

Evaluation of *Hevea brasiliensis* (Latex Timber Clone: RRIM 2001 and RRIM 3001) in Relation to Different Water Stress

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Abstract: Problem statement: Rubber, *Hevea brasiliensis*, has been traditionally planted in the humid tropics, which is characterized by high rainfall throughout the year. However, due to an increase in world's demand for rubber, future planting will be established in dry areas, characterized by prevalence water stress. Utilizing limited resource, in dry areas or to use water wisely is very important. This study provides a detail evaluation of morphological and physiological responses of rubber trees at nursery stage in relation to different water stress. **Approach:** Two new latex timber clones from Malaysia Rubber Board (MRB), RRIM 2001 and RRIM 3001 were used in this study. Five levels of treatment were used; plants irrigated for every two days, five days, 10 days, 15days and everyday which acted as control. The experimental design used was a Completely Randomized Block Design (RCBD) with four replications. **Results:** Fundamental changes of plant growth and physiological responses showed that treatment with well watered for clone RRIM 2001 (T1) had higher values than other treatments. Harvest index highest in well watered (T1) with mean 20.73, while T5 were lowest with the mean 5.03. Stomata conductance showed significant difference between T6 with $0.161 \mu\text{mol m}^{-2}\text{s}^{-1}$ compared to under stress treatments with $0.00 \mu\text{mol m}^{-2}\text{s}^{-1}$. There was treatment failure to adapt to water stress at treatments withholding water for 15days followed by treatments 10days and five days. **Conclusion:** RRIM 2001 and RRIM 3001 clones had responded to water stress by indicating changes in morphological and physiological responses. This indicated that *Hevea brasiliensis* cannot withstand water stress.

Keywords: Rubber, *Hevea brasiliensis*, Latex Timber Clones (LTC), water stress, growth, physiological responses, Completely Randomized Block Design (RCBD)

INTRODUCTION

Hevea brasiliensis, originated from Brazil have been widely planted in South East Asia. Nowadays, the usage of rubber has become more increasingly important in daily life. This scenario has triggered rubber planting to be shifted to marginal areas, such as dry areas (Noordin, 2009). Water has been a very important resource to agriculture since the issues of global warming and climate change arise. Water is scarce and its quality is decreasing in many parts of the world (Gholizadeh *et al.*, 2010; Fuller and Harhay, 2010; Raviv and Blom, 2001). Pertaining to water as an invaluable resource, there is a need to use this source wisely. Water deficit stress can be defined as a situation in which plant water potential and turgor are reduced to interface with normal functions (Shao *et al.*, 2008). Plant water status is also affected by reducing of water availability in plant. More than that, water stress influences plant growth at various levels, including cell

community (Al-Taisan, 2010; Blumwald *et al.*, 2004; Colom and Vazzana, 2001). The quantity and quality of plant growth depend on cell division enlargement and differentiation and all of these events are affected by water stress (Cabuslay *et al.*, 2002; Correia *et al.*, 2001). It also reduced plant growth inhibition of various physiological and biochemical processes such as photosynthesis, respiration translocation, ion uptake, carbohydrate, nutrients metabolism and hormone (Bhatt and Srinivasa, 2005; Chaitanya *et al.*, 2003; Blum, 1996).

Latex Timber Clones (LTC) are clones with high latex yield and rubberwood production. They exhibit good growth, good growth vigour and possess long straight boles. These clones are suitable for the production of latex and rubberwood or production of rubberwood (Malaysian Rubber Board, 2009). The parental of clone RRIM 2001 is RRIM 600 x PB 260. The laminae is elliptical obovate. Color of foliage is light green, semi glossy and smooth. Clone RRIM 3001 has an elliptical shape. The color of foliage is dark

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shining green. Both clone are recommended for both latex and timber production (Malaysian Rubber Board, 2009).

Soil from Munchong series are widely planted with rubber in Malaysia. The Munchong series soil is suitable for rubber plants and it has been classified as first class soil for rubber in term of soil-crop suitability (Malaysian Rubber Board, 2009). Different types of soil influences the growth performance of the crop (Heryati *et al.*, 2010). Munchong series soil is silty clay loam to silty clay with yellowish brown to strong brown. The structure of this soil series is moderate to strong fine and medium sub-angular blocky. In term of USDA soil taxonomy, Munchong Series has been classified as very fine, Typic Hapludox. In the FAO/UNESCO Legend, this soil has been classified as Haplic Ferrasol (Ogos, 1993).

MATERIALS AND METHODS

Plant materials and experimental treatments: This study was carried out under rain shelter, Field 2 at Universiti Putra Malaysia, Serdang, Selangor, Malaysia. The source of rubber clone was from Malaysia Rubber Board (MRB) and consists of three month rootstock from clone RRIM 2001 and RRIM 3001. The plants were selected according to the average height and girth. Polythene bags size used was 40 cm x 45 cm which can withhold the planting media up to 10kg. The media used was Munchong soil series. Sources of fertilizer are RISDA 1 fertilizer consisting of 10% N, 16% P, 9% K and 2.5% Mg. RISDA 1 is recommended by Rubber Industry Smallholders Development Authority for young rubber. Study about fertilizer on Latex Timber Clones has proved rubber plants will scorched and dead if overfertilized (Mokhatar and Daud, 2011).

Treatments 1 to 5 (T1 until T5) were from RRIM 2001, while treatments 6 to 10 (T6 until T10) were from RRIM 3001. For water stress treatments, various water frequencies by varying number of days was applied. Treatments comprised the control as well watered (T1 and T6), withholding water for two days (T2 and T7), withholding water for five days (T3 and T8), withholding water for 10days (T4 and T9) and withholding water for 15days (T5 and T10).

Water requirement determination: water requirement was determined by measuring water retention of the soil using a pressure chamber and the pressure plate. A core ring measuring about 7.6 and 4.0cm in diameter and depth, respectively and having known weight was hammered into the soil to ring depth. The samples

retaining rings placed on each of the four porous plates for 1, 10, 33 and 1500 kPa pressure. The core (undisturbed) sample was broken up into five pieces of equal sizes. One piece of sample in retaining ring was placed on each of the porous plates. For the 0 bar pressure (saturation), the samples is placed in a retaining ring on a coarse wire mesh. All ceramic plates were saturated for 24 hours by keeping the water level just below the edge of the ring. The plate with samples was placed inside the corresponding pressure chamber. The plate was connected to the outflow tube. The chamber was closed and pressure applied. Equilibrium was attained when no more outflows occurs. A period of 4-7 days is usually sufficient to achieve moist soil. The chamber opened, the samples removed and each of them was weighed (W_a). The sample oven-dried at 105°C for 24hours and each of the soil samples weighed again (W_b). The calculation for volumetric water content was: (m^3m^{-3}) , $\theta_v = (W_a - W_b) / W_b \times \rho_b$, where ρ_b =bulk density, W_a =dry weight, W_b =oven dried sample after dry weight.

Data collection: Height: plant height was measured from the soil level until the top of the plant shoot.

Girth: girth circumference was measured 10 cm from the soil level.

Dry weight: The leaf, stem and root were cut and placed in the 'Hot Air Oven' at 60°C for 48-72 hours. After that, the weights were determined using a weighing machine.

Harvest index: The harvest index is the ratio of economical yield to the biological yield and biological yield includes root weight (Gardner *et al.*, 1985) The calculation was; Harvest index, (HI) = Economical yield/Biological yield x 100.

Leaf area: Leaf area was measured by using the LI-3100 Area meter. The total leaves collected were measured for their total leaf area. **Photosynthesis rate:** The rate of photosynthesis had been measured by Portable Photosynthesis System Model LICOR-6200. The fully expanded leaves were selected to measure the photosynthesis rate.

Experimental design and data analysis: The study was conducted in a completely randomized block design with four replications. Each block comprised of 30 plants and each treatment consists of three samples (polythene bags). There were two clones consisting of five treatments per clone. Analysis Of Variance (ANOVA) on data obtained was performed using

Statistical Analysis System (SAS 9.1, SAS Institute, Inc. Cary NC. USA). Least Significant Different (LSD) test at $p < 0.05$ was employed for mean comparison.

RESULTS

Water requirement: Figure 1 shows moisture content at saturation (0.1kPa), field capacity (33kPa) and permanent wilting points (1500kPa) for sample are 0.365, 0.255 and 0.205 $m^3 m^{-3}$ respectively. The available water content for plant use is the difference between field capacity and permanent wilting point. The available water content for plant used was $0.255 - 0.205 = 0.05 m^3 m^{-3}$. The amount of water used for 10kg of Munchong soil series in this study is 0.5L.

Growth responses: Differences in water stress affected the growth response of *Hevea brasiliensis* (Table 1). These results showed that the plants gave positive responses when they were provided with enough water, while the plant growth were inhibited, the plants were stunted and dead under severe water stress condition.

Table 1: Growth responses of *Hevea brasiliensis* under water stress condition

Treatment	height (cm)	girth (cm)	Total leaf area (cm ²)	
RRIM 2001 well watered (T1)	68.33a		2.30a	1358.6a
RRIM 2001 withholding water for two days (T2)		62.10ab	2.03b	639.2bc
RRIM 2001 withholding water for five days (T3)		60.00ab	2.10ab	171.9d
RRIM 2001 withholding water for 10days (T4)		0.00c	0.00d	0.0d
RRIM 2001 withholding water for 15days (T5)		0.00c	0.00d	0.0d
RRIM 3001 well watered (T6)	60.33ab	2.13a		896.8b
RRIM 3001 withholding water for two days (T7)	57.67b	2.03b		724.8bc
RRIM 3001 withholding water for five days (T8)	58.67b	1.70c		400.5cd
RRIM 3001 withholding water for 10days (T9)		0.00c	0.00d	0.00d
RRIM 3001 withholding water for 15days (T10)		0.00c	0.00d	49.5d
LSD _{0.05}	9.60	0.19		411.85

Values in each column with same letter did not differ significantly at $p < 0.05$ according to LSD

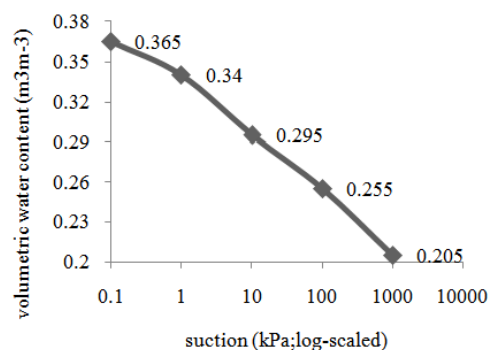


Fig. 1: Soil water retention curve

Table 2: Dry matter productions of *Hevea brasiliensis* under water stress condition

Treatment	Leaf dry weight (g)	Stem dry weight (g)	Root dry weight (g)	Total dry weight (g)	
RRIM 2001 well watered (T1)	5.73ab		8.39a	25.42ab	39.54a
RRIM 2001 withholding water for two days (T2)		4.87b	4.17b	13.97cde	23.00bc
RRIM 2001 withholding water for five days (T3)	0.53d	4.10b	18.67cd		23.30bc
RRIM 2001 withholding water for 10days (T4)	0.00d	0.95d	17.5cde		18.45c
RRIM 2001 withholding water for 15days (T5)	0.00d	1.23cd	19.45bc		20.68bc
RRIM 3001 well watered (T6)	6.53a	6.00ab	26.00a		38.53a
RRIM 3001 withholding water for two days (T7)	5.05b	4.48b	20.16ab		29.70b
RRIM 3001 withholding water for five days (T8)	2.74c	3.77b	13.00de		19.50c
RRIM 3001 withholding water for 10days (T9)	0.00d	0.97d	15.56cde		16.53c
RRIM 3001 withholding water for 15days (T10)	0.81d	3.24bcd	12.13e		16.19c
LSD _{0.05}	1.40	2.77	6.28		7.12

Values in each column with same letter did not differ significantly at $p < 0.05$ according to LSD

Table 2 showed that well watered (T1) gave the highest means, while treatment withholding water for 15days (T10) were under stressed showed slightly lower mean. From this data, T1 and T6 gave the higher values of total dry weight which means the plant growth steadily according to leaf, stem and root dry weight.

Figure 2 showed that well watered treatment (T1) gave the highest mean of harvest index among

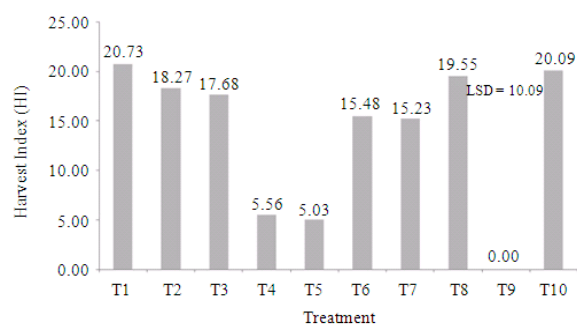


Fig. 2: Effect of water stress on Harvest Index (HI)

Table 3: Physiological responses of *Hevea brasiliensis* under water stress condition

Treatment	Photosynthesis rate ($\mu\text{mol m}^{-2}\text{s}^{-1}$)	Stomata conductance ($\mu\text{mol m}^{-2}\text{s}^{-1}$)
RRIM 2001 well watered (T1)	3.89b	0.11ab
RRIM 2001 withholding water for two days (T2)	2.06b	0.03bc
RRIM 2001 withholding water for five days (T3)	1.06b	0.05ab
RRIM 2001 withholding water for 10days (T4)	0.00b	0.00c
RRIM 2001 withholding water for 15days (T5)	0.00b	0.00c
RRIM 3001 well watered (T6)	11.26a	0.16a
RRIM 3001 withholding water for two days (T7)	4.07b	0.05ab
RRIM 3001 withholding water for five days (T8)	1.69b	0.02c
RRIM 3001 withholding water for 10days (T9)	0.00b	0.00c
RRIM 3001 withholding water for 15days (T10)	0.35b	0.00c
LSD _{0.05}	5.71	0.09

Values in each column with same letter did not differ significantly at $p < 0.05$ according to LSD

treatments with the mean 20.73, while T5 (withholding water for 15days) with the mean 5.03 was the lowest.

Physiological responses: Photosynthesis rate of well watered plants showed that T6 from clone RRIM 3001 were significantly higher than T1 (RRIM 2001).

From Table 3, the highest mean of stomata conductance among treatments was T6 (well watered) with the mean $0.161 \mu\text{mol m}^{-2}\text{s}^{-1}$, while the lowest mean was T4, T5 and T9 with $0.00 \mu\text{mol m}^{-2}\text{s}^{-1}$. The

leaves were falling and became chlorosis after 2 weeks of treatments for T4, T5 and T9.

DISCUSSION

Growth responses: The previous study about *Abelmoschus esculentus* under water stress has showed decline in the cell enlargement and more leaf senescence. These prove that water stress was a very important limiting factor at the initial phase of plant growth (Shao *et al.*, 2008). Water stress also results in reduction of leaf area, where the leaf growths were inhibited and the older leaves fell down (Anyia and Herzog, 2004). Reduction of expansion of young leaves and loss of older leaves caused a decreased in the LAR in the stressed plants (Paknejad *et al.*, 2009).

The stem dry weight reduced with increasing of water stress because of girth circumference reduction and plant death. Water stress condition affected the plant dry matter translocation, which occurred in the photosynthesis process. The allocation of dry matter will be enhanced to the root, to enhance water uptake for survival under drought stress (Leport *et al.*, 2006). The limitation of the size of the source and sink tissue were not only effects from drought stress, the other phenomenon such as the phloem loading, assimilates translocation and dry matter partitioning was also impaired by drought stress (Haghighi *et al.*, 2010).

The results indicated that harvest index and the end products of photosynthesis decreased under water stress condition. Other study on peanut with several soil water levels also gave the same results on harvest index (Songsri *et al.*, 2009).

Physiological responses: Photosynthesis process was inhibited when the water was not enough to translocate sucrose and hexose to the leaves as a sink and this was showed by the lowest value in the Table 3. Under water stress condition, photosynthesis pigments and compounds changed (Anjum *et al.*, 2003), apparatus damaged (Fu and Huang, 2001) and activities of enzymes in Calvin cycle also diminished, which lead to reduction in crop yield.

Internal water deficits results reduction of stomata conductance (Zhao *et al.*, 2010). This was caused by root volumes restrictions rather than a general shortage of soil moisture level. Oxygen levels limitation might also trigger the root to shoot signal via chemical means.

CONCLUSION

From the results, it can be concluded that the two clones of rubber, RRIM 2001 and RRIM 3001 had

responded to water stress by indicating changes in morphological and physiological responses. The changes in those aspects showed that treatment with well watered procedure for clone RRIM 2001(T1) had high values than other treatments. In water deficit condition, plant growth, photosynthesis rate and dry matter production were reduced. The results also showed that rubber plant cannot withstand water stress and dry areas.

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