EVALUATION OF DIFFERENT DROUGHT STRESS PERIODS ON *HEVEA BRASILIENSIS* GROWN IN ULTISOLS OF SOUTH EASTERN NIGEREIA AT NURSERY STAGE

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ABSTRACT

As global demand for natural rubber increases, a major challenge for cultivation of rubber plants is their inability to withstand unfavorable environmental conditions in the context of global climate change. Drought remains one of the most biologically demanding and ecologically limiting factors among all environmental constraints. Drought stress can occur at any stage of the growing process, and cause complete loss of crops or serious damage to yield. Field experiments were conducted on the evaluation of different drought stress periods on natural rubber *(Hevea brasiliensis)* at the Research Farm of National Root Crops Research Institute, (NRCRI) Umudike, South Eastern Nigeria during the 2012 and 2013 cropping season to screen 10 genotypes of rubber seedlings collected from Rubber Research Institute of Nigeria for tolerant to drought conditions, to select tolerant genotypes for development of new clones of natural rubber and to study the relationships between drought tolerant genotypes. The experiments were laid out in a Randomized Complete Block Design (RCBD) in the field using three replications. Thirty rubber seedlings per plot were transplanted from pre-nursery to the main nursery at the spacing of 100 x 30 cm on a well prepared bed. Results obtained in the field over the two years indicated that variations existed in the level of drought tolerance among the genotypes. For agronomic traits, all the traits showed significant differences ($P<0.05$) among the genotypes. Nig 804, RRIM 600 and GT1 recorded the fastest growth after exposure to 40 days of drought stress while Nig 800, PB5/51 and RRIM 628 recorded the least plant growth across the drought stress periods especially after 40 days of subjection to drought stress and the same trend was also observed in the number of leaves and plant girth recorded among the genotypes in both years. GT1, RRIM 600, PR107 and Nig 804 showed more tolerance to drought conditions from 0 to 40days than the other genotypes and PB5/51, RRIM 628 and Nig 800 were found to be more susceptible to drought when compared with the other genotypes in the field. Life saving irrigation may become an essential farm practice for the survival of these genotypes in the nursery as well as in the field during the dry seasons or periods of drought.

Key words: *Hevea* genotypes and drought stress periods

INTRODUCTION

Natural rubber tree (*Hevea brasiliensis*), is a plant of the genus *Hevea* (*Euphorbiaceae* family). It originated from the Amazon rainforest of Brazil in South America. Natural rubber was known by native Indians and was discovered by Christopher Columbus in South America about 1493. It was first defined by Austin Coate in 1500 as milk like juice found in the back of *Hevea* tree that becomes golden brown and thicker on exposure to air. He called the tree CAOUTCHOUC (weeping wood) (Ogowewo, 1986). *Hevea brasiliensis* is cultivated in the north equatorial region between 15^0 N and 15^0 S. Malaysia, Indonesia and Sri Lanka each produce more than 1 million tons per annum. The world production is about 5 million tons per annum. In 1994 Africa produced about 0.3m tons of dry rubber per annum. It is produced in Cote, d' Ivore, Nigeria, Liberia, little in Cameroun, Ghana and Guinea.

Rubber tree is a tall erect tree, with straight trunk which is covered with smooth, light grey back 6-15cm thick. The tree has deep taproots with lateral roots of 7-10m long. It has slender branches from an open leafy crown with spirally arranged trifoliate leaves (Duta, 1979). Eleven species of the genus *Hevea* have been documented (Zenghua, 1984) out of which *Hevea brasiliensis* (Muell Arg) is the major source of natural rubber because of its superior latex yield. *Hevea brasiliensis* is a quick growing tree rarely exceeding 25m in height, but wild trees of over 40m have been recorded. Rubber is successfully cultivated under humid lowland tropical conditions. In high rainfall areas, good drainage of the soil is important. Rubber can be propagated through seed. The economic lifespan of natural rubber plantation is 30-35years after which replanting is advised (Delabarre *et al.,* 2000).

Hevea brasiliensis was introduced to Nigeria in the late 18^{th} century. In Nigeria two (2) species of rubber do exist. These are *Hevea brasiliensis* Muell Arg and *Funtumia elastica*. The former was introduced to the country while the latter is indigenous to Nigeria. *Hevea brasiliensis* is grown in commercial plantation for production of latex. In terms of quantity and quality of latex yield *Hevea brasiliences* is superior to the *funtumia elastica*. The success of the tree in Nigeria during the last century is largely due to the fact that it has been free from introduced disease (Begho, 1999). The name rubber was given to *Hevea brasiliensis* by Priestly in the year 1770. The rubber tree is a native of the Amazonian rainforest of South America. It is a tropical crop that survives between 15^0N and 10^0S of the equator, where the climax vegetation is lowland tropical forest and the climate is hot and humid with temperature range of $25\text{-}30^0$c with a well distributed rainfall of 1800-2000mm per year. The crop does not perform well if there is a long dry season. It also does badly if the climate is excessively humid, as this encourages leaf diseases. The rubber tree can tolerate a wide range of soil conditions from sandy to loamy soils provided the soils are deep, fertile, well drained and slightly acidic with a soil p^H of 4-6 or 4-8. The rubber tree is a perennial and deciduous crop with an economic life span of 25-30 years.

In Nigeria, hybridization for genetic improvement of latex commenced in 1965 using many of the first set of high yielding clones from Malaysia and Sri-Lanka and a few high yielding primary clones from Java . Field evaluation and selection programmes have been conducted on the hybrids leading to selection and recommendation of sixteen MG clones with latex yield of 2000 – 3500 kg/ha/yr. (Alika, 1982, Omokahfe and Ugwa, 1997). The breeding population of natural rubber in Nigeria includes the primary clones such as GTI and TJIR I from Java, the hybrid clones developed in Malaysia and Sri Lanka and the MG clones. These clones have relatively common parentage which may be characterized by a narrow genetic base of the breeding population. In Nigeria, natural rubber production comes mostly from a single popular clone RRIN 800 series and it occupies most of the area under rubber cultivation. Although it is the highest yielding clone in Nigeria, it does not exhibit good drought tolerance capacity.

Intrinsic Water Use Efficiency in *Hevea* clones

Limited water availability is one of the major factors that affect productivity in crop plants. Generally, plants manage to survive water deficit to a certain extent either by morphological or physiological modifications that enable them to avoid or postpone desiccation stress. In Nigeria, 85% of the natural rubber cultivation areas are in the traditional rubber growing region where rainfall and other agro-climatic conditions are better suited for rubber cultivation than in non- traditional areas. Rubber cultivation is being extended to marginal areas of western and eastern parts of Nigeria with varied climatic constraints like moisture stress, high and low temperatures, drought and cold stresses which are major factors that limit growth and productivity of rubber in these regions. Among the various growth /productivity limiting factors, the negative impact of drought on yield has been well established in different *Hevea* clones (Jayasree *et al*., 2010).

The intrinsic water use efficiency of plants is known to be related to the efficiency of plants to grow with limited availability of water (Majkenn *et al;* 2005).The drought tolerant capacity of the modern *Hevea* clones is largely unknown. The present study was aimed at selecting *Hevea* clones that are tolerant to drought stress and the intrinsic water use efficiency (WUEi) of the *Hevea* clones in relation to drought tolerance mechanism was also studied. Present day rubber cultivation faces various climatic constraints even in traditional areas and these constraints are expected to become more serious in future. Soil, atmospheric drought, high temperature and diseases resistance are major environmental factors limiting growth and yield in *Hevea* (Mercy *et al*., 2010). Therefore, there is need to screen *Hevea* clones for tolerance to drought conditions, to select identified genotypes that are tolerant to drought stress for development of new clones of natural rubber and to study the inter- relationship among the drought tolerant genotypes and other traits which remains the objectives of this studies.

MATERIALS AND METHODS

Location and Planting Materials

Ten genotypes of rubber seedlings (*Hevea brasiliensis* Mull. Arg) obtained at Rubber Research Institute of Nigeria, Iyanomo, Benin City, Edo State, were evaluated at the research farm of the National Root Crops Research Institute (NRCRI), Umudike, (latitude 05^0, 29'N; longitude 07, 33'E) and 122m above sea level with mean annual rainfall of 2177 in the 2012 and 2013 cropping season. The genotypes are shown below: RRIM 600, NIG 800, NIG 801, NIG 802, NIG 803, NIG 804, PR 107, RRIM 628, GT I, and PB 5/51. These genotypes were subjected to drought stress treatments.

Pre- germination nursery or pre- nursery: The rubber seeds were spread in the pre- nursery bed where seeds are germinated before raising in the poly bag or ground nursery. The pre- nursery was small in size and was prepared by making a raised bed of 3m x 2m. The four sides of the bed were bordered by bamboo sticks to keep the raised soil intact. The seeds were sown in the field at Umudike in September, 10 2012 then at one month old when the seeds must have sprouted very well it was transplanted unto the main nursery.

Ground Nursery or Main Nursery: Sprouted seedlings were transplanted to the main nursery at one month old in October, 10 2012 and 2013 in a randomized complete block design (RCBD) with three replications. The ten genotypes of rubber seedlings were subjected to 26, 33 and 40 days of drought stress after two months of establishment which is referred to as 0drought. The land was cleared, ploughed, harrowed and made bed before transplanting. The soil was sandy loam and each plot size was $6m^2$ (3m x 2m with 1m apart) and contained 30 plants spaced 30cm within and 1m between the rows to give a seedling population of 33,333 seedlings per hectare. The inter plot spacing was 1m. The seedlings were watered twice daily (morning and evening) during the dry spell, three to four manual weeding was done to keep the field weed free. Recommended phosphate and urea (ratio 1:1) fertilizer at the rate of 150kg /ha (i.e 450g per plot) was broadcast after preparing the field.

Data Collection

After establishment of the 2012 experiment, there was no dry spell to enable us assess for drought tolerance/ resistance. Therefore, the experiment was extended to the next year 2013. The rubber genotypes were exposed to drought stress 441 days after planting and scores were taken after subjection to 26, 33 and 40 days of drought stress making it 467,474 and 481 days after planting. Data were collected on the following traits (plant height, number of leaves and plant girth) at various drought stress periods 2012 and 2013 experiments. Also the soil physico-chemical properties and agrometeorological data of the experimental site was taken.

- Plant height was measured as the distance from the ground level to the tallest leave using meter rule after establishment (0drought) and at 26, 33 and 40 days of drought stress. The sampling size was five plants per plot.
- Number of leaves per plant was obtained by sampling five stands per plot and counting the number of leaves of each plant within the net plot, after which their mean was calculated and recorded.
- Plant girth was obtained by using vernier caliper to measure the girth of five plants per plot and calculated the average per plant after establishment, at 26, 33 and 40 days of drought stress.

Data collected were subjected to analysis of variance using the GLM procedure of SAS and significant differences among means were separated using Fisher's least significant difference (F-LSD) at 5% level of probability.

RESULTS AND DISCUSSION

Soil Physico-chemical properties and agro meteorological data of the experimental site for the year 2012 and 2013

The result of the soil analysis of the experimental site for the year 2012 and 2013 is represented on Table 1. The soil texture of the site was sandy loam with sand, silt and clay having the proportions of 72%, 16.5%, 11.5% and 71%, 17.5%, 11.5% in 2012 and 2013 respectively. The soils were moderately acidic with pH of 4.6 and 4.35 in 2012 and 2013 respectively. The percentage organic carbon was 0.85 and 0.95; total percentage nitrogen was very low, 0.08 and 0.12 in 2012 and 2013 respectively. Extractable phosphorus was moderate 30.3 and 43.6 mg/kg in 2012 and 2013 respectively while exchangeable potassium for the two years of the research work was found to be very low. (Table 1)

Table 1 Soil physico-chemical properties of the experimental site in 2012 and 2013

Physical Properties	2012	2013
Sand (%)	72.00	71.00
Silt (%)	16.50	17.60
Clay (%)	11.50	11.40
Textural class	Sandy Loam	Sandy Loam
Chemical Properties		
P^H (water)	4.60	4.35
Extractable P (mg/kg)	30.30	43.6
Total N (%)	0.08	0.12
Organic Carbon (%)	0.85	0.95
Organic Matter (%)	1.58	2.22
Ca (C mol/kg)	3.00	3.80
K (Cmol/kg)	0.23	0.20
Na (Cmol/kg)	0.18	0.22
EA (Cmol/kg)	1.00	1.10
ECEC (Cmol/kg)	1.84	2.83
BS (%)	80.1	78.70

Source: National Root Crops Research Institute Umudike, Umuahia, Abia State.

Table 2 shows the average monthly rainfall at the experimental site in 2012 and 2013. Average monthly rainfall ranged from 0.0mm -362.0mm in 2012 and from75.0-466.1mm in 2013. The total rainfall in 2012 was 1896.8mm with a mean monthly rainfall of 111.08mm while in 2013 the total rainfall was 2210 with a mean monthly rainfall of 184.66mm. In 2012 average monthly rainfall was highest in July with 362.0mm while in 2013 its peak was in May with 466.1mm. There was no rainfall in January and December 2012 and January 2014.

Table 2: Mean monthly Rainfall (mm), Number of rainy days, Average temperature (^{0}C) and Relative humidity (%) of the experimental site in 2012 and 2013 at Umudike, Abia state

	2012				2013			
Months	**Rainfall (mm)**	**Number of rainy days**	**Average Temp. ^{0}C**	**R.H %**	**Rainfall (mm)**	**Number 0f rainy days**	**Average Temp. ^{0}C**	**R.H %**
January	0	0	27.0	50.5	75.4	2	29.1	46
February	82.2	7	28.5	70.0	84.8	3	29.6	50
March	50.0	2	29.5	66.5	40.8	8	30.3	62
April	142.0	17	28.5	74.5	92.8	9	29.3	65
May	233.7	16	28.0	76.0	466.1	16	29.0	69
June	213.0	14	26.5	81.5	239.4	14	27.5	78
July	362.0	24	25.5	86.0	280.5	18	26.2	76
August	161.8	19	26.0	82.0	237.1	15	26.1	68
September	349.0	25	26.0	82.0	318.0	18	26.6	70
October	244.6	16	25.5	78.0	184.8	14	27.4	73
November	58.5	6	27.5	75.5	99.5	8	28.1	89
December	0	0	26.0	61.5	90.8	7	27.0	60
Total	1896.8	146	324.5	884	2210	132	336.2	806
Mean	158.07	12.17	27.04	73.67	340	11	28.02	67.17
Jan.2014	0	0	33.4	75	-	-	-	-
Feb.2014	14	2	33.9	80	-	-	-	-

Source: National Root Crops Research Institute Umudike, Umuahia, Abia State

The mean effects of drought stress on plant height of 10 rubber genotypes evaluated in the year 2012 and 2013 cropping season are presented on Tables 3 and 4.

At 26 days after subjection to drought stress, plant height varied from 144.57cm in PB5/51 to 206.63cm in Nig 804. At 33 days after exposure to drought stress, plant height ranged from 144.57cm in PB5/51to 209.33cm in GT1 while at 40 days of subjection to drought stress, plant height varied from 144.67cm in PB5/51to 230.73cm in Nig 804. After a total of 40 days of drought stress, the fastest growth rate was recorded for Nig 804 with a plant height of 230.73cm, followed by GT1 with 217cm, Nig 802 with 207.07cm and Nig 800 and PR107 with 203.47cm and 203.3cm respectively (Table 3). However in 2013, plant height also varied from 29.43cm in RRIM 628 to 36.46cm in Nig 804 at the commencement of drought stress test. At 26 days after subjection to drought stress, plant height ranged from 31.84cm in RRIM 628 to 46.41cm in Nig 804. At 33 days after exposure to drought stress, plant height ranged from 31.4cm in RRIM 628cm to 48.31cm in Nig 804 while at 40 days of subjection to drought stress, plant height varied from 31.4cm in RRIM 628 to 50.4cm in RRIM 600. Then after a total of 40 days of drought stress, the fastest growth rate was recorded for RRIM 600 with a plant height of 50.4cm, followed by Nig 804 with 49.36cm, GT1 with 48.3cm while Nig 801 and Nig 803 had 46.57cm and 43.93cm respectively. Drought stress had significant effects ($P<0.05$) on the plant height among the genotypes in 2012 and 2013. However the effects of drought stress was most severe on Nig 800, PB5/51 and RRIM 628 which did not record any increase in plant height throughout the 33 and 40 days of drought stress (Tables 3 and 4).

Table 3: Effects of drought stress and genotypes on plant height (cm) of 10 rubber genotypes evaluated in the year 2012

	Drought stress periods (days)				
Genotypes	**0**	**26**	**33**	**4**	**Genotypes mean**
GTI	190.58	200.63	203.33	207.00	200.39
Nig 800	188.45	203.03	204.50	204.47	200.11
Nig 801	168.55	171.00	170.33	170.33	170.05
Nig 802	169.59	181.90	198.70	205.07	188.82
Nig 803	179.43	186.50	195.30	200.87	190.53
Nig 804	195.24	206.07	221.70	230.73	213.44
PB 5/51	138.58	144.57	144.57	144.27	142.99
PR107	177.63	186.17	196.80	203.60	191.05
RRIM 600	168.67	178.63	188.57	193.00	182.22
RRIM 628	149.79	157.20	157.83	157.83	155.66
Drought Means	172.65	181.57	207.73	192.92	

F-LSD $_{(0.05)}$
Genotypes means = 13.06***
Drought stress means = 8.26***
Genotype * drought stress means = 26.12*

Table 4: Effects of drought stress and genotypes on plant height (cm) of 10 rubber genotypes evaluated in the year 2013

	Drought stress periods (days)				
Genotypes	**0**	**26**	**33**	**40**	**Genotype mean**
GTI	35.07	41.48	45.74	48.30	42.648
Nig 800	31.45	34.33	34.33	34.33	33.61
Nig 801	36.03	41.27	41.68	41.57	40.14
Nig 802	32.42	42.30	42.03	42.00	39.75
Nig 803	33.28	41.02	42.00	43.93	40.06
Nig 804	36.46	46.41	48.32	49.37	45.14
PB 5/51	28.27	36.50	36.30	36.30	34.19
PR 107	34.54	40.87	42.20	42.20	39.95
RRIM 600	34.59	43.27	47.33	50.41	43.90
RRIM 628	29.43	31.84	31.40	31.40	31.02
Drought Means	33.15	39.74	41.50	42.46	

F-LSD $_{(0.05)}$
Genotypes means = 1.9643***
Drought stress means = 1.2424***
Genotype *drought stress means = 3.928698*

The decrease in plant height in some of these genotypes may be due to poor genetic constitution of the clones, the severity of the drought stress, coupled with intensity of the sun during the study period and other environmental factors. Nig 804 and GT1 showed more tolerance to drought stress in 2012 while GT1, Nig 804 and RRIM 600 showed more tolerance to drought stress in 2013 recording the highest plant height at 40 days of drought stress when compared with the other genotypes. This indicated that they possess genes with some level of tolerant to drought stress.

Tables 5, 6, 7 and 8 showed the mean effects of drought stress on number of leaves and plant girth of 10 rubber genotypes at seedlings stage in the nursery in 2012 and 2013

Number of leaves ranged from 62.13 in PB5/51 to 246.2 in GT1after 26 days of exposure to drought stress. At 33 days after exposure to drought stress, number of leaves varied from 53.73 in PB5/51 to 243.10 in GT1while at 40 days of subjection to drought stress, number of leaves ranged from 41.97 in PB5/51 to 235.27 in GT1. After a total of 40 days of drought stress, the highest number of leaves was recorded for GT1with 235.27 followed by RRIM 600 with 205.53, Nig 804 with 200.17 and by PR107 and Nig 801 with 187.30 and 170.13 respectively (Table 5).

Table 5: Effects of drought stress and genotypes on number of leaves of 10 rubber genotypes evaluated in the year 2012

	Drought stress periods (days)				
Genotypes	**0**	**26**	**33**	**40**	**Genotype mean**
GTI	266.26	246.20	243.10	235.27	247.71
Nig 800	204.46	184.63	161.97	136.97	172.01
Nig 801	225.0	190.87	182.27	170.13	192.07
Nig 802	205.67	183.07	173.73	157.63	180.03
Nig 803	215.93	194.77	183.47	169.43	190.9
Nig 804	255.33	230.27	221.27	200.17	226.76
PB5/51	101.20	62.133	53.733	41.967	64.758
PR 107	249.80	229.47	206.13	187.30	218.18
RRIM600	251.33	221.53	216.03	205.53	223.61
RRIM628	105.33	75.033	65.867	47.500	73.183
Drought Means	208.03	181.79	170.76	155.19	

F-LSD $_{(0.05)}$
Genotypes means = 6.9804***
Drought stress means = 4.4148***
Genotypes * drought stress means = 13.961***

The same trend was observed in 2013, number of leaves ranged from 12.6 in PB5/51 to 28.57 in GT1 after subjection to 26 days drought. At 33 days of exposure to drought stress, number of leaves varied from 10.2 in Nig 800 to 25.87 in GT1. While at 40 days after subjection to drought stress, number of leaves ranged from 6.4 in PB5/51 to 22.33 in GT1. Also after a total of 40 days of drought stress, the highest number of leaves was recorded for GT1 with 22.33 followed by RRIM 600 with 20.26 and Nig 804 with 17.87 (Table 6).

Table 6: The mean effects of drought stress and genotypes on number of leaves of 10 rubber genotypes evaluated in the year 2013

Genotypes	Drought stress periods				
	0	26 (days)	33 (days)	40 (days)	Genotype mean
GTI	33.30	26.57	25.87	22.33	27.52
Nig 800	28.80	14.73	10.20	8.866	15.65
Nig 801	29.60	20.33	16.33	10.60	19.22
Nig 802	24.40	15.67	12.27	9.600	15.49
Nig 803	29.00	20.07	16.80	13.13	18.00
Nig 804	30.30	24.20	20.07	17.86	23.11
PB 5/51	28.27	12.60	10.70	6.400	14.32
PR 107	31.47	25.87	20.57	14.78	23.17
RRIM 600	32.23	27.33	22.80	20.27	25.66
RRIM 628	28.13	16.67	10.47	6.600	15.47
Drought Means	29.60	20.60	16.33	13.04	

F-LSD $_{(0.05)}$ \
Genotypes means = 1.5055***
Drought stress means = 0.9522***
Genotype*drought stress means = 3.0109***

There was influence of drought stress on the seedlings of 10 rubber genotypes at 26, 33 and 40 days of drought exposure in 2012 and 2013 by indicating decreased in the number of leaves among the genotypes across the drought periods. The effect of drought was most severe on PB5/51, RRIM 628 and Nig 800 and PB5/51which showed a very high decreased in number of leaves throughout the 40 days of drought stress in both years (Tables 5 and 6). They seem to have been affected so much by drought at 40 days of drought stress while GT1and RRIM 600 recorded the highest number of leaves in 2012 and 2013 even though there were decreased in number of leaves in all the genotypes. This showed that these genotypes can tolerate drought periods more than the other ones even after 40 days of drought while the rest genotypes had little to zero tolerance of drought influences on them. As was reported by Samarappuli *et al,* (1992a), also wide variability in number of leaves per plant was observed in this work and this could be attributed to broad genetic base, potentially important in broadening the existing narrow genetic base of cultivated rubber in Nigeria. Being a likely repository of gene conferring tolerance to various biotic and abiotic stresses, these genotypes are useful in developing *Hevea* clones tolerant to drought stress, so that rubber cultivation can be extended to non rubber growing areas experiencing adverse climatic conditions. As soil and atmospheric drought is a serious issue limiting rubber cultivation, developing drought tolerant clones is very important (Mercy *et al.,* 2010).

Plant Girth: Plant girth varied from 2.11cm in RRIM 628 to 4.26cm in GT1 at 26 days after subjection to drought stress. At 33 days after exposure to drought stress, plant girth ranged from 2.05cm in PB5/51to 4.99cm in Nig 804 while at 40 days of subjection to drought stress, plant girth varied from 2.0cm in PB5/51to 4.79cm in RRIM 600. At 33 days of drought imposition the highest plant girth was recorded for Nig 804 with a plant girth of 4.99cm followed GT1 with 4.54cm whereas at 40 days of exposure to drought stress, RRIM 600 exhibited the highest plant girth of 4.96cm followed by Nig 804 with 4.71cm and GT1 with 4.64cm in 2012 (Table 7).

Table 7: Effects of drought stress and genotypes on plant girth (cm) of 10 genotypes of rubber seedlings evaluated in the year 2012

	Drought stress periods				
Genotypes	**0**	**26 (days)**	**33 (days)**	**40 (days)**	**Genotype mean**
GTI	3.067	4.257	4.543	4.647	4.129
Nig 800	3.337	3.460	3.613	3.613	3.506
Nig 801	3.216	3.023	3.043	3.790	3.268
Nig g802	3.210	3.127	3.160	3.513	3.288
Nig 803	3.736	3.370	3.400	3.401	3.477
Nig 804	3.331	3.503	4.993	4.710	4.134
PB 5/51	3.321	2.567	2.047	2.00	2.484
PR 107	3.110	3.133	3.250	3.257	3.188
RRIM 600	3.147	4.153	4.327	4.797	4.106
RRIM 628	2.546	2.112	2.077	2.027	2.191
Drought Means	3.202	3.269	3.142	3.571	

F-LSD $_{(0.05)}$
Genotypes means = 0.2956***
Drought stress means = 0.187***
Genotypes * drought stress means = 0.5912**

In 2013, plant girth varied from 1.2cm in PR 107 to 2.0cm in RRIM 600 after establishment (0drought), at 26 days after subjection to drought stress, plant girth ranged from 1.24cm in RRIM 628 to 2.41cm in RRIM 600. At 33 days after exposure to drought stress, plant girth ranged from 1.17cm in RRIM 628 to 2.5cm in GT1, while at 40 days of subjection to drought stress, plant girth varied from 1.03cm in RRIM 628 to 2.5cm in GT1. After a total of 40 days of drought imposition the highest plant girth was recorded for GT1 with a plant girth of 2.52cm followed by RRIM 600 with plant girth of 2.31cm (Table 8).

Table 8: Mean effects of drought stress and genotypes on plant girth (cm) of 10 genotypes of rubber seedlings evaluated in the year 2013

	Drought stress periods				
Genotypes	**0 (days)**	**26 (days)**	**33 (days)**	**40 (days)**	**Genotype mean**
GTI	1.9667	2.3333	2.5067	2.5233	2.3325
Nig 800	1.7200	1.9467	1.6067	1.2733	1.6367
Nig 801	1.5600	1.8800	1.7700	1.4733	1.6708
Nig 802	1.7400	1.9933	1.6867	1.6267	1.8117
Nig 803	1.9133	1.9267	1.7667	1.7000	1.8517
Nig 804	1.9567	2.1800	2.0133	1.9633	2.0283
PB 5/51	1.4333	1.4967	1.2800	1.1200	1.3325
PR 107	1.2567	1.6800	1.8433	1.8867	1.6667
RRIM 600	2.0733	2.4133	2.4000	2.3133	2.3000
RRIM 628	1.9900	1.2400	1.1700	1.0300	1.1583
Drought Means	1.90900	1.90900	1.80467	1.72100	1.68100

F-LSD $_{(0.05)}$
Genotypes means = 0.2214***
Drought stress means = 0.1400**
Genotype *drought stress means = 0.4428*

There were significant differences ($p<0.05$) among the genotypes in both years. The effect of drought stress was more pronounced in Nig 800 with plant girth of 3.46cm, 3.31cm and 3.31 cm, Nig 803 with plant girth of 3.37cm, 3.4cm and 3.4cm, PB5/51 with 2.5cm, 2.04cm and 2.0cm, PR 107 with 3.13cm, 3.25cm and 3.25cm and RRIM 628 with 2.11cm, 2.02cm and 2.02cm after 26, 33 and 40 days of drought stress respectively in 2012. Also in 2013, the effect of drought stress was more pronounced in Nig 800 with plant girth of 1.94cm, 1.60cm and 1.27 cm, PB5/51 with plant girth of 1.49cm, 1.28 and 1.12cm and RRIM 628 with 1.24cm, 1.17cm and 1.03cm, after 26, 33 and 40 days of drought stress respectively. Meanwhile GT1 and PR107 were the only genotypes that consistently had increase in their plant girth. However, this was in conformity to the finding of Samarappuli *et al.*, (1992a) who reported that genotypes like PB5/51and RRIM 628 when compared with others does not grow vigorously under drought stress. This may be due to the severity of the drought stress that reduced the soil moisture content in the field.

CONCLUSION

Plant growth and productivity is adversely affected by environmental, abiotic and biotic stresses. Drought is one of the abiotic stresses that cause serious damage to plants especially rubber plant that is rain forest crop. Therefore understanding the extent of drought stress tolerance in rubber plant is very crucial, also important is screening genotypes for drought tolerance, characterization for effective documentation, and evaluation for efficient deployment into the breeding program. This has largely been achieved by this study. By studying the level of drought tolerance and susceptibility within the genotypes, it has been shown that thought there was wide variation among the genotypes for most agronomic traits, plant height, number of leaves and plant girth defined the variations among the 10 genotypes of rubber seedlings. From the results, it can be concluded that GT1, RRIM 600 and Nig 804 proved to be more tolerant to drought conditions when compared with other genotypes after 40 days of drought stress and PR107 showed less tolerance while RRIM 628, PB5/51 and Nig 800 had earlier responded to drought stress by indicating changes in morphological responses in the field for the two years work. The result also showed that rubber seedlings cannot withstand drought stress at nursery stage for a long period in the field. The recommendations made in this regard are; (a) selecting drought tolerant genotypes like RRIM 600, GT1, Nig 804 and PR 107 for rubber improvement in Nigeria. (b) choosing young seedlings budded with these genotypes as planting materials since rubber plant is not grown directly from the seed, it is grown by budding rubber seedling, so there is need to incorporate these genotypes into rubber breeding programme. (c) The selected genotypes with intrinsic drought tolerant qualities should be included in future breeding programmes for evolving genotypes that can better tolerate drought condition.

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