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GROWTH AND PHYSIOLOGICAL RESPONSE OF SELECTED CLONES OF RUBBER GROWN UNDER DIFFERENT WATER FREQUENCIES

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Abstract

Effects of water frequencies on growth and physiological response of different clones of rubber were investigated**.** Different clones of rubber were screened with different watering frequencies as everyday watering (EW), every 2 days (E2D), every 3 days (E3D), every 5 days (E5D), and every 7 days (E7D). The treatments EW and E2D were found to be suitable for all the five clones for increasing as shown in plant height. A similar result was also found for plant biomass after 4 and 8 months of treatments. Noticeably, watering had a pronounced positive effect on clone RRIM 3001 and greatly increased vigorous growth as shown in its highest height, largest girth circumference and relative growth rate after 8 months of different watering frequencies. This clone equally showed superior performance with a significantly higher total plant biomass after 4 and 8 months of watering frequencies compared to the other four clones. The result could be used in water management and the clone RRIM 3001 could be suitable for rubber production at the nursery stage and replanting exercise in rubber plantations.

Introduction

Latex timber clones (LTCs) is known for its adaptation to Malaysian climate, but it may be affected by water stress condition because of the northern and western coast of Peninsular Malaysian experience dry conditions from May to September, leading to drought conditions in many areas. This condition is believed to be the effect of the global warming phenomenon that shifted the rainfall patterns over different regions of Malaysia. Low water availability is the major environmental factor limiting growth, development, and the agricultural production of plants worldwide (Silva *et al*. 2013). An estimated one**-**third of the world's terrestrial area suffers from water stress, which is predicted to increase owing to global warming, enhancing the reduction in crop production in many key production regions (Tack *et al*. 2015).

Physiologically, several plant processes are negatively affected by water stress. These effects occur through osmotic stress and different biochemical responses in plants such as cell turgidity, stomatal conductance, transpiration, photosynthesis, respiration, antioxidant activity, and light absorption and capture, resulting in reduced crop production (Velázquez-Márquez *et al.* 2015). According to Chaves *et al.* (2002), the effects of low water availability on plant physiological processes are influenced by both the intensity and duration of the environmental stress as well as the genetic capacity of the genotype/species to cope with stress. The growth and development of plant depend on continued cell division and on progressive tissue differentiation and expansion until the characteristic form of the plant morphologies and physical structure of the plants developed. Plant growth and development involve plant water uptakes and translocations within the plant body.

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Plants growing in soil at field capacity soil moisture level could be under water stress.This phenomenon exists because plant water stress develops as a result of the excessive rate of water loss and an inadequate rate of absorption of water. In areas where water is limited and due to a reduction in land designated for rubber planting areas, the effects of water stress on the physiological and growth of rubber LTCs are of particular interest for the establishment of LTCs of rubber clone. To date, there are limited data which would allow the prediction of growth responses of this crop as a result of varying levels of water stress. Thus, the present study was carried out to evaluate the effect of water stress on rubber focusing mainly on responses to water frequencies under stimulated water stress environments.

Materials and Methods

The experiment was conducted at Field 2, University Putra Malaysia under a rain shelter house with the arched roof covered by ultraviolet (UV)-resistant clear or transparent polyethene (PE) film, 0.1 mm thick. Five LTCs seedlings (budded plant) aged 4 months (3 leaves whorls) used are LTCs RRIM 3001, 2025, 2001, 928 and PB350. The seedlings were grown in polybag size 20 × 20 inches and filled with 35 kg Munchong Series (Typic Hapludox/Haplic Ferralsol) soil. The soil moisture content was determined using water retention method (Teh and Jamal 2006) with the formula:

Wet basis (%) = $[W_d – D_d \text{ (g)} / W_d – D \text{ (g)}] \times 100$

Dry basis (%) = $[W_d – D_d \text{ (g)} / D_d – D \text{ (g)}] \times 100$ or $[W_b \text{ (\%)} / 100 – W_b \text{ (\%)}] \times 100$

Bulk density = $[D_w \text{ (g)} / R_v \text{ (cm}^3)$

% moisture content (w/w) = Dry basis (%)

% moisture content (v/v) = Dry basis (%) x Bd (gm/cm^3)

where, W_d = Wet weight of the soil with dish, D_d = Dry weight of the soil with dish, D = Dish weight, W_b = Wet basis moisture content, B_d = Bulk density, D_w = Dry weight of the soil R_v = Ring volume.

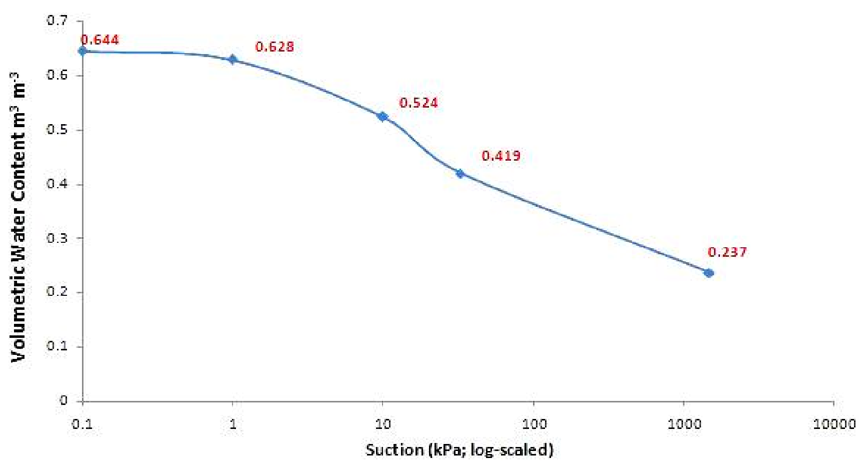

Fig. 1. Munchong series (Typic Hapludox/ Haplic Ferralsol) soil water retention curve.

Average dry basis (%) different pressure chamber suctions was plotted to the log scale chart with the volumetric water content (m^3 m^{-3}) on the y-axis and the soil suction on the x-axis at different pressure: 0, 1, 10, 33 and 1500 kPa (Fig. 1). Five watering frequencies were adopted as treatments (EW = Everyday watering, E2D = Every 2 days watering, E3D = Every 3 days watering, E5D = Every 5 days watering and E7D = Every 7 days watering) and subsequent recovery (Field capacity total volumetric water content 0.419 m^3 m^{-3}). The soil moisture was measured using portable soil moisture meter ECH_2O echo probe with echo check meter. The experiment was carried out until the seedlings reach the age of 12 months. Soil water requirement was calculated base on volumetric water content as follows:

$$[(\text{Field capacity} \times \text{height of soil}) - (\text{Current soil moisture} \times \text{height of soil})] \times [\text{Area}]$$

Morphological data such as vegetative growth consisting of plant height and girth circumference were measured in cm at 15 cm from the budding point. Plants were harvested at 4 and 8 months after treatments (MAT). The dry weight of plant stem, leaf and root was determined after drying to a constant weight at 80°C oven dried for 72 hrs and the plant biomass was determined using a weighing scale. Relative growth rates were calculated using the formula described by Gardner *et al.* (1990). Relative water content (RWC) was taken and calculated as described by González and González (2001).

Results and Discussion

Result of interaction between clone and watering frequencies are presented in Table 1. There was significant difference ($p \leq 0.01$) at 4 and 6 (MAT) of the plant growth as shown in plant height increment. RRIM 2025 produced the greatest plant height increment with everyday watering (EW) and every 2 days watering (E2D) compared to water stress treatment of E3D, E5D and E7D. This may be due to high photosynthesis rate and root moisture absorption rates (Mokhatar *et al.* 2011). Clone RRIM 3001 with EW treatment had higher plant height increment compared to the E2D treatment but similar result was found between the treatment E2D and E3D but higher than the treatments E5D and E7D (87.72 > 82.97 cm = 82.87 > 77.7 > 71.9 cm, respectively), at 6 (MAT). The result also showed that, RRIM 928 and RRIM 3001 with the treatment E5D had the highest plant height increment compared to the RRIM 2025, PB 350 and RRIM 2001. According to Nobel (2009) the actual water content in plant cells is changed by changing the types of cells and physiological conditions of plants and water uptake by plants is essential for cell expansion process which is an important element in the process of plant growth.

Result of interaction between clone and watering frequencies are presented in Table 2. There was significant difference between clones and watering interaction ($p \leq 0.01$) on plant girth circumference at 2 (MAT). The result found that at 2 (MAT) imposed, RRIM 3001 with EW had bigger plant girth than the treatment E2D and E5D. Also at 8 (MAT), clone RRIM 3001 showed largest plant girth than RRIM 2005, RRIM 2001, RRIM 928 and PB 350. This could have been due to the quality of the clone among the latest clones with better interaction with soil and water treatment. A similar result was reported by Salisu *et al.* (2013). Noticeably, RRIM 928 with the treatment EW had bigger plant girth than the treatment E7D. This indicated that the clone could perform optimally when well watered EW (Rodrigues *et al.* 1995).

There was a significant interaction between various *H. brasiliensis* LTCs affected with different watering frequencies at 8 (MAT) ($p \leq 0.001$). The highest total plant biomass was recorded from RRIM 3001 with everyday watering (EW) and every 2 days watering (E2D) compared to other clones as shown in Table 3. The critical time for the recovery of photosynthesis was recognized and this aided plant growth and another biomass yield as shown in the total plant biomass of the clone RRIM 3001. Highest total plant biomass reported at 8 (MAT) was imposed. This was obvious in RRIM 3001 with everyday watering (EW) and every 2 days watering (E2D) compared to other clones. This was similar to the result of a study conducted by Pandey *et al.* (2000).

Table 1. Effect of watering frequencies and rubber clones on plant height increment.

Clones	Watering frequencies	Plant height increments (cm)			
		2 Months	4 Months	6 Months	8 Months
RRIM 3001	EW	24.12 ± 2.78abc	51.22 ± 0.65abc	87.72 ± 2.45a	119.57 ± 2.58ab
	E2D	23.85 ± 2.59abc	50.72 ± 0.89abcd	82.97 ±1.66bcd	118.30 ± 3.54abcd
	E3D	17.50 ± 2.50defgh	50.25 ± 0.48abcd	82.87 ± 0.85bcd	115.55 ± 0.61bcdefg
	E5D	11.80 ± 1.70hijk	43.67 ± 0.78fgh	77.77 ±1.87efg	110.45 ± 1.46gh
	E7D	11.80 ±1.79hijk	44.77 ± 1.08fg	71.95 ±1.76hij	111.00 ± 0.93gh
RRIM 2025	EW	26.40 ±2.34a	53.77 ± 1.15a	86.75 ± 0.98ab	117.50 ± 1.11abcde
	E2D	21.20 ± 2.73abcdef	51.85 ± 1.97ab	84.97 ± 1.61abc	116.82 ± 1.14abcdef
	E3D	15.00 ± 2.88fghij	45.82 ± 1.88efg	79.22 ± 1.67def	111.50 ± 1.08fgh
	E5D	15.62 ± 1.51efghi	44.05 ±1.21fgh	71.00 ± 1.23ij	108.27 ± 1.89hi
	E7D	13.22 ± 1.54ghijk	47.22 ± 2.29cdef	76.27 ± 1.67fgh	108.37 ± 1.01hi
RRIM 2001	EW	19.67 ±1.88bcdef	52.92 ± 1.34ab	83.10 ± 1.00bcd	115.42 ± 0.67bcdefg
	E2D	24.62 ± 0.79ab	52.40 ± 0.88ab	86.32 ± 0.77ab	118.62 ± 3.61abcd
	E3D	16.27 ± 2.17efghi	45.27 ± 1.35efg	77.70 ± 1.97efg	111.80 ±1.62efgh
	E5D	15.70 ± 0.95efghi	46.90 ± 0.49def	73.87 ± 0.46ghi	111.45 ± 1.13fgh
	E7D	9.00 ± 0.80jk	40.15 ± 1.24hi	68.77 ± 1.78j	103.70 ± 0.74ij
RRIM 928	EW	25.45 ± 4.22ab	51.77 ± 2.23abcd	84.25 ± 2.61abc	118.97 ± 1.92abcd
	E2D	21.62 ±1.80abcde	53.55 ±1.63a	84.60 ± 0.34abc	121.47 ± 3.42a
	E3D	20.55 ± 0.51abcdef	46.92 ± 1.18def	79.22 ±0.68def	114.77 ± 1.14bcdefg
	E5D	15.62 ±1.80efghi	47.12 ± 1.77def	78.05 ± 1.97efg	113.42 ± 2.63defgh
	E7D	8.57 ±1.58k	38.97 ± 0.76i	69.20 ± 1.31j	99.57 ± 2.17j
PB 350	EW	23.55 ± 3.53abcd	52.05 ± 0.95ab	84.30 ± 0.70abc	118.02 ± 1.65abcd
	E2D	23.95 ± 1.55abc	51.67 ± 1.82ab	84.10 ± 1.41abc	119.30 ± 2.38abc
	E3D	18.30 ± 3.19cdefg	48.97 ± 1.91bcde	81.45 ± 2.48cde	113.70 ± 2.79cdefgh
	E5D	8.87 ± 2.03jk	42.25 ± 0.60ghi	70.00 ± 0.83ij	108.15 ± 2.69hi
	E7D	10.10 ± 0.81ijk	42.35 ± 2.32ghi	69.97 ±1.15ij	103.77 ±1.42ij

Source	F value (Approx. Pr > F)			
	2 Months	4 Months	6 Months	8 Months
Clones	0.46 (0.7668)	0.50 (0.7322)	2.81 (0.0318)	1.54 (0.1985)
Watering	34.80 (< 0.0001)	44.02 (< 0.0001)	81.83 (< 0.0001)	37.16 (<0 .0001)
Clones × watering	1.27 (0.2430)	2.54 (0.0037)	2.75 (0.0018)	1.60 (0.0915)

Mean ± SE (n = 4) and F-test non-significant or significant at $p < 0.05$, 0.01 or 0.001, respectively. Values followed by the same letter within each vertical column (a, b, c) are not significantly different with the least significant level of 5% (LSD).

Table 2. Effect of watering frequencies and rubber clones on plant girth circumference.

Clones	Watering frequencies	Plant Girth Circumference (cm)			
		2 Months	4 Months	6 Months	8 Months
RRIM 3001	EW	2.40 ± 0.07a	4.17 ± 0.11abc	6.82 ± 0.34ab	8.37 ± 0.11ab
	E2D	2.00 ± 0.36bcd	4.27 ± 0.16ab	6.97 ± 0.23a	8.75 ± 0.06a
	E3D	1.62 ± 0.11defghij	3.50 ± 0.21e	4.57 ± 0.23d	7.30 ± 0.17def
	E5D	1.40 ± 0.14hijk	3.37 ± 0.22ef	4.20 ± 0.26de	6.77 ± 0.17fgh
	E7D	1.27 ± 0.17jk	2.35 ± 0.15i	3.32 ± 0.16fg	6.55 ± 0.18ij
RRIM 2025	EW	1.95 ± 0.24cde	4.15 ± 0.22abc	6.82 ± 0.38ab	8.15 ± 0.15bc
	E2D	1.80 ± 0.07cdefg	4.15 ± 0.11abc	6.27 ± 0.36bc	7.95 ± 0.15bc
	E3D	1.82 ± 0.13cdefg	3.82 ± 0.23bcde	4.40 ± 0.26de	6.85 ± 0.32efgh
	E5D	1.57 ± 0.08efghij	3.52 ± 0.17e	4.35 ± 0.09de	6.82 ± 0.13efgh
	E7D	1.47 ± 0.10ghijk	2.40 ± 0.08hi	3.45 ± 0.08fg	6.17 ± 0.18hi
RRIM 2001	EW	1.75 ± 0.15cdefgh	4.15 ± 0.05abc	6.95 ± 0.39a	8.17 ± 0.23b
	E2D	2.02 ± 0.02abc	4.45 ± 0.16a	6.02 ± 0.04c	8.02 ± 0.13bc
	E3D	1.77 ± 0.07cdefgh	3.55 ± 0.05e	4.67 ± 0.04d	6.75 ± 0.19fgh
	E5D	1.65 ± 0.15cdefghij	3.52 ± 0.17e	4.10 ± 0.16de	6.50 ± 0.23ghi
	E7D	1.57 ± 0.10efghij	2.35 ± 0.14i	3.35 ± 0.11fg	5.72 ± 0.18jk
RRIM 928	EW	1.87 ± 0.10cdef	4.17 ± 0.08abc	6.02 ± 0.21c	7.60 ± 0.31cd
	E2D	1.62 ± 0.13defghij	4.02 ± 0.13abcd	5.90 ± 0.04c	7.37 ± 0.07de
	E3D	1.87 ± 0.04cdef	3.75 ± 0.15cdef	4.55 ± 0.02d	6.97 ± 0.13efg
	E5D	1.67 ± 0.08cdefghi	3.02 ± 0.16fg	4.15 ± 0.12de	6.37 ± 0.19hi
	E7D	1.47 ± 0.14ghijk	2.20 ± 0.17i	3.05 ± 0.19g	5.32 ± 0.17jk
PB 350	EW	2.37 ± 0.075ab	4.20 ± 0.14abc	6.97 ± 0.38a	8.05 ± 0.25bc
	E2D	1.75 ± 0.05cdefgh	4.25 ± 0.20ab	6.50 ± 0.21abc	7.95 ± 0.15bc
	E3D	1.32 ± 0.13ijk	3.62 ± 0.13de	4.62 ± 0.13d	7.05 ± 0.22defg
	E5D	1.50 ± 0.12fghijk	2.82 ± 0.07gh	3.82 ± 0.11ef	6.55 ± 0.18ghi
	E7D	1.12 ± 0.11k	2.05 ± 0.20i	3.15 ± 0.21g	6.05 ± 0.32ij
Source		F value (Approx. Pr > F)			
		2 Months	4 Months	6 Months	8 Months
Clones		0.78 (0.5406)	1.92 (0.1158)	2.72 (0.0359)	11.31 (<.0001)
Watering		17.67 (<0.0001)	125.27 (<0.0001)	222.01(<0.0001)	107.36 (<0.0001)
Clones × watering		2.54 (0.0038)	1.11 (0.3595)	1.42 (0.1593)	1.18 (0.3058)

Mean ± SE (n=4) and F-test non-significant or significant at, $p < 0.05$, 0.01 or 0.001, respectively. Values followed by the same letter within each vertical column (a, b, c) are not significantly different with the least significant level of 5% (LSD).

Table 3. Effect of watering frequencies on total plant biomass of selected rubber clones.

Clones	Watering frequencies	Total biomass (g/tree)	
		4 Months	8 Months
RRIM 3001	EW	820.25 ± 6.97a	2539.50 ± 29.35a
	E2D	837.50 ± 29.56a	2613.50 ± 92.72a
	E3D	725.25 ± 10.28b	1892.50 ± 114.69ef
	E5D	709.25 ± 6.45b	1518.50 ± 23.21ij
	E7D	664.50 ± 2.63de	1513.00 ± 31.11ij
RRIM 2025	EW	809.00 ± 5.73a	2330.75 ± 61.30b
	E2D	807.50 ± 9.74a	2346.25 ± 41.56b
	E3D	703.00 ± 8.12bc	1614.00 ± 73.34hi
	E5D	685.25 ± 7.19bcd	1501.25 ± 26.29ij
	E7D	640.50 ± 12.02e	1475.50 ± 26.62ij
RRIM 2001	EW	791.00 ± 1.47a	2072.75 ± 67.45cd
	E2D	802.00 ± 8.28a	2234.75 ± 46.71bc
	E3D	715.75 ± 4.15bc	1593.75 ± 49.06hi
	E5D	681.75 ± 3.92cde	1522.00 ± 47.52ij
	E7D	639.75 ± 7.46de	1445.00 ± 81.52ij
RRIM 928	EW	805.75 ± 18.31a	2038.50 ± 94.76de
	E2D	796.00 ± 2.16a	2054.50 ± 58.45de
	E3D	692.75 ± 6.62cde	1699.00 ± 81.43gh
	E5D	691.75 ± 3.14cd	1494.75 ± 23.32ij
	E7D	650.75 ± 2.78de	1396.25 ± 52.41j
PB 350	EW	824.50 ± 4.09a	2286.00 ± 18.76b
	E2D	805.25 ± 8.48a	2274.50 ± 70.57b
	E3D	699.00 ± 21.67cde	1835.00 ± 46.60fg
	E5D	674.00 ± 17.36de	1535.25 ± 37.98hij
	E7D	651.25 ± 4.68cde	1422.75 ± 58.83j

Source		F value (Approx. Pr > F)	
		4 Months	8 Months
Clones		4.63 (0.0022)	16.07 (< 0.0001)
Watering		227.64 (< 0.0001)	227.07 (< 0.0001)
Clones × Watering		0.72 (0.7633)	3.12 (0.0005)

Mean ± SE (n = 4) and F test non-significant or significant at, $p < 0.05$, 0.01 or 0.001, respectively. Values followed by the same letter within each vertical column (a,b,c) are not significantly different with the least significant level of 5% (LSD).

Effects of watering frequencies with various LTCs on plant relative growth rate (RGR) are presented in Table 4. There was a significant interaction between clones and watering frequencies on plant relative growth rate ($p \leq 0.05$). The RRIM 3001 recorded the highest mean of PGR 0.2845 g/g compared to other clones. Low RGR values also have a low biomass production and highest values of biomass production produce an average RGR (Erice *et al.* 2010). Watering frequencies had highly significant effects ($p \leq 0.0001$) on plant relative water content at 8 (MAT) as shown in Table 5.

Table 4. Effect of watering frequencies on plant relative growth rate (g/g) on rubber clones.

	Relative growth rate (g/g)				
Clones	EW	E2D	E3D	E5D	E7D
RRIM 3001	0.2825 ± 0.0039ab	0.2845 ± 0.0104a	0.2383 ± 0.0159efg	0.1903 ± 0.0046j	0.2055 ± 0.0044ij
RRIM 2025	0.2645 ± 0.0076abcd	0.2665 ± 0.0067abc	0.2073 ± 0.0099hij	0.1960 ± 0.0041j	0.2085 ± 0.0079hij
RRIM 2001	0.2405 ± 0.0078defg	0.2563 ± 0.0065cdef	0.1998 ± 0.0075ij	0.2005 ± 0.0092ij	0.2025 ± 0.0131ij
RRIM 928	0.2318 ± 0.0117fgh	0.2368 ± 0.0070efg	0.2235 ± 0.0137ghi	0.1928 ± 0.0039j	0.1905 ± 0.0085j
PB 350	0.2550 ± 0.0011cdef	0.2595 ± 0.0087bcde	0.2418 ± 0.0089defg	0.2060 ± 0.0089ij	0.1948 ± 0.0102j
Source		F value (Approx. Pr > F)			
Clones		6.43 (0.0002)			
Watering		58.46 (<.0001)			
Clones × watering		2.15 (0.0148)			

Mean ± SE (n = 4) and F-test non-significant or significant at $p < 0.05$, 0.01 or 0.001, respectively. Values followed by the same letter within each vertical column (a, b, c) are not significantly different with the least significant level of 5% (LSD).

Table 5. Effect of watering frequencies on plant relative water content in rubber clones.

Clones	Relative water content (%)				
	EW	E2D	E3D	E5D	E7D
RRIM 3001	89.24 ±1.31a	86.85 ±0.68ab	84.33 ±1.73bcdefg	82.67 ±1.56cdefgh	81.68 ±2.46efgh
RRIM 2025	87.42 ±0.31ab	85.73 ±1.32abcd	81.45 ±0.88fgh	84.58 ±0.96bcdef	81.39 ±1.04fgh
RRIM 2001	86.59 ±0.74ab	85.61 ±2.21abcd	82.19 ±2.34cdefgh	80.07 ±0.83h	80.70 ±2.53gh
RRIM 928	86.63 ±0.45ab	86.62 ±1.23ab	82.58 ±1.34cdefgh	82.36 ±1.16cdefgh	81.94 ±0.90defgh
PB 350	85.95 ±1.03abc	85.46 ±1.97abcde	84.94 ±1.93bcdef	82.42 ±1.06cdefgh	81.49 ±1.57fgh
Source			F value (Approx. Pr > F)		
Clones			1.26 (0.2942)		
Watering			16.38 (0.0001)		
Clones × watering			0.63 0.8471		

Mean ± SE (n = 4) and F-test non-significant or significant at, $p < 0.05$, 0.01 or 0.001, respectively. Values followed by the same letter within each vertical column (a, b, c) are not significantly different with the least significant level of 5% (LSD).

Clones showed significant difference ($p \leq 0.01$) on total plant biomass at 4 and 8 (MAT) ($p \leq 0.0001$), respectively. Merine *et al.* (2015) mentioned that, watering frequency could have a significant effect on overall total plant biomass including the stem dry weight. Interestingly, Xu *et al.* (2015) observed that plant biomass could increase under drought stress of some plant species. Manzi *et al.* (2015) observed that, root could survive under long-term water stress due to the activities of the root aerial organs. Availability of nutrient like N could equally have a significant impact of plant biomass yield noticeable in leaf dry biomass (Ashraf *et al.* 2017).

The aforesaid results obviously show the effect of watering frequencies at EW and E2D had a profound effect on the plant biomass at 4 and 8 (MAT) and relative growth rate at 8 (MAT). The water frequencies are equally considered suitable for all the clones used in the study. The effect was noticeable on the RRIM 3001 and the effect of the different watering frequencies was profoundly showed on its total plant biomass at 4 and 8 (MAT) of watering frequencies compared to the other four clones. Consequently, the water frequencies EW and E2D and RRIM 3001 could be considered the most suitable for latex timber production and water management in the rubber plantation industry, specially for the replanting exercise.

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