

## Assessment of rubber tree panels under crowns resistant to South American leaf blight

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**Abstract** – The objective of this work was to assess the performance of panel clones under crowns resistant to South American leaf blight (*Microcyclus ulei*). The experiment was carried out with 18 panel clones crown-budded with *Hevea pauciflora* x *H. guianensis*, in a Xanthic Ferralsol (Oxisol) in Manaus, AM, Brazil. The following parameters were evaluated: dry rubber yield, plant nutritional status, and anatomical and physiological characteristics of the latex vessels. In the first three years of evaluation, the panel clones IAN 2878, IAN 2903, CNS AM 7905, CNS AM 7905 P1, and PB 28/59 showed the highest dry rubber yield potential, while the clones IAN 6158, IAN 6590, and IAN 6515 should not be recommended for crown budding. Higher potassium and copper foliar content in panel clones were associated to an increase in dry rubber yield. The simultaneous evaluation of anatomical and physiological characteristics of latex is fundamental for the selection of panel clones in the Amazon region. Crown budding is an efficient technology for South American leaf blight management in endemic regions.

**Index terms:** *Hevea*, *Microcyclus ulei*, Amazon, crown budding, nutritional status.

## Avaliação de painéis sob copas de seringueira resistentes ao mal-das-folhas

**Resumo** – O objetivo deste trabalho foi avaliar o desempenho de clones de painéis enxertados com copas resistentes ao mal-das-folhas (*Microcyclus ulei*). O experimento foi realizado com 18 clones de painéis enxertados com copas *Hevea pauciflora* x *H. guianensis*, em Latossolo Amarelo distrófico, em Manaus, AM. Foram avaliados os seguintes parâmetros: produtividade de borracha seca, estado nutricional das plantas e características anatômicas e fisiológicas dos vasos laticíferos. Nos três primeiros anos de avaliação, os clones de painel IAN 2878, IAN 2903, CNS AM 7905, CNS AM 7905 P1 e PB 28/59 apresentaram os maiores potenciais de produção de borracha seca, enquanto que os clones IAN 6158, IAN 6590, and IAN 6515 não devem ser recomendados para enxertia de copa. Maior conteúdo foliar de potássio e de cobre nos clones de painéis esteve associado a maiores produções de borracha seca. A avaliação simultânea de características anatômicas e fisiológicas dos vasos laticíferos é fundamental para seleção de clones de painéis na Região Amazônica. A enxertia de copa é uma tecnologia eficiente para o manejo do mal-das-folhas, em regiões endêmicas.

**Termos para indexação:** *Hevea*, *Microcyclus ulei*, Amazônia, enxertia de copa, estado nutricional.

### Introduction

In the Amazon, South American leaf blight (SALB) caused by the fungus *Microcyclus ulei* P. Henn. V. Arx. has led to a decline in rubber production and to the consequent migration of *Hevea* plantations to other locations without the disease (Gasparotto et al., 1997). However, crossing *Hevea* spp. to obtain crown clones resistant to SALB has produced extremely positive results. The most promising clones achieved dry rubber yield above 1,000 kg ha<sup>-1</sup> per year in the initial two years of tapping (Moraes & Moraes, 2008), similar to the results obtained in other rubber regions in Brazil

(Gonçalves et al., 2001a; Virgens Filho et al., 2001; Gonçalves et al., 2007; Silva et al., 2010).

The potential of *Hevea brasiliensis* (Willd. ex A. Juss.) Müll. Arg. to produce latex depends on genetic and environmental factors. These variables are even more complex in crown budding, since two grafts are used in the same plant, i.e., root and panel, and panel and crown – the latter being the result of an interaction between two different species of *Hevea* with distinct physiological and anatomical characteristics, such as diameter and number of laticiferous vessel rings, senescence, resistance to diseases, and bark thickness.

In general, regardless of the results found, studies on crown-budded clones resistant to SALB are limited

to panel clone CNS AM 7905 – *H. brasiliensis* primary screening in the nursery, at Embrapa Amazônia Ocidental, Manaus, AM, Brazil (Moraes & Moraes, 2008). This clone lacks the depressive effect of crowns from different rubber tree species on dry rubber yield, which has not been observed in experiments with other productive clones (Bahia & Sena-Gomes, 1981; Moraes & Moraes, 1997, 2004). However, new studies should not be limited to just one clone. It is necessary to develop other promising panel clones, in case clone CNS AM 7905 becomes susceptible to any kind of disorder, such as predisposition to tapping panel dryness.

In the crown and panel screening process, besides rubber yield, the evaluation of the anatomical, biochemical, and biophysical characteristics of latex and of the plant nutritional status are important to check the positive effect of crown clones on latex flow and regeneration (Jacob et al., 1989b; Moraes & Moraes, 1995).

The objective of this work was to assess the performance of 18 panel clones crown-budded with *H. pauciflora* x *H. guianensis* resistant to South American leaf blight (*Microcyclus ulei*), planted in a Xanthic Ferralsol (Oxisol) in Manaus, AM, Brazil.

## Materials and Methods

The rubber tree trial was established in 2002 at the experimental area of Embrapa Amazônia Ocidental

(2°53'29"S and 59°58'40"W), in Manaus, AM, Brazil. The soil is a Xanthic Ferralsol (Oxisol), with high clay content (730 g kg<sup>-1</sup> of clay) and the following chemical attributes: pH (H<sub>2</sub>O), 4.3; 1.55 g kg<sup>-1</sup> of total N; 2.4 mg dm<sup>-3</sup> of P (Mehlich 1); 47.1 mg dm<sup>-3</sup> of K; 7.2 mg dm<sup>-3</sup> of Na; 0.24 cmol<sub>c</sub> dm<sup>-3</sup> of Ca; 0.12 cmol<sub>c</sub> dm<sup>-3</sup> of Mg; 1.45 cmol<sub>c</sub> dm<sup>-3</sup> of Al; 8.04 cmol<sub>c</sub> dm<sup>-3</sup> of H+Al; 46.9 g kg<sup>-1</sup> of organic matter (OM); 0.25 mg dm<sup>-3</sup> of Cu; 333.2 mg dm<sup>-3</sup> of Fe; 5.15 mg dm<sup>-3</sup> of Mn; 0.68 mg dm<sup>-3</sup> of Zn (micronutrients were extracted by Mehlich 1); 6.3 of V% (Claessen, 1997).

The climate of the region is classified as Afi, wet tropical, according to Köppen, with abundant rainfall throughout the year (average of 2,250 mm), always higher than 60 mm in the month with the lowest rainfall, and average temperature of approximately 26°C (Vieira & Santos, 1987).

The area was deforested in 1976 using a bulldozer, then cultivated with rubber trees until 1985, abandoned for eleven years, and bulldozed again to remove tree trunks during soil preparation. A randomized complete block design was used with seven plants per plot and three replicates. A total of 18 panel clones were assessed (Table 1); however, clone RRIM 600 (Tjir 1 x PB 86), currently the most planted in Southeast Brazil, was not included in the present work, since it showed unsatisfactory growth in the nursery under the edaphoclimatic conditions of the region.

**Table 1.** Clones evaluated and their parents, Manaus, AM, Brazil<sup>(1)</sup>.

Clone	Parents
CNS AM 7905	<i>Hevea brasiliensis</i> – primary nursery selection
CNS AM 7905 P1	Polyploid of CNS AM 7905
PB 28/59	PBIG seedling
Fx 4098	PB 86 x FB 74
Fx 3864	PB 86 x FB 38
PB 314	RRIM 600 (Tjir 1 x PB 86) x PB 235 [PB 5/51 (PB 56 x PB 24)] x PB S/78
IAN 2880	Fx 516 (F 4542 x AVROS 363) x PB 86
IAN 2878	Fx 516 (F 4542 x AVROS 363) x PB 86
IAN 2903	Fx 516 (F 4542 x AVROS 363) x PB 86
IAN 6590	Fx 43-651 [Fx 213 (F 4542 x AVROS 183) x AVROS 183] x PB 186
IAN 3156	Fx 516 (F 4542 x AVROS 363) x PB 86
IAN 3044	Fx 516 (F 4542 x AVROS 363) x PB 86
IAN 6158	Fx 43-655 [Fx 213 (F 4542 x AVROS 183) x AVROS 183] x PB 186
IAN 6158 P4	Polyploid of IAN 6158
IAN 3087	Fx 516 (F 4542 x AVROS 363) x PB 86
FDR 1057	<i>Hevea brasiliensis</i>
IRCA 111	PB 5/51 (PB 56 x PB 24) x RRIM 600 (Tjir 1 x PB 86)

<sup>(1)</sup>CNS, Centro Nacional de Seringueira, Amazonas; PB, Prang Besar; PBIG, Prang Besar Isolated Garden; Fx, Ford Cross; FB, Ford Belém; IAN, Instituto Agrônômico do Norte; Tjir, Tjirandji; AVROS, Algemene Vereniging Rubber Planters Oostkust Sumatra; IRCA, Institut de Recherche sur le Caoutchouc en Afrique.

Ilegitimate seeds of *H. brasiliensis* (random crossing) were sown in sand seedbeds, and the seedlings were transplanted into the nursery at the “white point” and “spider paw” growth stages. Before seedling transplant into the final position, base grafting was done in the panel clone nursery, and bare root plants were transferred to plastic bags. The seedlings were transplanted into the final position after the second emission of mature leaves (Moraes et al., 2008). Seedling management for crown budding followed the procedures described by Zeid (1977). Crown budding was carried out using *H. pauciflora* x *H. guianensis* hybrids eight months after transplanting into the final position and was concluded before the ninth month after panel clone base grafting. Plant density was 476 plants per hectare and crown budding height was 1.7 m, according to Moraes (2002).

Before plowing, 1.0 Mg ha<sup>-1</sup> of dolomitic limestone – 26.4% of CaO, 12.4% of MgO, 80.0% of effective calcium carbonate (ECC) – was applied to the soil. Two months later, a broadcast application was done using triple superphosphate (686.3 kg ha<sup>-1</sup> of P<sub>2</sub>O<sub>5</sub>), copper sulfate (5.0 kg ha<sup>-1</sup> of Cu), zinc sulfate (5.0 kg ha<sup>-1</sup> of Zn), and boric acid (1.5 kg ha<sup>-1</sup> of B), followed by soil disaggregation using a rotary hoe. Fertilizer broadcast applications were split into six monthly doses starting in the second month, using urea (696.9 kg ha<sup>-1</sup> of N), ammonium sulfate (464.4 kg ha<sup>-1</sup> of N), and potassium chloride (696.1 kg ha<sup>-1</sup> of K<sub>2</sub>O). The other cultivation treatments (hoeing, spraying, etc.) were identical to those described by Moraes et al. (2008).

In the third year after planting, leaflet samples were collected according to the method recommended by Shorrocks (1962), in order to assess the nutritional status of the plants. Total leaf contents of N, P, K, Ca, Mg, S, B, Cu, Fe, Mn, and Zn were determined following the methodology described by Malavolta et al. (1997).

In the second year of tapping, latex samples were collected without stimulation from spiral cuts in the median part of the panel to determine contents of inorganic phosphorus (Pi), Mg, thiols (R-SH), bursting index of laticifers (BIL), and sucrose. In test tubes containing 9.0 mL of 2.5% trichloroacetic acid, 1.0-mL latex composite samples were collected from three plants per plot, from each of the three blocks, 10 min after tapping started. The tubes with 10% latex were shaken, placed into polystyrene boxes containing ice,

and transported to the laboratory. After coagulation, the clots were pressed inside the test tubes using a glass stirring rod and removed, so that only the supernatant remained in the tubes (Moraes & Moraes, 1995). The Mg content in the latex was assessed in the supernatant diluted in 2.5% trichloroacetic acid (Moraes & Moraes, 1997). Sucrose was determined using the anthrone method (Ashwell, 1957), while thiols (R-SH), BIL, and Pi were evaluated according to the methods described by Boyne & Ellman (1972), Ribaillier (1968), and Tausski & Shorr (1953), respectively. The circumference of the trunk was measured and virgin bark samples were collected 1.3 m above ground level to determine the number of latex vessel rings, density and diameter of laticiferous vessels, bark thickness, and average distance between consecutive latex vessel rings.

Tapping began in late 2007, five years after planting, when 80% of the plants had trunk circumference over 45 cm, with two spiral-cut tappings per week, according to the following model: 1/2s, d/3, 6d/7, 10m/y, et. 2.5%, Pa (1:1) (Benesi & Oliveira, 2000). Yield was expressed in kilograms of dry rubber per hectare per year, using the formula adapted from Melhoramento Genético da Seringueira (1987),

$$\text{DRY} = (\text{ADT}/\text{TF}) \times \text{NTT} \times \text{DRYTT},$$

in which: DRY is dry rubber productivity (kg ha<sup>-1</sup> per year), ADT is the appropriate days for tapping, TF is the tapping frequency, NTT is the number of trees being tapped per hectare (400 plants), and DRYTT is the dry rubber yield per tree per tapping.

Dry rubber yield, plant nutritional status, and latex anatomical and physiological characteristics were analyzed using analysis of variance. Mean differences were compared using cluster analysis (Scott & Knott, 1974), at 5% probability.

## Results and Discussion

Over a three-year period, panel clones PB 28/59, IAN 2878, CNS AM 7905 P1, CNS AM 7905, and IAN 2903 showed statistically better performance, with average dry rubber yields over 1,800 kg ha<sup>-1</sup> per year (Table 2). These results are similar to those obtained by Gonçalves et al. (2001a), Virgens Filho et al. (2001), and Gonçalves et al. (2007) for the best clones selected for the state of São Paulo, Brazil.

Nevertheless, the clones PB 314, IAN 6158, IAN 3087, IAN 6590, IAN 6515, IAN 6158 P4, and FDR 1057, when crown-budded, showed poor performance, with dry rubber yields below 1,000 kg ha<sup>-1</sup> per year, even though they produced good yield under other edaphoclimatic conditions (Pereira et al., 1999; Gonçalves et al., 2001b; Silva et al., 2010). The poor results found for these clones do not prevent their use in future studies carried out in other regions. Gonçalves et al. (2001b) tested nine clones from the Amazon region in a crown budding experiment, in a plateau in the state of São Paulo, and concluded that three of them had higher dry rubber yields than RRIM 600, the main clone cultivated in Brazil. Factors such as low natural soil fertility in the Amazon (Moreira & Fageria, 2009) and crown budding with different species of rubber tree, including *H. pauciflora* x *H. guianensis* (Moraes

& Moraes, 2008), may have negatively influenced latex biosynthesis and, consequently, led to lower yields.

Except for IAN 6158, the clones evaluated had average trunk circumference above 45 cm (Table 3), a parameter considered ideal to start tapping (Moraes et al., 2008).

The high content of Pi found for clones PB 28/59, IAN 3044, and IAN 3156 (Table 3) may have positively influenced yield, which was not observed for clones CNS AM 7905 P1 and CNS AM 7905. According to Jacob et al. (1989a) and Moraes & Moraes (2004), Pi content reflects the intensity of latex synthesis, since two molecules of isopentenyl pyrophosphate are liberated for the incorporation of isoprene into the macromolecule of latex and P is liberated due to the use of adenosine triphosphate (ATP). The concentration of Mg in the latex ranged from 4.4 to 10.3 mmol L<sup>-1</sup>. Only clone CNS AM 7905 had more than 10.0 mmol L<sup>-1</sup> of Mg, an amount considered non-limiting to latex biosynthesis in laticiferous vessels (Moraes & Moraes, 1997, 2008).

Similarly to the results obtained by Jacob et al. (1989b) and Moraes & Moraes (1997), the clones that had higher dry rubber yields (CNS AM 7905 P1, CNS AM 7905, and PB 28/59) showed the lowest sucrose contents in the latex, possibly due to a more intensive use of this compound during latex biosynthesis and to the dilution effect caused by higher latex export.

R-SH content ranged from 0.05 to 0.58 mmol L<sup>-1</sup> (IAN 2880 and IAN 6515, respectively), with a mean value of 0.20 mmol L<sup>-1</sup>, considered low by Moraes & Moraes (2004). It was expected that the clones with higher dry rubber yields show the highest R-SH contents and the lowest BIL values, since thiols play a vital role in maintaining membrane integrity, leading to low BIL values and preventing premature coagulation of the latex (D'Auzac & Jacob, 1989); however, this was not observed in the present study. These results could be explained by the higher number of latex vessel rings found for clone PB 28/59 and by the higher diameter and density of laticiferous vessels for clones IAN 2880, CNS AM 7905, and CNS AM 7905 P1, which caused higher latex flow before coagulation.

The number and diameter of latex vessel rings are important characteristics of the laticiferous system that are directly correlated to latex yield (Hénon & Nicolas, 1989; Webster & Paardekooper, 1989; Mesquita et al.,

**Table 2.** Dry rubber yield over a three-year period of 18 rubber tree panel clones crown-budded with *Hevea pauciflora* x *H. guianensis*<sup>(1)</sup>.

Panel	Dry rubber yield (kg <sup>-1</sup> ha <sup>-1</sup> per year)			
	2008	2009	2010	Average
CNS AM 7905	1,822.8b	1,926.1a	1,979.3b	1,909.4a
CNS AM 7905 P1	1,928.3a	2,012.2a	2,349.0a	2,095.8a
PB 28/59	2,180.1a	1,834.1b	1,934.8b	1,983.0a
FX 4098	910.3d	1,171.2b	1,539.2c	1,206.9c
IAN 2880	1,700.0c	1,383.4c	1,468.8c	1,517.4b
IAN 2878	1,931.8a	1,782.4b	1,731.7b	1,815.3a
FX 3864	685.7e	1,617.9b	1,480.6c	1,261.4c
PB 314	1,226.5d	1,188.6c	583.4e	999.5d
IAN 2903	1,822.8b	2,238.8a	1,431.7c	1,831.1a
IAN 3156	1,159.0d	1,594.8b	1,069.7d	1,274.5c
IAN 3044	1,522.3c	1,665.7b	1,463.5c	1,550.5b
IAN 6158	699.6e	567.7e	672.8e	646.7e
IAN 3087	722.2e	746.5d	972.4d	813.7d
FDR 1057	1,123.6d	831.8d	700.5e	885.3d
IRCA 111	1,417.4c	966.5d	1,175.9d	1,186.6c
IAN 6158 P4	460.7e	796.2d	1,468.3c	908.4d
IAN 6590	0.0f	0.0f	0.0g	0.0g
IAN 6515	419.7e	424.3e	329.6f	391.2f
Mean	1,207.4	1,258.1	1,247.3	1,237.6
Standard deviation	624.7	624.5	609.3	578.0
CV (%)	13.72	-	-	-
Minimal	0.0	0.0	0.0	0.0
Maximum	2,180.1	2,012.2	2,349.0	2,096.5

<sup>(1)</sup>Means followed by equal letters in the columns do not differ by the Scott-Knott test at 5% probability. In average, four trees per block were considered for the first year (2008), five trees per block for the second year (2009), and six trees per block for yield stimulation for the third year (2010).

2006). However, this is not a general rule, as observed by Tixier (1953) for clone AVROS 256, in Indochina, Southeast Asia. In the present study, clones FDR 1057, PB 314, and IAN 3087 showed a large number of latex vessel rings, above 29, which was the number reported by Gonçalves et al. (2001b) for clone RRIM 600, but had low average dry rubber yields. Therefore, using these variables as the only criteria to select crown budding clones may cause loss of promising materials, such as clones Fx 4098 and Fx 3864, which showed average dry rubber yields above 1,200 kg ha<sup>-1</sup> per year. Factors including Mg, Pi, and sucrose contents in the latex, among others, may also interfere positively or negatively with yield.

The results observed for bark thickness were higher than those obtained by Gonçalves et al. (2001b) for Amazonian clones and for RRIM 600 (5.6±0.7 mm), cultivated in the state of São Paulo. Average distance between consecutive latex vessel rings (ADBCLVR) ranged from 125.9 to 511.0 mm (IAN 2878 and IAN 6158, respectively), and the three clones with the

highest dry rubber yields were within the group with the lowest ADBCLVR values. As expected, an inverse relationship between the diameter of laticiferous vessels and ADBCLVR was observed.

Due to the lack of standard concentrations of foliar nutrients for the crown under study, data obtained for crown hybrids *H. pauciflora* x *H. rigidifolia* and *H. pauciflora* x *H. guianensis* by Pereira & Pereira (1986) and Moraes & Moraes (2008), respectively, were used as reference. The mean foliar contents of N (24.1±3.7 g kg<sup>-1</sup>), P (1.3±0.2 g kg<sup>-1</sup>), K (6.8±1.9 g kg<sup>-1</sup>), Ca (5.5±1.1 g kg<sup>-1</sup>), S (1.6±0.2 g kg<sup>-1</sup>), Cu (6.1±0.8 mg kg<sup>-1</sup>), and Mn (163.3±40.5 mg kg<sup>-1</sup>) found in the present study were close to the range observed by these authors. However, the mean foliar contents of B (49.1±5.0 mg kg<sup>-1</sup>), Fe (93.8±5.2 mg kg<sup>-1</sup>), and Zn (27.5±4.9 mg kg<sup>-1</sup>) were lower than those reported by Moraes & Moraes (2008).

The clones with mean dry rubber yields above 1,900 kg ha<sup>-1</sup> (CSN AM 7905 P1, PB 28/59, and CSN AM 7905) showed the highest foliar contents of Cu and K, but intermediary foliar content of Mg

**Table 3.** Anatomical and physiological characteristics of latex produced by 18 rubber tree panel clones crown-budded with *Hevea pauciflora* x *H. guianensis* in the second year of tapping<sup>(1)</sup>.

Clone	Pi (mg L <sup>-1</sup> )	Mg (molar)	Sucrose --- (mmol L <sup>-1</sup> )	R-SH ---	BIL (%)	d (5 mm)	Number of rings	LVD ----- (mm)	BT -----	ADBCLVR -----	Circumference (cm)
CNS AM 7905	11.3d	7.0b	4.4e	0.09e	42.0a	66.1a	27d	13.6a	8.0b	208.0c	54.0b
CNS AM 7905 P1	7.1d	6.6b	2.5f	0.11e	40.0a	66.1a	39c	13.9a	11.6a	206.9c	50.6b
PB 28/59	29.3b	10.3a	4.8e	0.06e	29.3b	62.1b	55a	10.6b	10.4a	189.1c	58.0a
Fx 4098	9.3d	9.1a	11.1a	0.09e	41.1a	60.8b	13e	10.9b	7.8b	404.7b	57.8a
IAN 2880	10.3d	6.2b	7.4c	0.05e	30.6b	68.8a	43b	13.6a	9.1a	177.1c	53.4b
IAN 2878	8.0d	4.9c	6.6c	0.11e	34.5b	65.7a	39c	12.0b	7.2b	125.9c	52.6b
Fx 3864	10.8d	8.3a	10.7a	0.29c	32.4b	60.3b	15e	10.4b	8.6a	368.9b	53.6b
PB 314	13.2c	9.9a	6.5c	0.10e	34.3b	65.1a	39c	13.7a	8.8a	197.7c	46.1b
IAN 2903	7.1d	4.4c	5.6d	0.17d	36.3a	56.9b	33c	10.1b	7.6b	184.8c	48.6b
IAN 3156	16.0c	6.9b	5.8d	0.29c	33.3b	63.4a	35c	11.0b	9.9a	235.2c	50.6b
IAN 3044	17.6c	7.6a	7.4c	0.22d	20.4c	59.3b	44b	11.0b	9.0a	225.7c	49.6b
IAN 6158	8.2d	5.0c	8.0b	0.29c	29.2b	65.1a	25d	10.8b	6.4b	511.0a	42.2b
IAN 3087	8.4d	9.1a	10.0a	0.24d	30.1b	55.6b	47b	10.2b	9.8a	370.3b	62.6a
FDR 1057	8.2d	8.8a	9.1b	0.19d	31.4b	58.7b	39c	13.2a	8.8b	248.9c	64.4a
IRCA 111	10.2d	6.7b	7.4c	0.09e	30.9b	65.6a	31d	11.3b	10.3a	254.3c	54.9b
IAN 6158 P4	9.4d	4.7c	5.6d	0.33c	30.4b	61.8b	22d	11.6b	6.8b	265.1c	47.9b
IAN 6590	11.8d	5.8b	5.6d	0.45b	42.5a	65.4a	21d	10.6b	7.1b	189.6c	56.1a
IAN 6515	65.5a	8.3a	10.4a	0.58a	36.0a	58.9b	23d	9.8b	5.5b	136.5c	52.3b
Mean	14.5	7.2	7.1	0.20	35.0	62.5	33	11.6	8.5	250.0	53.1
Standard deviation	13.8	1.8	2.4	0.14	5.5	3.7	11.5	1.4	1.6	101.0	5.5
CV (%)	18.31	17.19	13.81	24.07	12.96	7.33	13.70	10.36	12.82	24.31	10.88
Minimal	7.1	4.4	2.5	0.05	20.4	55.6	13.0	9.8	5.5	129.9	42.2
Maximum	65.9	10.3	11.1	0.58	42.5	68.8	55.0	13.9	11.6	511.0	64.4

<sup>(1)</sup>Means followed by equal letters, in the columns, do not differ by the Scott-Knott test at 5% probability. Pi, inorganic phosphorus in the latex; Mg, magnesium in the latex; R-SH, thiols; BIL, bursting index of luitoids; d (5 mm), density of laticiferous vessels in 5 mm per ring; LVD, laticiferous vessel diameter; BT, bark thickness; ADBCLVR, average distance between consecutive latex vessel rings.

**Table 4.** Foliar nutrient content in 18 rubber tree panel clones crown-budded with *Hevea pauciflora* x *H. guianensis*<sup>(1)</sup>.

Clone	N	P	K	(g kg <sup>-1</sup> )				(mg kg <sup>-1</sup> )			
				Ca	Mg	S	B	Cu	Fe	Mn	Zn
CNS AM 7905	25.9a	1.7a	12.3a	3.8b	2.2c	1.7a	46.4a	8.1a	87.3a	119.1b	28.3b
CNS AM 7905 P1	26.0a	1.5a	8.9b	3.9b	2.3c	1.7a	54.5a	7.1a	91.5a	139.8b	32.9b
PB 28/59	26.2a	1.4a	8.4b	5.5a	2.4c	1.6a	51.6a	7.3a	91.4a	170.0b	27.8b
FX 4098	25.8a	1.5a	7.1c	4.4b	1.8c	1.8a	47.7a	6.8a	94.1a	128.9b	28.8b
IAN 2880	24.5a	1.2b	6.0c	6.5a	1.7c	1.4a	46.8a	5.9a	89.8a	81.6b	17.6c
IAN 2878	25.3a	1.2b	5.2c	5.8a	3.1c	1.6a	46.0a	6.4a	87.5a	170.3b	22.5c
FX 3864	24.1a	1.1b	6.8c	6.2a	2.5c	1.5a	36.4b	5.4a	103.3a	189.5a	26.8b
PB 314	21.1a	1.1b	6.6c	6.2a	2.2c	1.4a	56.3a	4.8a	89.9a	169.5b	35.9a
IAN 2903	24.8a	1.3b	5.9c	6.0a	2.0c	1.4a	53.6a	6.5a	84.9a	169.6b	26.8b
IAN 3156	23.1a	1.4a	7.0c	4.3b	1.9c	1.6a	44.1a	6.4a	96.3a	205.6a	27.7b
IAN 3044	22.3a	1.1b	5.8c	6.8a	2.7c	1.7a	45.9a	5.4a	97.1a	228.9a	36.6a
IAN 6158	22.9a	1.3b	7.0c	4.5a	1.9c	1.4a	50.2a	5.4a	90.1a	191.5a	29.1c
IAN 3087	24.0a	1.3b	6.7c	3.9b	2.1c	1.8a	51.6a	6.0a	93.7a	156.3b	30.1b
FDR 1057	26.3a	1.5a	7.6c	6.2a	3.5b	1.9a	47.0a	6.4a	99.8a	150.1b	26.5b
IRCA 111	21.9a	1.4a	6.9c	5.3a	1.8c	1.7a	51.5a	5.6a	99.5a	151.8b	22.8b
IAN 6158 P4	21.7a	1.2b	2.3d	5.2a	4.9a	1.8a	57.9a	5.9a	100.9a	132.0b	19.4c
IAN 6590	25.2a	1.2b	6.4c	7.4a	2.9c	1.8a	47.1a	5.3a	92.5a	250.3a	26.6b
IAN 6515	22.7a	1.2b	5.9c	6.2a	2.8c	1.6a	49.0a	5.9a	98.1a	134.3b	28.2b
Mean	24.1	1.3	6.8	5.5	2.5	1.6	49.1	6.1	93.8	163.3	27.5
Standard deviation	3.7	0.2	1.9	1.1	0.8	0.2	5.0	0.8	5.2	40.5	4.9
CV (%)	13.6	14.86	20.93	14.70	23.02	11.68	10.21	15.76	9.31	20.34	16.22
Minimal	21.1	1.1	2.3	3.8	1.7	1.4	36.4	4.8	84.9	81.6	17.6
Maximum	26.3	1.7	12.3	7.4	4.9	1.9	57.9	7.3	100.9	250.3	36.6

<sup>(1)</sup>Means followed by equal letters, in the columns, do not differ by the Scott-Knott test, at 5% probability

(Table 4), considered an important criterion for crown selection (Moraes & Moraes, 2004). According to Jacob et al. (1989b) and Tungngoen et al. (2009), higher foliar content of Cu is an important feature, since this nutrient inhibits the activity of sucrose synthase, the enzyme responsible for sucrose neosynthesis in the latex, and maintains the substrate for latex synthesis available. The foliar content of K is equally important – this nutrient participates in glycolysis, respiration, laticiferous vessel formation, and osmotic rebalancing after tapping (Jacob et al., 1989b). These results show that dry rubber yield can be improved by using the correct fertilizer management indicated by the assessment of soil fertility and the nutritional status of rubber trees.

### Conclusions

1. Crown budding is an efficient technology for South American leaf blight management in endemic regions.

2. Panel clones IAN 2878, IAN 2903, CNS AM 7905, CNS AM 7905 P1, and PB 28/59 have the highest average dry rubber yield potential, while

clones IAN 6158, IAN 6590, and IAN 6515 are not recommended for the management system used in this study.

3. The simultaneous evaluation of anatomical and physiological characteristics of latex is fundamental for the selection of panel clones, under the edaphoclimatic conditions of the Amazon region.

4. Higher foliar content of Cu and K is associated to higher dry rubber yields of panel clones crown-budded with *Hevea pauciflora* x *H. guianensis*.

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