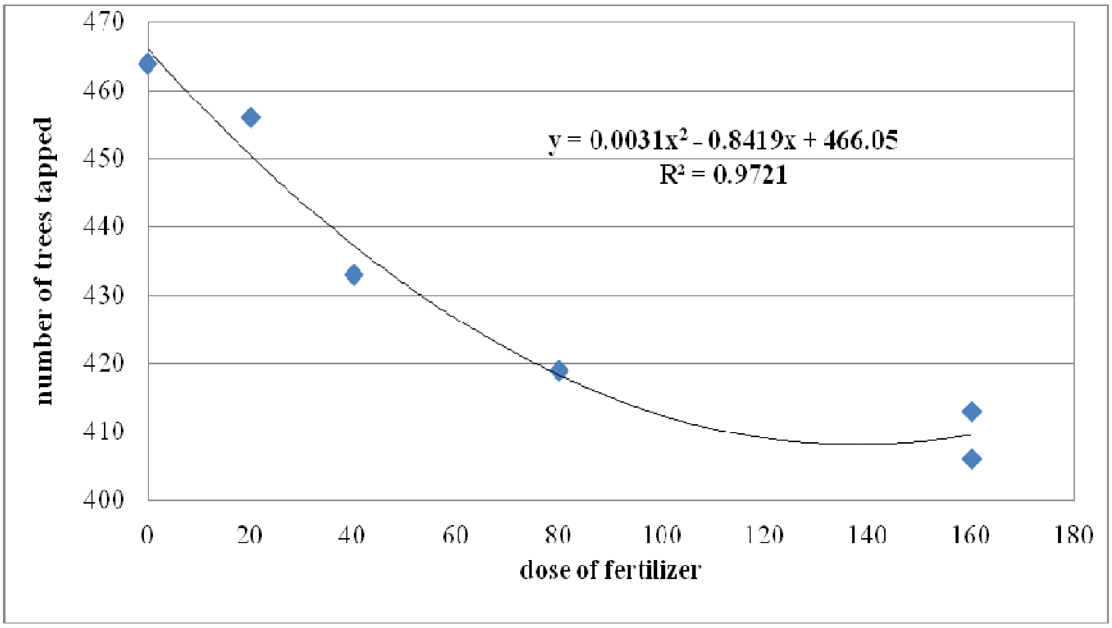

Figure 1: Correlation between the dose of fertilizer ($kg.ha^{-1}.yr^{-1}$) and the number of trees tapped

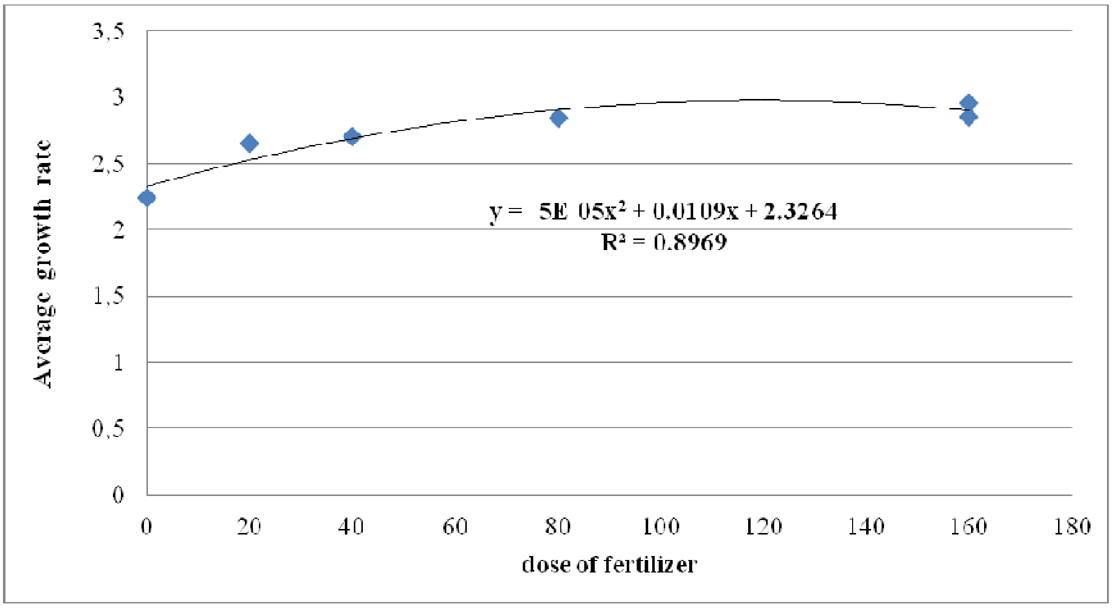

Figure 2: Correlation between the dose of fertilizer ($kg.ha^{-1}.yr^{-1}$) and the rate of radial growth of trees (%)

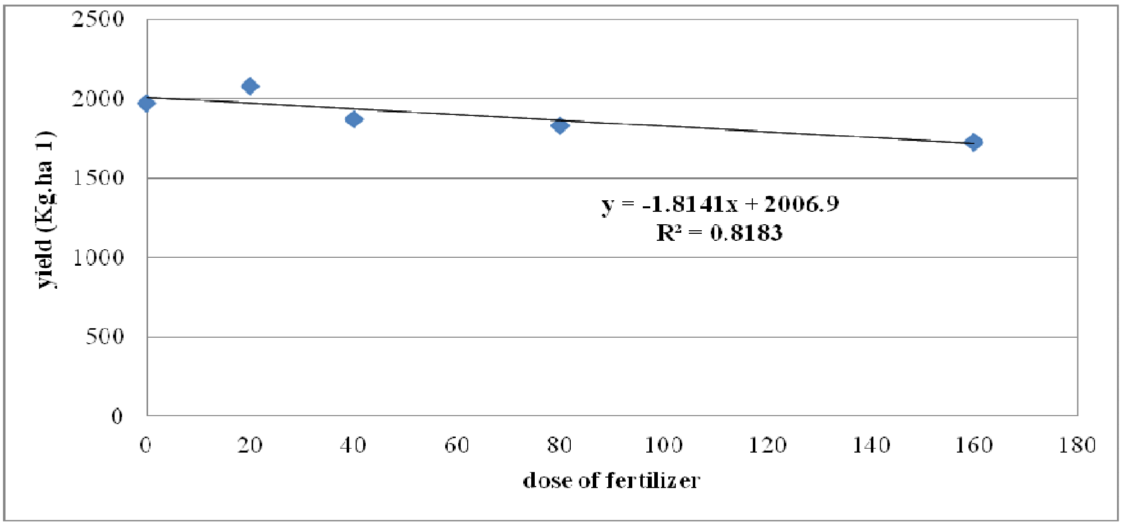

Figure 3: Correlation between the dose of fertilizer (kg.ha^{-1}.yr^{-1}) and the yield of trees (Kg.ha^{-1})

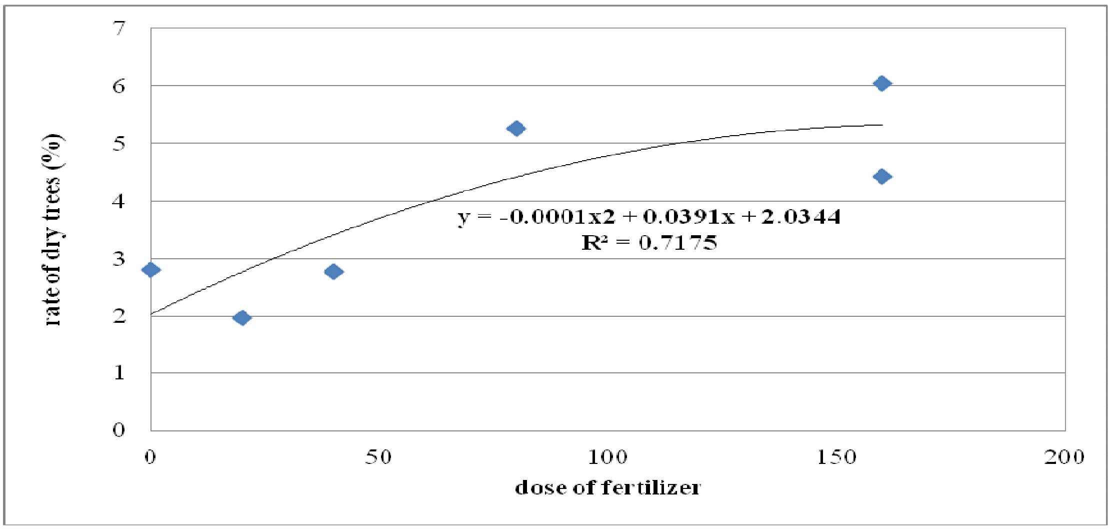

Figure 4: Correlation between the dose of fertilizer (kg.ha^{-1}.yr^{-1}) and the rate of dry trees (%)

4.2. Economic viability of mineral fertilization of clone PB 235: The profitability of mineral fertilization of clone PB 235 was assessed on the database of fifteen years of experimentation in comparison with the unfertilized control (Table 6). Income Variations (VR) compared to the unfertilized control, following the sale of the rubber yielded by the different treatments (Table 7), enabled to note that only the half-dose (1/2D) with 1240 USD has had a positive balance (VR>0). The other fertilized treatments had all a negative balance (VR<0) with the maximum loss (2975 USD) showed by the 4DT dose. The total fertilization expenses (CTF), were certainly more important with the dose of fertilizer spread, but they were not proportional to the latter. The ½ D dose with 518 USD.ha-^{1}, was the least expensive of the treatments, while the 4DP one, with 2621 USD.ha^{-1} was the most expensive. The analysis to determine the profit margin (MB), revealed that concerning clone PB 235, fertilization resulted in a gain of income (1240 USD) and productivity (722 USD.ha^{-1}) higher for treatment ½ D (immature stage; 52.5 kg.ha^{-1} Urea, 155 kg.ha^{-1} PCa_3 and 245 kg.ha^{-1} KCl) compared to the control. The other treatments (1 dose, 2 doses and 4 doses) proved to be unprofitable with heavy losses of productivity (1943 to 5513 USD.ha^{-1}).

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Table 6: Rubber yield expenses related to the spreading of fertilizer during the experiment

Amortization costs				Treatment (½ D)			Treatment (1 D)			Treatment (2 D)			Treatment (4 DT)			Treatment (4 DP)		
Type of equipment	CU (USD.ha^{-1})	Life cycle (years)	Annual CA (USD.ha^{-1})	Duration of use (years)	Qté	CT (USD.ha^{-1})	Duration of use (years)	Qté	CT (USD.ha^{-1})	Duration of use (years)	Qté	CT (USD.ha^{-1})	Duration of use (years)	Qté	CT (USD.ha^{-1})	Duration of use (years)	Qté	CT (USD.ha^{-1})
Scales (peson) (Nb)	50.0	5.0	10.0	13.0	1.0	130.0	13.0	1.0	130.0	13.0	1.0	130.0	13.0	1.0	130.0	15.0	1.0	150.0
Tarpaulin (m)	0.8	2.0	0.4	13.0	6.0	31.2	13.0	7.0	36.4	13.0	9.0	46.8	13.0	10.0	52.0	15.0	10.0	60.0
Plastic buckets (Nb)	2.0	2.0	1.0	13.0	3.0	39.0	13.0	3.0	39.0	13.0	4.0	52.0	13.0	6.0	78.0	15.0	6.0	90.0
Markers (Nb)	1.2	2.0	0.6	13.0	1.0	7.8	13.0	1.0	7.8	13.0	1.0	7.8	13.0	1.0	7.8	15.0	1.0	9.0
Dosettes (Nb)	0.1	1.0	0.1	13.0	3.0	3.9	13.0	3.0	3.9	13.0	3.0	3.9	13.0	3.0	3.9	15.0	3.0	3.9
Total equipment cost						211.9			217.1			240.5			271.9			312.9

Key :
CU = Unit Cost, CA = Amortization Cost , CT= Transportation cost, Qté = Quantity, Nb = Number , m = meter.

Table 7. Analysis of viability of mineral fertilization of clone PB 235, of *Hevea brasiliensis* over 15 years

Clone	Age	Treat	Yield (P)		Income (R)	Income Variation (VR) compared to the control (0 D)	Labour Cost (CMO)		Fertilizer Purchase Cost (CAE)							Fertilizer Transportation Cost (CTE)		Fertilizer Spreading Equipment Cost (CME)	Total Cost Fertilization (CTF)	Profit Margin (MB)
			Average Qty	Total Qty	R	VR	Qty	CMO	Qty Urea	CT (Urea)	Qty PCa3	CT PCa3	Qty KCl	CT (KCl)	CAE	Qty	CTE	CME	CTF	MB
			Kgha-1		(USD.ha-1)		h-jha-1	(USD.ha-1)	kg ha-1	(USD.ha-1)	kg ha-1	(USD.ha-1)	kg ha-1	(USD.ha-1)		kgha-1	(USD.ha-1)			
PB 235	12	0 D	1 974	33 106	23306	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		½ D	2 079	34 867	24546	1240	28	84	52,5	0	155	50	245	133	208	452,5	14	212	518	722
		1 D	1 873	31 412	22114	-1192	30	90	105	26	310	99	490	266	417	905	27	217	751	-1943
		2 D	1 830	30 691	21606	-1700	36	108	210	52	620	198	980	531	833	1 810	54	241	1236	-2936
		4 DT	1 722	28 879	20331	-2975	42	126	420	104	1240	397	1960	1062	1667	3 620	109	272	2173	-5148
		4 DP	1 729	28 997	20414	-2893	54	162	420	207	1240	602	2880	1062	2010	4 540	136	313	2621	-5513

0 D : Without KCl
1 D : 20 kg.ha^{-1}.yr^{-1} KCl
1 D : 40 kg.ha^{-1}.yr^{-1} KCl
2 D : 80 kg.ha^{-1}.yr^{-1} KCl
4 DT : 160 kg.ha^{-1}.yr^{-1} KCl
4 DP : 160 kg.ha^{-1}.yr^{-1} KCl

5 DISCUSSION

5.1. Effect of mineral fertilization on the agrophysiological parameters clone PB 235: Mineral fertilization had a positive effect on the radial vegetative growth of the trunk of rubber trees, resulting in a strong correlation between the dose of fertilizer and the number of tappable trees. These results are important because they express the positive effect of fertilizer on rubber trees, in the latex harvesting period as well as at the immature stage when the trees provide only primary biomass production through the radial growth (Keli *et al.*, 1992; Allé *et al*, 2014.). Moreover, the results obtained are important from the perspective of improving and sustainably maintain a good productivity and a high yield due to the fact that there is a very strong correlation between the girth of rubber trees and the number of number of latex vessel mantles (Obouayeba, 2005 Obouayeba *et al*, 2002, 2012). As rubber yield is provided by latex vessels (Jacob *et al.*, 1994), it can be inferred that fertilization which increases the radial growth of the trunk, and therefore the number of latex vessels, would guarantee a high yield. However, the results indicate, compared with the control (0D), a smaller effect of fertilization on rubber yield, except for the only case of half-dose (1/2D) which increases it by 5.30 %. Furthermore, the results of the different parameters that reflect the efficiency of fertilization indicate that it should be performed with relatively low doses of fertilizer, notably potassic. These key findings corroborate the works of several authors on rubber trees (Jessy *et al.*, 2006; Wijaya, 2009; Jessy, 2011; Shafar *et al*, 2012). However, as regards to the yield expressed in kg.ha^{-1}, parameter taken into account by producers, this fertilization seems relatively less interesting despite the positive effect of the half-dose which application increases productivity by 5.30 %.

5.2. Economic viability of mineral fertilization of clone PB 235: The economic analysis shows that mineral fertilization, notably potassic, gives a positive profit margin (MB). It has, indeed, revealed that concerning clone PB 235, the potassic mineral fertilization over fifteen years with treatment ½ D resulted, relatively to the unfertilized control, in gains of yield (1240 USD.ha^{-1}) and productivity (722 USD.ha^{-1}). All the other doses of fertilizer (1D, 2D, 4DT and 4DP) have, on the contrary, induced losses of yield (from 1192 to 2975 USD.ha^{-1}) and productivity from 11943 to 5513 USD.ha^{-1}. These results express the important fact that only the half dose spread in industrial plantation is profitable and likely to be recommended in rubber plantations.

6 CONCLUSION

The study showed that the nitrogenous, phosphatic and potassic mineral fertilization of rubber tree clone PB 235 improves the radial vegetative growth of the trunk at immature and mature stages. Mineral fertilization at immature stage, for 5 years, followed by a dozen years of potassic fertilizer (½, 1 and 2 doses) increases productivity of the rubber trees of clone PB 235. However, this positive effect is mitigated and even annihilated by the loss of tappable trees likely due to the larger volume of fertilized rubber trees compared to the unfertilized control. Only the application of the half-dose of fertilizer gives strong agrophysiological results and a positive profit margin. It is profitable and likely be recommended in rubber tree plantations.

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