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Chemical control of *Phragmanthera capitata* in plantations of three clones (GT 1, PB 235 and PB 217) of *Hevea brasiliensis* (Euphorbiaceae) in Côte d'Ivoire

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1 SUMMARY

***Phragmanthera capitata* is a hemiparasite of cultivated plants including rubber tree, *Hevea brasiliensis.* Growth of this plant on the host reduces the rubber yield by 10%. Herbicides were used to efficiently control the hemiparasite. Three clones PB 235, GT 1 and PB 217 of *Hevea brasiliensis* were used. Doses of 4, 6, 8 and 10 ml glyphosate (360 g/l) were injected at the root or the base of the host trunk at beginning of defoliation. Observations were made on the mortality of *P. capitata* tufts, the physiological profile and the morphology of rubber trees, rubber yield and presence of glyphosate residues in latex. A dose of 10 ml glyphosate (360 g/l) injected per tree at the base of the trunk provided the best mortality rates (65 to 86%) of *P. capitata.* The dose had no negative effect on the rubber yield (g/tree) and the physiological functioning of the treated trees. Glyphosate residue quantities lower than 1.8 and 0.20 mg/l were recorded in the serum of rubber and latex + ammonia of the rubber trees treated respectively.**

2 INTRODUCTION

Loranthaceae is a family of vascular phanerogamous plants which parasite cultivated or spontaneous plants, usually found in tropical and subtropical regions. The family comprises about 77 genera and 950 species (Polhill and Wiens, 1998). In Côte d'Ivoire, 11 species of Loranthaceae have been described (Bale and Halle, 1961). They parasitize tree species and many cultivated plants: cocoa, coffee, shea butter, African locust, guava, citrus and other fruit trees, oil palm, conifer (Bale and Halle, 1961; Traore and Da, 1996; Koffi, 2004). Of the 11 species, *Phragmanthera capitata*, *Tapinanthus* sp. and *Globimetula* sp. colonize rubber tree plantations (Soro *et al.*, 2010; Wahounou *et al.*, 2010). *Phragmanthera capitata* is the commonest species in Côte d'Ivoire (Wahounou *et al.*, 2010). By consuming Loranthaceae fruits, birds act as vectors (Priya, 1983; Boussim, 2002) and facilitate seeds dispersal. This mode of propagation of the parasite is probably at the origin of the spectacular development of *P. capitata* in Côte d'Ivoire. Seed germination success leads to the fixation of the parasite on the host tree through cortical cords and collect water and minerals using suckers attached to the host xylem vessels (Bannister *et al.*, 2002). Development of the hemiparasite leads to, on more or less long term, the weakening of the distal part of the parasitized branch and even to the death of the host. The fast growth of the hemiparasite on the host tree represents a real threat in rubber growing environment. Wahounou *et al.* (2010) reported no attacks of cultivated plants by *P. capitata* in the 1980s while, nowadays, nearly 4.5% of rubber tree orchard is attacked by hemiparasite and represent a real concern for farmers. These parasites spread throughout the rubber tree orchard, damage the plantation and reduce rubber yield by 10% (Wahounou *et al.*, 2010). This situation causes great concern among producers, who fear a growing deterioration of the plantation environmental health. In the actions for control of these parasites, even if hand pruning may appear to be an efficient mean on shea (Traore and Da, 1996), this method turned out to be painful because of the large size of rubber trees, with multiple safety hazards faced by workers (Zhiwe *et al.*, 1995; Dibong *et al.*, 2010). Facing difficulties manually control development of hemiparasite, chemical control by means of herbicide application was envisaged (Zhiwe *et al.*, 1995; Baillon *et al.*, 1988; Boussim and Medah, 2009; Boussim *et al.*, 2012). The herbicides including glyphosate, Miesangling 3, Triclopyr, 2.4-D (2.4-dichlorophenoxyacetic acid), 2.4.5-T (2.4.5-trichlorophenoxyacetic acid), 2.4-MCPB (methyl-2 acid, chlo-4 phenoxybutyric) and Asulam, sprayed on the foliar system of the parasite or injected at the base of the trunk of the parasitized tree, have shown some efficiency in the control of *P. capitata* on various cultivated plants. To determine methods of controlling *P. capitata*, a study was conducted from 2010 to 2013 in Côte d'Ivoire. The study was part of a research project of the rubber sector, CNRA-FIRCA, and showed that among several herbicides tested, glyphosate has proved most efficient to control these parasites. This article reports on works series of that research project, notably the study that aimed at determining the efficient mode of application and dose of glyphosate to ensure better control of *P. capitata* without causing harm to rubber trees.

3 MATERIALS AND METHODS

3.1 Plant material and chemical used: Rubber trees parasitized by *Phragmanthera capitata* were investigated. Experiments were done on monoclonal plots of rubber clones PB 217, PB 235 and GT 1 belonging to classes of slow, moderate and fast metabolism respectively. These clones came from three experimental plots, planted in 1989, 1989 and 1986 at the station of Anguédédou, according to a row spacing of 2.80 x 7 m, that is, a density of 510 trees per hectare. These selected plots were heavily infested by *P. capitata*. The glyphosate used is a nonselective weed killer used to control adventives. Glyphader 360 SL is formulated soluble concentrate (SL) with 360 g/l glyphosate as isopropylamine salt (IPA). The doses of glyphosate (360 g/l) injected at the root (6, 8 and 10 ml) or at the base of the trunk of the tree (4, 6, 8 and 10 ml) were applied at start of defoliation (January-February).

3.2 Choice of trees, treatments and experimental design: The selected plots were covered by making observations tree by tree. The trees attacked by *Phragmanthera capitata*, as well as their healthy homologous of noticeably the same girth and serving as control in the trial, were marked with paint. The rubber trees having at least three tufts of *P. capitata* were selected. The girth was measured on the tree at 1.70 m height above the ground. After measurement, the trees parasitized by *P. capitata* having similar girth (more or less 5 cm difference) were selected and plotted on a detailed oriented planting scheme. A hole of 1 cm diameter and 5 cm depth was made at the base of the trunk of the rubber tree at 50 cm above the ground, right above the bulbous basal part of the trunk called "elephant foot" by professionals. This gallery was performed using a BOSCH drill manufactured in Malaysia (GSB 16 RET Professional 2800 rpm, 600 W, 220 V, 50 Hz and 2.6 A), equipped with a spiral screw 15 cm long and 1.5 cm in diameter. On a side root, the same gallery was made at 50 cm from the trunk. The herbicide treatment consisted in sampling 4, 6, 8 and 10 ml of glyphosate (360 g/l) with a medical syringe of 10 ml, and then injecting the different doses in the gallery at the root or at the base of the trunk which entrance was closed by application of a fungicide paste, for example Otina C, so as to avoid contamination by caulicolous parasites. Each dose was tested on 10 trees per clone. The application of herbicides was performed at the beginning of defoliation of rubber trees. The control was made up of perforated trees without injection of glyphosate. For each clone, the design used was the *"one tree plot design"* (mono tree design), with a total randomization and two factors, which are the dose including 4, 6, 8 and 10 ml and the method of application, at the base of the trunk or at the root of the rubber tree. The number of treatments was 3 for injections at the root and 4 for injections at the base of the trunk. This brings the total number of treatments to seven (7). For each treatment, 10 randomized trees were used per treatment, each being a repetition. The control trees were also randomized.

3.3 Observation and measurements: Observations carried out tree by tree focused on the mortality of *P. capitata* tufts, the rubber yield and the latex biochemical parameters (dry rubber content, sucrose contents, inorganic phosphorus contents and thiol contents) of rubber trees. In addition, glyphosate residue analyses were measured in the latex 12 months after application of herbicide on the rubber tree. *P. capitata* tufts mortality expressed in percentage (%) indicated the efficiency of the herbicide. Observations made once a month after injection of glyphosate consisted in counting the dead and living tufts per parasitized and treated tree, and on the control too. Mortality of treated trees tufts was compared with each other and with those of untreated trees (control). The mortality rate was determined by the following formula:

$$\text{Mortality Rate (\%)} = \frac{100 * \text{NTM}}{\text{NTV} + \text{NTM}}$$

where, NTM: number of died tufts and NTV: number of living tufts.

The relative mortality rate of tufts according to the control (relative mortality) was given by:

$$\text{Mortality Rate (\%)} = \text{MFAPA\%} - \text{MFANT \%}$$

where MFAPA: Mortality of parasitized and treated tree tufts and MFANT: mortality of untreated tree tufts (natural mortality). Rubber yield was checked twice a month. After injection of glyphosate, the yields recorded were compared per treatment and of untreated rubber trees (control). The yield was expressed in grams of dry rubber per tree and per tapping (g/t/t). This yield is the result of upward quarter spiral tapping in d4 every 4 and 5 days with one day of rest (S/4Ud46d/7) (Vijayakumar *et al.*, 2009). The coagulum was collected and weighed tree per tree every four days for PB 217 and GT 1 clones and five days for PB 235 clone during the period from March to December. To assess the impact of herbicides on the physiology of treated trees and latex biochemical parameters such as dry rubber content (DRC), sucrose contents and inorganic phosphorus contents (Pi), thiol contents (RSH) were analysed after 1-year trial. Latex physiological parameters were assessed once a year between August and December. Latex samples were collected by microdiagnosis method (Jacob *et al.*, 1995) and extracted with Trichloroacetic acid. The sucrose, inorganic phosphorus and the reduced thiols were measured in the TCA extract following Ashwell (1957), Taussky and Shorr (1953) and Boyne and Ellman (1972). The results are expressed as mmole per liter of latex (mM). Dry rubber content was determined after acid coagulation of known weight of latex drying in oven at 80°C and weighed again and expressed as per cent.

Glyphosate residue analysis (mg/l of latex) was searched in the latex of treated trees with 10 ml of glyphosate (360 g/1) at the base of the trunk. Thus, the latex was collected in test tubes after tapping. Two treatments were applied to the collected latex. On one hand, the collected latex was made incoagulable by mixing 25 ml latex with 5 ml ammonia. On the other hand, a serum was obtained after coagulation of the rubber by transferring 1 ml of latex into a pillbox containing 9 ml of trichloroacetic acid (TCA). The latex and serum were analyzed at the National Agricultural Development Support Laboratory (LANADA) after extraction, purification and determination by Shimadzu HPLC. Chromatograms reading enabled to quantify the level of glyphosate residues (mg/l) in the latex.

3.4 Data Analysis: All data were analyzed using XLSTAT 7.0.5 software. Evaluation of glyphosate dose effect on *Phragmanthera capitata* was carried out by comparing the average mortality rate of tufts and rubber yield and physiological profile of rubber trees. To normalize the distribution and equalize variances, "tufts mortality" and "dry content" variables underwent arcsine√ transformation. The comparison between averages was made by the Student Duncan test with 5% probability.

4 RESULTS

4.1 Glyphosate action on *Phragmanthera capitata* tufts mortality: Application of glyphosate at the base of the trunk enabled the eradication by 73.95% of *P. capitata* tufts in all clones put together (Table 1). Analysis of variance of the three clones revealed a significant “glyphosate dose” effect at the threshold of 5% and the existence of 2 to 3 homogeneous glyphosate dose groups. The efficiency varied according to the clone. The mortality rates of *P. capitata* tufts recorded were 86.50, 70.23 and 65.13% for clones PB 217, PB 235 and GT 1 respectively.

Table 1. Effect of glyphosate on the mortality of *Phragmanthera capitata* tufts after application at the base of the trunk of rubber trees of clones PB 217, GT1 and PB 235.

Clones	Dose (ml)	Tufts mortality (%)	Relative mortality (%)*
PB 217	10	88.54 a	86.50 a
	8	48.61 b	46.57 b
	6	48.19 b	46.15 b
	4	4.17 c	2.13 c
	0	2.04 c	
PB 235	10	76.32 a	70.23 a
	8	59.40 b	53.31 b
	6	40.16 c	34.07 c
	4	24.93 c	18.84 c
	0	6.09 d	
GT1	10	75.71a	65.13a
	8	74.19ab	63.41ab
	6	69.14ab	58.56ab
	4	58.34b	47.86b
	0	10.58c	

*The averages of the same column followed by the same letter are not significantly different at the threshold of 5% according to the Student Newman and Keuls test. *Relative mortality corresponds to the mortality rate by subtracting the rate of naturally dead tufts in the untreated object. Quantity 0 ml represents the control*

Injection of glyphosate at the root led to mortality of 63.16% of *P. capitata* tufts in all clones put together (Table 2). The results of statistical analyses showed that the mortality rate of tufts varied significantly (at the threshold of 5%) depending on the injected dose of glyphosate. The dose of 10 ml glyphosate injected at the root brought the best *P. capitata* tufts mortality rate (about 63.16%) followed by 8 ml (43.14%) and 6 ml (29.38%). Injected at the base of the trunk, the 10 ml dose gave the best *P. capitata* mortality rate (73.95%) followed by that of 8 ml (54.43%), 6 ml (46.26%) and 4 ml (22.94%), regardless the clone.

Table 2. Effect of glyphosate on the mortality of *Phragmanthera capitata* tufts after injection at the root of rubber trees of clones PB 217, GT1 and PB 235.

Clones	Dose (ml)	Tufts mortality (%)	Relative mortality (%)*
GT1	10	74.72a	63.15a
	8	66.79a	55.22b
	6	45.811b	34.24c
	0	11.57c	
PB 217	10	71.18 a	62.85 a
	8	54.56 b	46.23 b
	6	44.17 b	35.84b
	0	8.33 c	
PB 235	10	71.93 a	63.49 a
	8	36.42 b	27.98 b
	6	26.49 b	18.05 b
	0	8.44 c	

*The averages of the same column followed by the same letter are not significantly different at the threshold of 5% according to the Student Newman and Keuls test. *Relative mortality corresponds to the mortality rate by subtracting the rate of naturally dead tufts in the untreated object. Quantity 0 ml represents the control*

4.2 Action of glyphosate (360 g/l) on the yield and physiological profile of rubber trees: The yield of parasitized trees treated with glyphosate in three clones of rubber trees are shown in Table 3. As for injections at the base of the trunk or root, the analysis of this parameter did not give any quantity effect of glyphosate. Tables 4 and 5 show the physiological parameters of clones PB 235, GT 1 and PB 217 treated with injection of glyphosate at the base of the trunk or root of rubber trees. The analysis of the parameters of latex Micro diagnosis (dry content, sucrose, inorganic phosphorus and thiol groups) showed no significant difference between untreated infected trees and those treated with herbicide.

Table 3: Rubber yield (g/t/t) of clones PB 235, GT1 and PB 217 after injection of glyphosate at the base of the trunk

Clones	Dose (ml)	Yield (g/t/t)	
		Injection at the base of the trunk	**Injection at the root**
PB 235	10	95.80 a	92.90 a
	8	98.63 a	79.15 a
	6	94.70 a	77.39 a
	4	90.73 a	
	0	83.14 a	95.00 a

GT 1	10	97.51a	112.52a
	8	89.51a	83.29a
	6	101.06a	126.82a
	4	106.66a	98.64a
	0	98.63a	
PB 217	10	184.88 a	162.03 a
	8	187.55 a	177.33 a
	6	176.87 a	205.64 a
	4	167.70 a	-
	0	160.04 a	173.11 a

For each column, the average yields followed by the same letter are not significantly different at the threshold of 5% according to the Student Newman and Keuls test. Quantity 0 ml represents the control

Table 4: Effect of glyphosate on latex biochemical parameters after injection at the base of the trunk of trees of clones PB 235, GT1 and PB 217

Clone	Quantity (ml)	Dry rubber cont. (%)	Thiols cont. (m.mol.l-1)	Sucrose cont. (m.mol.l-1)	Inorganic phosphorus cont. (m.mol.l-1)
PB 235	10	63.50 a	0.08 a	3.94 a	20.85 a
	8	65.70 a	0.08 a	3.50 a	14.00 a
	6	65.48 a	0.09 a	2.95 a	20.50 a
	4	62.70 a	0.08 a	2.42 a	20.61 a
	0	64.00 a	0.14 a	2.24 a	16.33 a
GT 1	10	47.46a	0.19a	7.26a	11.24a
	8	43.98a	0.14a	8.11a	11.26a
	6	50.61a	0.12a	7.24a	9.75a
	4	49.48a	0.12a	6.97a	11.44a
	0	50.03a	0.12a	5.32a	10.52a
PB 217	10	65.53 a	0.38 a	9.07 a	23.10 a
	8	73.45 a	0.33 a	9.16 a	16.88 a
	6	72.29 a	0.30 a	8.85 a	20.03 a
	4	72.77 a	0.34 a	9.92 a	19.42 a
	0	74.15 a	0.37 a	6.88 a	16.65 a

The averages of the same column followed by the same letter are not significantly different at the threshold of 5% according to the Student Newman and Keuls test. Quantity 0 ml represents the control. Dry rubber cont: dry rubber contents; Thiols cont : thiols contents; Sucrose cont. : sucrose contents; Inorganic phosphorus cont: inorganic phosphorus contents.

Table 5: Effect of glyphosate on latex biochemical parameters after injection at the root of the trees of clones PB 235, GT 1 and PB 217

Clone	Quantity (ml)	Dry rubber cont. (%)	Thiols cont (m.mol.l-1)	Sucrose cont. (m.mol.l-1)	Inorganic phosphorus cont (m.mol.l-1)
PB 235	10	62.28 a	0.078 a	4.00 a	18.54 a
	8	64.48 a	0.104 a	2.22 a	15.05 a
	6	63.39 a	0.135 a	2.08 a	16.27 a
	0	65.40 a	0.126 a	2.55 a	16.25 a
	10	50.86a	0.14a	6.17a	12.07a
	8	50.72a	0.19a	6.53a	11.12a

	6	52.08a	0.12a	5.01a	11.16a
GT 1	0	50.03a	0.12a	5.33a	10.52a
	10	59.99 a	0.373 a	11.36 a	25.79 a
	8	68.25 a	0.375 a	9.92 a	24.07 a
	6	67.17 a	0.540 a	9.77 a	22.53 a
PB 217	0	70.40 a	0.361 a	9.00 a	19.08 a

The averages of the same column followed by the same letter are not significantly different at the threshold of 5% according to the Student Newman and Keuls test. Quantity 0 ml represents the control. Dry rubber cont: dry rubber contents; Thiols cont : thiols contents; Sucrose cont. : sucrose contents; Inorganic phosphorus cont: inorganic phosphorus contents.

4.3 Glyphosate residue analysis in latex:

Level of glyphosate residue was determined in latex of three rubber tree clones (PB 217 GT 1 and PB 235). The residues were found in the latex. In serum of rubber, the level of glyphosate residues was below 2 mg/l (Table 6). The lowest level was recorded in clone GT 1. Notably the amount of glyphosate residues in the latex and the TCA of GT 1 was significantly inferior to that of PB 235, which was the same as that of PB 217. In the latex made incoagulable by ammonia, glyphosate residue levels were 0.20 mg/l for the three tested clones. No difference was highlighted on the quantity of residue compared to the clone tested.

Table 6. Glyphosate residue analysis (360 g/l) in the serum of rubber and latex made incoagulable by ammonia

Clone	Latex + TCA (mg/l)	Latex + ammonia (mg/l)
PB 235	1.72 a	0.18a
GT1	1.12b	0.17a
PB 217	1.54 ab	0.19 a

5 DISCUSSION

These investigations on the use of glyphosate (360 g/l) showed its efficiency in controlling Phragmanthera *capitata* in rubber trees. Glyphosate (360 g/l) injection caused 73% mortality rate in *P. capitata* tufts whatever the clone and dose. This efficiency was expressed by the death of hemiparasite tufts after injection of glyphosate at the base of the trunk or root of rubber trees. Tufts mortality observed was probably due to translocation of the herbicide in the rubber tree branches parasitized by *P. capitata.* This assertion is supported by the conclusion of the works of Hager and Sprague (2002) indicating that the herbicide requires to be absorbed and transported in order to reach the site organs where it would express its action. This translocation via xylem vessels (Concenco and Leandro, 2011) would be facilitated by increased foliar call and specified in period of rubber tree defoliation. Through suckers, the hemiparasite would absorb, indeed, water and minerals of the rubber tree spreading the 2-N-phosphonomethylglycine (glyphosate).This substance inhibits the 5- enolpyruvylshikimate-3-phosphate synthase (EPSP synthase) involved in the synthesis of phenylalanine, tyrosine and tryptophan (Pfeiffer, 2009). Inhibition of the synthesis of these aromatic amino acids would result in the death of *Phragmanthera capitata* tufts. However, recent works by Vered et Galili (2010) corroborating and citing those of Galili et Hoefgen (2002) and Li et Last (1996) highlighted that the aromatic amino acids are key molecules in plant metabolism and that they are not only essential constituents of the protein synthesis in plants, but they also serve as precursors to a wide variety of secondary metabolites important for the vegetative growth of the plant. This leads us to deduce that the glyphosate inhibition of the synthesis of the aromatic amino acids probably explains the death of *Phragmanthera capitata* tufts. Furthermore, injection of herbicide at early leaf yellowing in the period of natural defoliation, for each clone, would prevent the rubber tree leaf system to be the target of glyphosate (360 g/l) system, which would make the herbicide more efficient. This study also revealed variability in mortality according to the dose of glyphosate (360 g/l) injected into the rubber trees. The use of glyphosate (360g/l) has revealed indeed a significant "dose" effect of glyphosate. The dose of 10 ml glyphosate (360 g/l) was in fact more efficient than the other doses 8, 6 and 4 ml. This study results are consistent with those of Boussim *et al* (2012) and Medah (2001) who demonstrated the efficiency of glyphosate (360 g/l) in the control of *Loranthus* sp. parasitizing Shea. This variability might be due to the efficiency threshold of glyphosate (360 g/l) related to the distribution and absorption of the herbicide by the parasite. These results confirm previous findings by Frochot *et al* (1983) and Baillon *et al* (1988) regarding the efficiency of herbicides. Indeed, from the injection place to the action site , glyphosate (360 g/l) driven by the flow of sap could be metabolized through apoplastic and symplastic pathways of xylem vessels. The metabolized herbicide would cause the dispersion of small doses (inferior or equal to 6 ml) injected at the base of the trunk or at the root, which would not reach then the target organs. It results in a low mortality of *Phragmanthera capitata* sp. compared to the dose of 10 ml injected into the rubber trees. In contrast, Fan Zhiwei *et al* (1995) in China showed a 90% mortality of *Loranthus* tufts in trees injected with doses of 2, 4 and 6 ml of 10% L glyphosate. This mortality rate could be explained by the sensitivity of *Taxillus chinensis* to glyphosate. It is interesting to note that the efficiency of glyphosate in controlling *Phragmanthera capitata* is different according to the two injection modes studied. The injection of the herbicide at the root of the rubber tree or at the base of the trunk gave statistically similar mortality rates for each dose of glyphosate (360g/l). This efficiency similarity could be explained by the fact that glyphosate (360 g/l) is a systemic herbicide that is translocated through the xylem, both at the root level and at the trunk level. The rubber yield of infected trees treated with glyphosate (360 g/l) was analyzed in two clones. This analysis showed that the average yield of dry rubber, per gram, per tree and per tapping, since the beginning of the experiment did not differ between treated and untreated trees. In *Hevea brasiliensis*, flow and regeneration are two factors that can limit the production of latex (Jacob *et al.*, 1995). Glyphosate (360 g/l) probably does not have a harmful effect on the general processes of regeneration of latex and its easy and prolonged flow. Indeed, according to Compagnon (1986), the mechanism for synthesizing rubber does not involve the site of action of glyphosate. Similarly, analyses of latex through Micro Diagnostics latex (MDL) taking into account the determining of dry content, the content of inorganic phosphorus, thiol groups, and sucrose in fresh latex showed a proper physiological functioning of trees treated with glyphosate (360 g/l) in three clones. This result shows that application of glyphosate at the base of the trunk or at the root of rubber trees do not affect, a priori the physiological functioning of rubber trees treated. By these parameters reflecting the activity of regeneration of the latex within the latex vessels, energy processes of cellular anabolism, activation of invertase and the initial substrate of the isoprene synthesis, were not affected regardless the dose and mode of application of glyphosate (360 g/l). This study results are in accordance with those of Wahounou *et al* (2012) who reported that glyphosate (360 g/l) injected has no negative effect on the rubber yield of (g/tree) and the physiological functioning of treated trees regardless of the dose. This study revealed traces of glyphosate in the latex of treated trees. Natural rubber being an inedible product, the tolerance threshold has not been established up to now. However, it would be wise to carry out technological analyses to assess the impact of traces of glyphosate on the technological quality of latex.

6 CONCLUSION

Glyphosate is an herbicide that, once injected at the base of the trunk at beginning of defoliation, at a dose of 10 ml per tree enables to efficiently control *Phragmanthera capitata* in rubber cultivation. Injection of different doses of glyphosate at the base of the trunk or at the root of rubber trees resulted in different mortality rates of tufts depending on the dose of herbicide applied. These rates were superior to 65% in trees of clones PB 235, GT 1 and PB 217 with 10 ml injected at the base of the trunk. This dose has no harmful effect on the rubber yield of rubber trees and the physiological functioning of their latex system, let alone on their morphology. However, traces of glyphosate in the latex of rubber trees treated would require investigations in order to estimate their impact on the technological quality of natural rubber.

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