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Immature growth performance of three important rubber tree (*Hevae brasiliensis*) clones in a drought-prone area

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Abstract

Adaptation of rubber tree clones to water-limited areas and maintenance of trunk radial growth are important keys for performance of genetic material. The rubber farmers need to shorten the interim phases to produce latex, which is considered "immature" phase, i.e. the time without income. The objective of this study was to compare the performance of three important rubber tree clones: GT1, the elder clone as control, which is still widely used in Cambodia and West Africa; RRIM600, the "all-round" clone, the most planted clone in Thailand, the first world producer; and RRIT251, the expanding clone, recommended by the Rubber Authority of Thailand, all in the field condition. The investigation was conducted in a drought-prone area of Northeast Thailand, where the dry season lasts 5 to 6 months. The cumulated growth and the annual growth were analyzed 4.5 years after planting. The trunk girth and height were measured monthly. Main climatic variables were hourly recorded. The year was separated in three periods: the leaves-shed season from January to April, the wet season from May to September, and the dry season with canopy maintenance from October to December. The results showed significant clonal effect on both trunk girth and height; however, with relatively low differences. The trunk girth of clone RRIT251 was about 29 cm and 10% higher than GT1. The difference was not significant in RRIM600. The annual girth increment was mainly located in wet season (63%) without clonal effect. The clonal difference was occurred in the dry season, where RRIT251 was better performed particularly in the leave-shed period preceding wet season. On a monthly basis, the relative trunk girth increment rate was highly negatively related to the vapor pressure deficit. We hypothesized that rubber clones shared a common strategy of dehydration avoidance, while RRIT251 expressed a little less degree of avoidance.

Keywords: GT1; RRIM600; RRIT251; immature growth; drought-prone area.
Abbreviations: T_average_average temperature; T_max_maximum temperature; T_min_minimum temperature; ETo_evapotranspiration; VPD_vapor pressure deficit; TG_trunk girth; TH_tree height; GI_girth increment; HI_height increment.

Introduction

The rubber tree (*Hevea brasiliensis*), native to Brazil (parts of the Amazon Basin and Matto Grosso) and the Guianas, is a commercial crop, which produces natural latex (Webster and Paardekooper, 1989), and is a natural source of timber (Silpi et al., 2006). Approximately 70 percent of all natural rubber is produced in the ASEAN countries (FAOSTAT, 2018), of which Thailand is the main producer (4.47 million tons in 2016). Since 1980, due to high demand and the lack of available land, rubber plantations have extended from the southern provinces (traditional area) to the northern (5%) and northeastern (22%) areas of Thailand (non-traditional areas), where sub-optimal environmental conditions exist for rubber plantations (OAE, 2016). In the Northeast region, the annual rainfall ranged from <1000 to <2000mm, with a long dry period extending between five to six months (Sangchanda et al., 2014). As reported by the Global Climate Risk Index in 2018, Thailand is a country highly vulnerable to climate change (Eckstein et al., 2018). Recently, several regions of Thailand suffered from extreme events as drought or flooding. In rubber tree cultivation, the "immature" phase defines the necessary time to reach an average sufficient trunk size in the plantation to start the tapping of latex, the "opening" phase. The standard trunk girth varies according countries between 45 to 50 cm at 100 to 120 cm above the ground level (Gunasekara et al., 2007; Chantuma et al., 2011; Obouayeba et al., 2011). Usually reaching to this phase takes 5 to 7 years after planting as optimum. This time is essential for farmers who wait for the income of latex production (Gunasekara et al., 2007). Drought has been reported to delay the mature phase up to nine years after planting (Chandrashekar et al., 1998; Devakumar et al., 1998; Clermont-Dauphin et al., 2013), resulting in a 30 percent reduction in annual latex production (Rao et al., 1998).

Our experiments have focused on three important clones. RRIM600 is the most planted clone worldwide, which accounts for roughly 75% of plantations in Thailand (Pethin et al., 2015). RRIT251 is a new clone launched by the Rubber Authority of Thailand (RAOT), which is now replacing RRIM600 in the replanting process. Lastly, GT1 is an elder clone as control, which covers most plantations in Cambodia, Côte d'Ivoire, and West Africa. Our work intends to provide information for ecophysiological studies and breeding programs of rubber trees in drought situations. To the best of our knowledge, no investigation has been reported to compare the immature growth of these clones in a water-limited area. Thus, the first objective of this study was to compare the cumulated growth of these clones during the immature phase in a drought-prone area located in the Northeast Thailand. We expected that RRIT251 performed better than the older clones. The second objective was to compare growth responses according to seasons. We expected to have clonal difference in dry season.

Results

Cumulated growth and annual increment

At the end of the experiment, at 4.5 years old, the trunk girth at 170cm above ground (TG) was significantly different between clones ($P < 0.008$). TG of clone RRIT251 (29.4 cm) was slightly (10%) higher than GT1 (26.4 cm), while RRIM600 was in intermediate position (Fig 2a). The annual girth increment (GI) followed the same trend (8.4 cm year^{-1} for RRIT251) but without significant difference (Fig 2b). The relative GI rate was relatively high (about 40%) but without clonal difference (Fig 2c). Both the final tree height (TH) and the annual height increment (HI) were not different between clones, with values 800 cm and 200 cm, respectively (Figs 3a and 3b). Additionally, relative height increment rate was about 40% without significant difference between clones (Fig 3c).

Changes according seasons

Monthly GI showed a high seasonality (Fig 4). There was a large decrease from February to April at the leave-shed period. It rapidly increased when the rainfall commenced. The highest GI was found around 2 cm in July and August, and it slowly decreased up to December. Parted in three main seasons (Fig 5), 63 percent of the radial increment occurred during the wet season where the clonal effect was not significant. 11 percent occurred in the preceding leaves-shed season and 26 percent the following dry season. Interestingly, RRIT251 tend to have a higher growth in the dry seasons with a statistical significance in the leaves-shed season ($P < 0.02$). For HI, there were also clonal difference according seasons, but in the wet season and in the dry season ($P < 0.001$, Fig 6). The HI of clone RRIM600 was predominant in the wet season, whereas the other two clones better grew in the dry season. The HI appeared delayed behind GI. The monthly relative girth increment was plotted versus rainfall and vapor pressure deficit (Fig 7). The relationship with rainfall displayed an expected positive relationship. However, the data were too far from a normal distribution to go further in analysis. The relationship with VPD, from 1.0 kPa to 2.5 kPa, was highly negative and significant. No starting plateau or increase was observed. The trends could not be separated between clones. By contrast, there was no significant relationship between relative height increment and VPD (data not shown).

Discussion

Our results confirmed the hypothesis that RRIT251 provides the best performance in immature growth under water-limited conditions. However, the significant difference with GT1 was modest (10%) after 4.5 years. Moreover the difference was not significant versus RRIM600. In such water limited areas, the trees generally reach a latex tappable size (45-50 cm of trunk girth at 100-120 cm above soil level) at about 9 to 10 years, while it takes 5 to 7 years in optimal conditions (Chandrashekar et al., 1998). Hence, at 29 cm after 4.5 years, there is still 4 to 5 years to reach the tappable size. In clonal trials, the genetic effect versus environment is expected to increase with time. Withanage et al. (2005) evaluated the genetic and the environment contributions in a multi-fields clonal study at 5 years old and 38 cm of mean trunk girth (120 cm above soil level) and reported increase of 36 and 57%, respectively. Then it is likely that the advantage of RRIT251 will increase with age. On the other hand, good performance of RRIM600 was expected. Despite its old age (created in 1940 and released in the 1950), this clone is classified in the class of drought tolerant clones. RRM600 had the first rank in the rare internationally published clonal trial done in water-limited area (Chandrashekar, 1997). However, the details of clonal differences in drought responses are poorly known.

In our results, trunk increment occurred mostly during the wet season with 63% of the annual amount. This conclusion agreed with the previous results of Chandrashekar et al. (1998) who worked in similar constraining climatic conditions in the Konkan region of western India. Our results confirmed the hypothesis that difference appears in dry season between clones. The trend of higher annual girth increment of RRIT 251 was explained by the trend of higher growth in dry seasons not in wet season. This was again in agreement with the previous results of Chandrashekar et al. (1998; 2005). They observed over 15 clones that leading clones had higher growth in mid-seasons (transitions before and after wet season). One hypothesis is that such clones had higher drought tolerance beside a common behavior of drought escape through main growth in wet season. The relationships of monthly relative girth increment with rainfall and above all VPD confirmed the importance of the wet season, with high soil water availability and low evaporative demand. However, it could be noticed that in the wet season the average VPD was higher than 1 kPa, which suggest some air dryness constraint. In contrast to VPD, the response of the relative girth increment rates was similar between clones. The accuracy of girth measurement and the high inter-individual variability did not go further in clonal comparison. Ecophysiological studies on water relations of rubber trees had shown low resistance of xylem vessel to cavitation, (Sangsing et al., 2004), hydraulic segmentation between petiole and branches (Jinagool et al., 2015) and isohydric behavior (Isarangkool Na Ayutthaya et al., 2011). All these features support water use strategy avoiding dehydration. However, such strategy may slightly differ between clones with little less avoidance in the case of RRIT251. This hypothesis deserves further researches

Table 1. Summary of climatic conditions; rainfall, temperature, reference evapotranspiration (ETo), and vapor pressure deficit (VPD); divided into three seasons: leaves-shed season from January to April; wet season from May to September; and dry season from October to December.

Variables	Seasons		
	Leaves-shed (Jan-Apr)	Wet (May-Sep)	Dry (Oct-Dec)
Cumulated seasonal rainfall (mm)	104	1,825	55
Average daily temperature (^{o}C)	24.9	27.7	25.3
Average daily ETo (mm)	3.96	2.65	2.92
Average daily VPD (kPa)	1.79	1.16	1.57

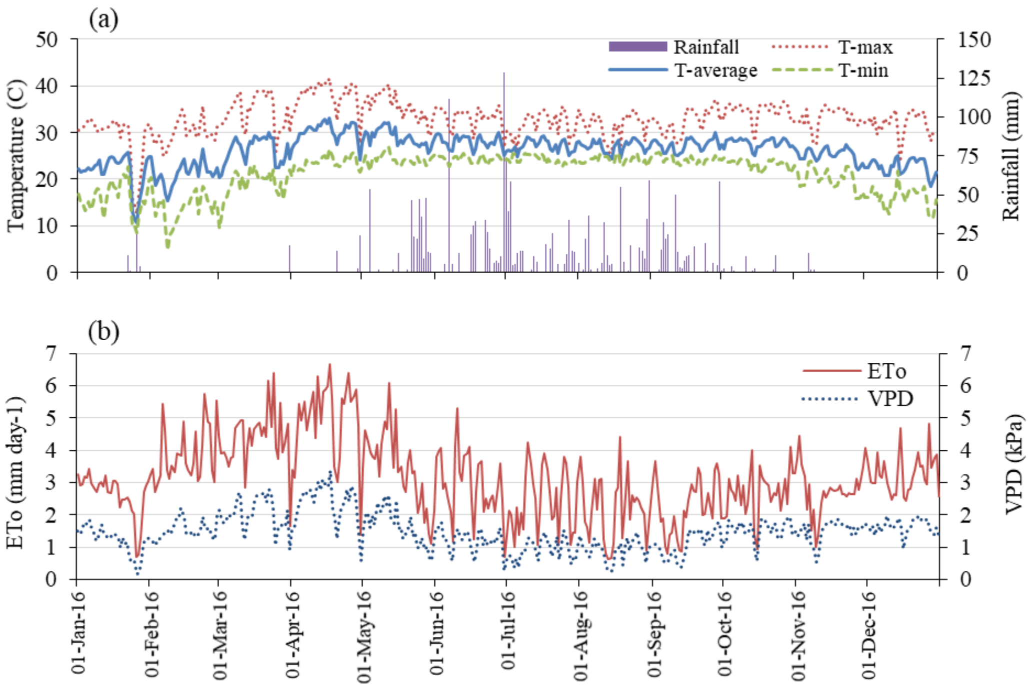

Fig 1. Daily changes in 2016 climatic conditions; a) temperature and rainfall, b) reference evapotranspiration (ETo) and vapor pressure deficit (VPD).

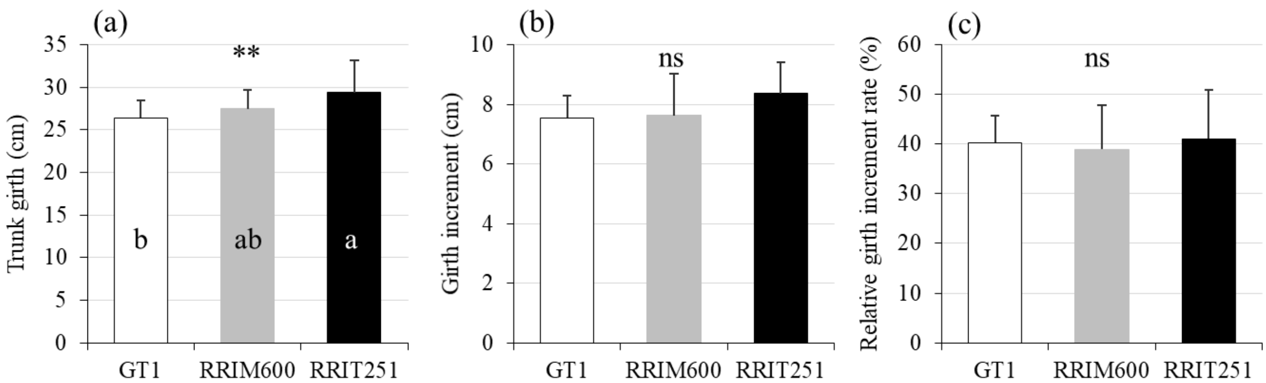

Fig 2. Comparison of the trunk girth at 170cm above ground of the three clones at the end of the study in December 2016 (a) final trunk girth; (b) girth increment; and (c) relative girth increment rate based on the initial trunk girth in January 2016. ** and ns indicate the significancy of differences between the three clones. Vertical bars indicate standard deviations of means (n=18).

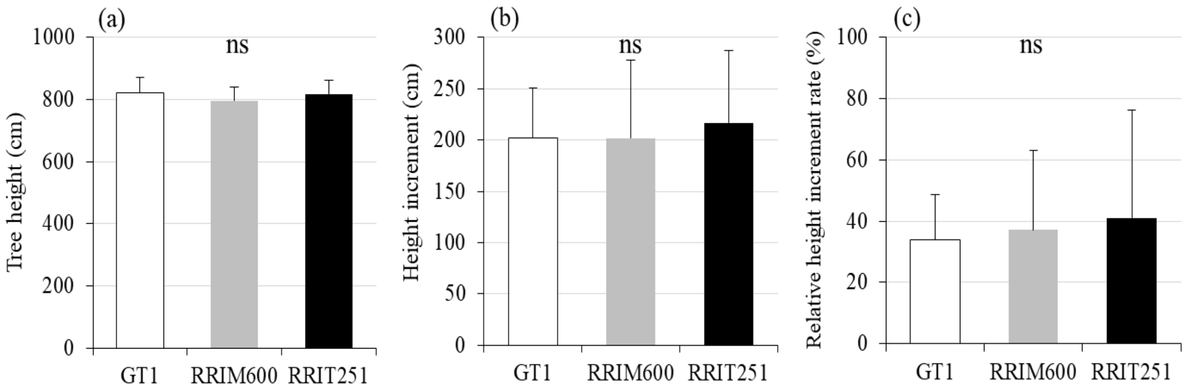

Fig 3. Comparison of the tree height of the three clones at the end of the experiment in December 2016 (a) tree height, (b) height increment, and (c) relative height increment rate based on the initial tree height in January 2016. Same additional details such as Fig 2.

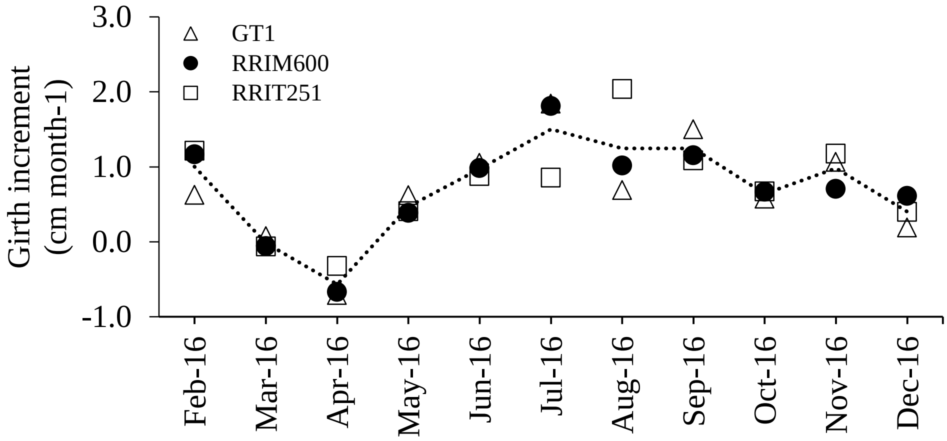

Fig 4. Monthly trunk girth increment at 170 cm above ground of the three rubber clones (n=18 per clone). The dotted line is the average value of the three clones (n=54).

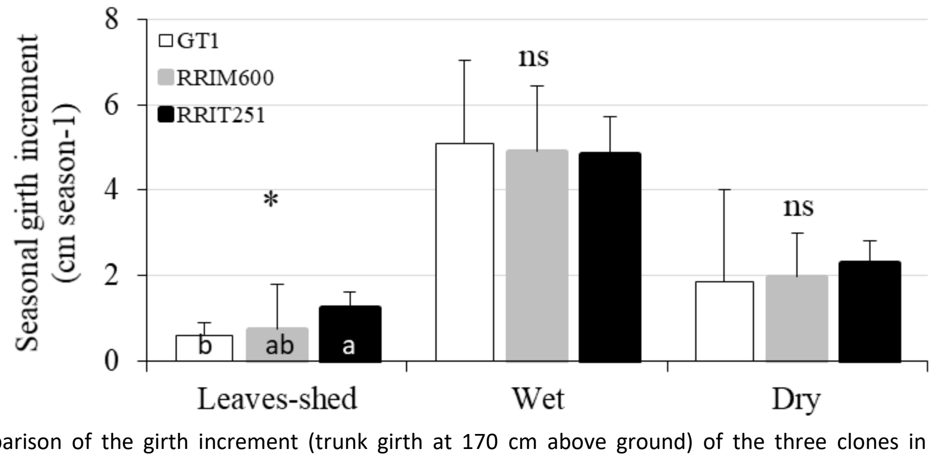

Fig 5. Comparison of the girth increment (trunk girth at 170 cm above ground) of the three clones in three different growth seasons: leaves-shed season from January to April (Leaves-shed); wet season from May to September (Wet); and dry season from October to December (Dry). Same additional details such as Fig 2.

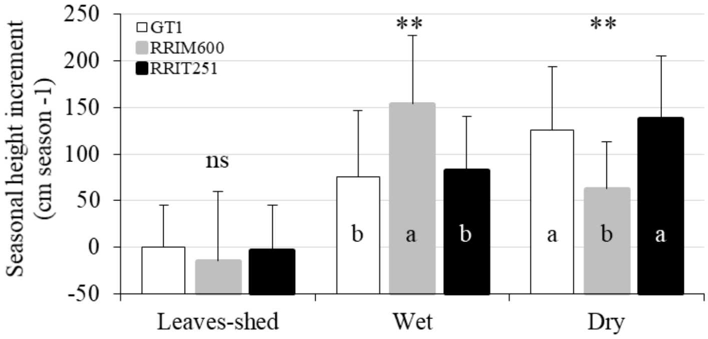

Fig 6. Comparison of the tree height increment of the three clones in three different growth seasons: leaves-shed season from January to April (Leaves-shed); wet season from May to September (Wet); and dry season from October to December (Dry). ** and ns indicate the significant difference at *P <0.01* and non-significant difference. Same additional details such as Fig 2.

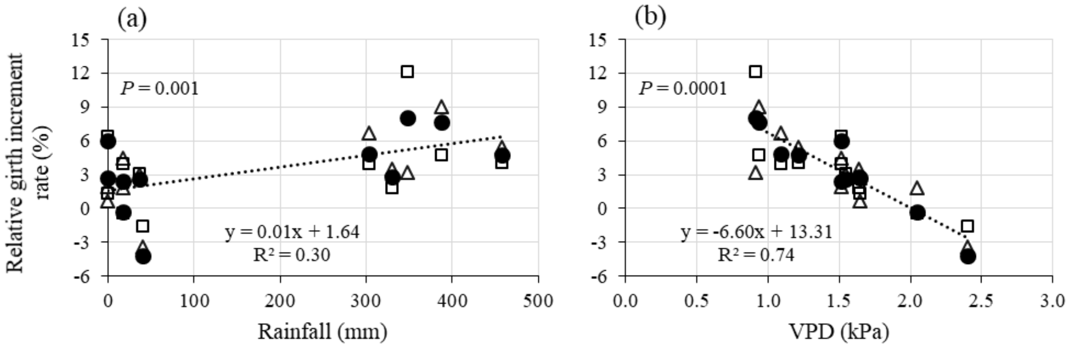

Fig 7. Relationships of monthly relative girth increment rate with rainfall (a) and vapor pressure deficit (VPD) (b), with the three rubber tree clones: GT1 (open triangle), RRIM600 (closed circle), and RRIT251 (open square).

combining growth analysis and water relation traits in a field trial.

Materials and methods

Experimental site, plant material, and climatic conditions

Hevea brasiliensis (Müll. Arg.) is indigenous to the forests of the Amazon basin within 5° latitude of the equator, i.e. under a wet equatorial climate with no marked dry season (Watson, 1989). The cultivation first developed in areas of similar climate particularly in SouthEast Asia. Since it has extended in the wetter areas of tropical wet-dry climates, including areas where there is a marked dry season as in our study. The experimental field was located at the Nong Khai Rubber Research Center (NRRC), in the Rattanawapi district (N18° 09’ 05.8” E103°10’05.5”), Nong Khai province of Northeast Thailand. The soil in the first meter is of clay loam type with pH about 5.5: clay (40%), loam (24%) and sand (36%). The climatic conditions correspond to a Tropical savanna climate (Aw) with very distinct wet and dry seasons of relatively equal duration. The stand was designed according to a randomized complete block (RCBD) comprising five blocks and three clones of treatment (GT1, RRIM600, and RRIT251) with four trees as replication per clone within the blocks and with a 4x4 m spacing. The stand was planted in June 2012 and the study was conducted in the 4th year, from January to December, 2016. The annual rainfall was on average 2060 mm (± 138 mm) over the five rainy seasons since planting. The dry seasons were severe in all cases with length around 6 months. In 2016, the climatic conditions were very similar to previous years. The details are displayed in Fig 1. The annual temperature was about 26 ^{o}C. The lowest temperature of 22 ^{o}C was occurred in January and February, while the highest, 30^{o}C, observed in April. Rainfall started in May and stopped at the end of September (Fig 1a). There was little, if any, rainfall after early November. The annual rainfall reached 1984 mm; 90 percent of which took place between May and September. The evaporative demand as expressed by daily VPD reached its highest value in April (3.4 kPa) and lowest value in August (0.3 kPa, Fig 1b). The reference evapotranspiration (ETo) logically followed the trend of VPD, showing extremely high values in April, above 5 mm day^{-1}. In order to compare clone responses, the growing year was divided into three main seasons: i) the leaves-shed season, with high evaporative demand from January to April; ii) the wet season, with high rainfall and the lowest evaporative demand, from May to September; and iii) the dry season, with drying soil and increasing evaporative demand, from October to December (Table 1).

Data collection and analysis

The trunk girth at 170cm above the ground (TG, cm) was measured every month to estimate girth increment (GI) per month (cm month^{-1}) and season (cm season^{-1}), and the final GI (cm) at the end of the experiment. The relative girth increment rates (%) were calculated by dividing the increment by the initial value. Also, the tree height (TH, cm) was measured every month to estimate season increment (cm season^{-1}), and the final height increment (HI, cm) at the end of the experiment. The relative height increment rates (%) were calculated by dividing the increment by the initial value. An automatic weather station (CR1000, Campbell Scientific, Inc., Logan, Utah, USA) recorded hourly values of climatic variables: air temperature, relative humidity, incoming short wave radiation, and rainfall. A one-way ANOVA was performed to compare the differences of each treatment. The significant difference was tested using the Tukey's test at P <0.05. Regression and other statistical analyses were performed with XLSTAT 2018 software version 20.6 (Addinsoft, Paris, France).

Conclusion

In a drought-prone area of Northeast Thailand, growth analysis 4.5 years after planting showed significant but relatively low differences in trunk girth and height between three presumed contrasted clones. The trunk girth of RRIT251 (new released clone) was slightly higher (10%) than the elder one (GT1). The difference was not significant with RRIM600, the most planted clone in Southeast Asia and Thailand in particular. The trunk girth increment in the last year was mainly located in wet season (63%). The clonal difference appeared in the dry season where RRIT251 better performed particularly in the leave-shed period preceding wet season. The low differences in trunk girth are expected to increase with the time necessary to reach the trunk tappable girth, about 9 years in this sub-optimal area. On a monthly basis, the relative trunk girth increment rate was highly negatively related to the vapor pressure deficit (VPD). However, the high inter-individual variability and accuracy of trunk girth measurement did not go further in clonal comparison. Our hypothesis is that RRIT251 has a little less degree of avoidance within the common avoidance strategy shown by rubber clones. This hypothesis deserves further researches combining growth analysis and water relation traits in a field trial.

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