International Journal of Plant & Soil Science

Volume 35, Issue 13, Page 154-164, 2023; Article no.IJPSS.98999
ISSN: 2320-7035

Watering Rates and Its Response to Cocoa (*Theobroma cacao* L.) Genotypes Growth Development

Nduka Beatrice Abanum [a], Ibrahim Olalekan Sobowale [b*] and Olufemi Aremu-Dele [a]

[a] Agronomy Division, Cocoa Research Institute of Nigeria, Nigeria.
[b] Crop Improvement Division, Cocoa Research Institute of Nigeria, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2023/v35i133000

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/98999

Original Research Article

Received: 25/02/2023
Accepted: 27/04/2023
Published: 20/05/2023

ABSTRACT

Cocoa genotypes exhibiting different responses to water and watering rates to growth parameters necessitate this study. Seedlings were raised from cocoa hybrids genotypes (CRIN Tc1 – 8) and F3 Amazon. The seeds after 4 days of sowing were subjected to 3 watering rates of 50 ml, 100 ml and 150 ml applied once every two days and arranged in a CRD design between December 2020 - May 2021 at Cocoa Research Institute of Nigeria (CRIN) Ibadan Nursery. Data collected include the percentage of germination at 2-4 weeks after sowing (WAS), growth parameter (plant height, girth, leaf area, number of leaves), and destructive sampling (fresh and dry weight of shoot weight, root weight and Taproot length) which were statistically analyzed with SAS tools. The watering rates had no significant effect on cocoa seedling emergence date. Least plant heights were observed when 50ml watering rate was applied on CRINTc-1 (25.00cm), CRINTc-2 (26.53cm), CRINTc-4 (24.10 cm), CRINTc-6 (27.52cm) and CRINTc-8 (28.75cm) at 20WAS. Stem girth, number of leaves and fresh root weight were not significantly enhanced by the watering levels on the cocoa

---

**Corresponding author: E-mail: sobolekky@gmail.com;*

genotypes. The result also reveals that the dry shoot weight was greater than the dry root weight of their corresponding treatments. The 3 watering levels had no considerable effect on the emergence of the cocoa genotypes but influenced the morphological traits, fresh and dry weight of the shoot and root parameters of the cocoa genotypes. 100 ml watering rate applied on the cocoa genotypes performed more appreciably followed by 150 ml.

Keywords: Cocoa; genotypes; nursery; watering.

1. INTRODUCTION

Cocoa (*Theobroma cacao* L.) is among the most important export perennial crops [1] in Nigeria. It's raised vegetatively or by seed in the nursery before transplanting to the field. The quality status of cocoa seedlings nursery production is a key to successful field establishment in most cocoa plantations. Meanwhile attempts to increase cocoa seedling production by farmers are mostly characterized by poor growth development due to insufficient water application rates [2]. This report by Agele et al. [2] was supported by Daba and Tadese [3] who stated that sufficient water quantity and good quality are extremely important in the nursery site for the production of tree seedlings. Mhango et al. [4], Mng'omba et al. [5], Oboho and Igharo [6] reported that nursery operators experience economic loss through stunted growth and increase mortality rate which might be attributed to poor watering. These peculiarities mentioned above may increase the timing for grafting to take place, transplanting or delay the sales of the seedlings according to Mng'omba et al. [5]. More so the water availability and exact volume of water required for the survival and development of nursery seedlings as reported by Morrison et al. [7] is a challenge among small-scale farmers.

Water apart from it being a major constituent of any living organisms is involved in biochemical processes according to Oboho and Igharo [6]. Water and its importance for plant growth cannot be over emphasized as it not only controls transpiration, it affects the inflow of nutrient solutions [8]. While crops growing in excessively wet soils tends to grow abnormally, are susceptible to diseases and less productive than those grown under normal moisture conditions [9], Its worthy to state here that water deficit suppresses plant growth, inhibition of various physiological and biochemical processes, such as photosynthesis, respiration translocation, ion uptake, carbohydrates, nutrient metabolism, and hormones [10,11] but physiologically, the reactions of plants to water deficits differs because it's based on severity and the duration of water stress as reported by Shao et al. [12]. Water stress either deficit or excess act as a very important limiting factor to plant growth and establishment at the initial phase of planting [12]. Therefore, Bae et al. [13] reported that Cocoa plant does not accommodate a lengthy period of water stress. While Raja Harun and Hardwick [14] reported that cocoa is less efficient in controlling water loss when checked with other economical tree crops loss. This is because water needs among cocoa genotypes as reported by Ayegboyin and Akinrinde [15] vary. More so report from research conducted by Dias et al. [16] identify genotypes that possess character for good growth, high yield and efficient water use efficiency (WUE) which he said is important for breeding. Mng'omba et al. [5] in their research conclude that sustainability of water uses, and its cost implication is paramount in commercial nurseries. Thus, according to Krishnan et al. [17] increase in water use demand in agriculture cannot be over emphasized. The present study was therefore proposed to identify a probable rate of watering on the CRIN Cocoa hybrids morphological growth, root enhancement and biomass development to promote water conservation in the nursery stage of cocoa production.

2. MATERIALS AND METHODS

A five-month nursery experiment was conducted between December 2020 to May 2021 in Cocoa Research Institute of Nigeria (CRIN) Ibadan, Oyo State research nursery house situated at the coordinate 7°12ˈ26ˈˈN 3°51ˈ06ˈˈE. The experiment was designed to understand how three different rates of watering affect the growth and development of nine different cocoa genotypes. The topsoil used in this study was scraped from fallow land within the Research Institute, air-dried and sieved from debris before 727.45 g of this topsoil was filled into 25 cm by 12.5 cm black nursery polythene bags and watered to field capacity. The filled bags were placed in the nursery house for a day to rest before planting. Fresh cocoa pods from nine genotypes with physiologically matured attributes were harvested from among the CRINTc series released in the year 2011, apart from F3 Amazon which was from the 3rd filial generation of the Upper Amazonian cocoa variety. The eight hybrids genotypes pedigree were: CRIN Tc1 (T65/7 × N38), CRIN Tc2 (T101/15 × N38), CRIN Tc3 (P7 × PA150), CRIN Tc4 (T56/7 × T57/22), CRIN Tc5 (T82/27 × T12/11) CRIN Tc6 (PA150 × T60/887) CRIN Tc7 (T82/27 × T16/17) CRIN Tc8 (T65/7 × T9/15). The word T represents *Theobroma*, while c means *cacao*. The cocoa seed (beans) extracted from each of the pods mentioned above were sown a day after harvesting, adequately watered, and top of the soil covered with sawdust to facilitate early germination. The experimental layout was a factorial fitted in a Completely Randomized Design (CRD) with three replications. Four days after sowing the seedlings were subjected to three levels of watering treatments (50 ml, 100 ml and 150 ml) applications once every two days. Data collected were on number of days to germination (2-4 weeks after sowing (WAS)) before 100% germination). Data collected includes Plant height (Measure with meter rule), girth (Measured with Vernier caliper), leaf area (The leaf area was obtained using the leaf area meter and multiple with cocoa leaf index), and the leaves number that was visual, manually counted and recorded. The experiment was monitored for five months and terminated with the destructive sampling of each treatment to obtain the fresh and dry weight of shoot weight (g), root weight (g) and Taproot length (cm) *(TRL)*. All data collected were subjected to Analysis of Variance (ANOVA) using [18] statistical tools, while treatment means were separated using Tukey's Studentized Range (HSD) Test.

3. RESULTS AND DISCUSSION

Among the techniques used in nursery farming operations, watering can be group as the most important because it either improves or slows growth performance or may cause waterlogging in the soil if it is not properly managed which may lead to the death of the plant. Our study shows that the varying watering treatments affected the seed germination of the cocoa genotype although they were not statistically and significantly enhanced. The results obtained in Table 1 show no significant (p>0.05) differences among the cocoa varieties and the rate of watering application across the seedlings emergence dates but CRINTc 8 and F3 Amazon attained 100% emergence earlier at 2 and 4 weeks after sowing compared to others varieties when 50 ml water was applied. While CRINTc 1 and 4 cocoa genotype attained 100% germination at 4 weeks after sowing with 100ml of water application. More so CRINTc 7 having a watering rate of 100 ml and 150ml attained 100% germination also at 2WAS at p>0.05. Table 1 buttress water as an essential requirement for germination but disagrees with the finding reported by Oboho and Igharo [6] which stated that watering should enhance germination significantly as obtained in the pre germination of *Pycnanthus angolensis* species. On the other hand, this work supports the finding of Gush and Moodley [19] whose view on watering stated that very little quantity of water is needed for forest seedlings healthy growth performance, but when watering is frequently applied, it might lead to plant vigor reduction and seedling death if the soil becomes waterlogged.

Plant height is a representative of plant growth index and vigour as seen in Table 2. Highest occurrence of least plant heights were observed when 50ml watering rate was applied on CRINTc-1, CRINTc-2, CRINTc-4, CRINTc-6 and CRINTc-8 at 20 WAS. The results obtained in this study showed that the CRINTc 8 variety having 150 ml of water application produced significantly tallest plant height of 20.92 cm, 26.65 cm, 28.48 cm at 4, 8 and 12th WAS (Table 2). Furthermore, in Table 2, CRINTc 5 with 100ml of watering application was significantly enhanced with mean values of 35.58 and 37.52 cm obtained at 16 and 20th WAS respectively at p>0.05 when compared to the other watering rate and cocoa varieties used. This observation agrees with the finding of Tolulope and Joshua [20] that stated an increased volume of watering significantly increases *Dioscoreophyllum cumminsii* plant height but its contrary to the report obtained from Olajide et al. [21] on *Dialium guineense*, who find no significant effect on plant height under watering regime.

Stem girth at 4, 16 and the 20th WAS as seen in Table 3 was not significantly enhanced (p>0.05) in all the parameters measured and varieties used in this study. However, the 8th WAS, CRINTc 5 variety having 100 ml watering rate had significantly the highest value of 5.03 cm, while the least mean value of 3.54 cm was recorded in the F3 Amazon variety when the least watering rate of 50 ml was applied. Furthermore, 150 ml of watering significantly enhanced an increased stem girth growth of 12th WAS but at 16-20th WAS stem girth becomes significantly static among the different cocoa varieties irrespective of the levels of water applications. However 150 ml watering rate applied to all the varieties did not give the thickest stem girth at 16 and 20th WAS in all the varieties except CRINTc 8 which is contrary to the findings of Buriro et al. [22] who observed an increase in stem girth with higher watering levels in *Helianthus annuus* and Agele et al. [23] who also observed that drought conditions reduced growth indicators such as stem girth in *Vitellaria paradoxa.*

Table 1. Response of cocoa genotypes seed emergence to watering rates at 2 and 4 weeks after sowing (WAS)

Watering rate →	50ml		100ml		150ml	
Genotypes↓	**2 WAS**	**4 WAS**	**2 WAS**	**4 WAS**	**2 WAS**	**4 WAS**
CRIN Tc1	66.67a	100.00a	33.33a	100.00a	33.33a	100.00a
CRIN Tc2	16.67a	100.00a	16.67a	83.33a	16.67a	83.33a
CRIN Tc3	33.33a	83.33a	33.33a	83.33a	83.33a	100.00a
CRIN Tc4	50.00a	83.33a	33.33a	100.00a	50.00a	66.67a
CRIN Tc5	66.67a	100.00a	33.33a	83.33a	16.67a	100.00a
CRIN Tc6	83.33a	100.00a	50.00a	83.33a	66.67a	100.00a
CRIN Tc7	83.33a	83.33a	100.00a	100.00a	100.00a	100.00a
CRIN Tc8	100.00a	100.00a	100.00a	100.00a	83.333a	83.33a
F3 Amazon	100.00a	100.00a	66.67a	100.00a	66.67a	66.67a

Means with the same letter (s) in a column are not significantly different (P≤0.05)

Table 2. Response of cocoa genotypes and watering rates on plant height development

Plant Height (cm)					
Treatments	**4 WAS**	**8 WAS**	**12 WAS**	**16 WAS**	**20 WAS**
CRIN Tc1-50ml	12.07bcde	16.52bc	18.05d	23.28c	25.00b
CRIN Tc1-100ml	11.95bcde	19.32bc	20.93bcd	23.93bc	27.15b
CRIN Tc1-150ml	13.78abcde	19.3bc	23.70abcd	25.38bc	27.57b
CRIN Tc2-50ml	7.27e	15.55c	19.55cd	24.55bc	26.53b
CRIN Tc2-100ml	11.65cde	18.73bc	21.18bcd	25.15bc	30.30ab
CRIN Tc2-150ml	12.23bcde	18.80bc	22.30abcd	28.68abc	32.75ab
CRIN Tc3-50ml	16.95abcd	21.78abc	23.03abcd	24.52bc	27.58b
CRIN Tc3-100ml	12.67bcde	18.05bc	21.35bcd	24.33bc	27.32b
CRIN Tc3-150ml	12.33bcde	20.20abc	23.50abcd	24.83bc	25.68b
CRIN Tc4-50ml	9.67de	16.70bc	20.87bcd	22.22c	24.10b
CRIN Tc4-100ml	13.08bcde	18.28bc	22.75abcd	27.90abc	29.58ab
CRIN Tc4-150ml	17.47abc	22.48abc	23.53abcd	25.47bc	27.45b
CRIN Tc5-50ml	16.68abcd	22.60abc	26.38abc	27.92abc	28.98ab
CRIN Tc5-100ml	15.32abcd	21.90abc	27.65ab	33.58a	37.52a
CRIN Tc5-150ml	11.82cde	19.50bc	23.7abcd	26.20abc	28.33ab
CRIN Tc6-50ml	16.42abcd	19.75abc	23.48abcd	25.65bc	27.52b
CRIN Tc6-100ml	12.80bcde	18.75bc	23.00abcd	25.97bc	28.10ab
CRIN Tc6-150ml	17.12abc	20.27abc	22.02abcd	25.68bc	28.18ab
CRIN Tc7-50ml	17.20abc	22.72abc	23.98abcd	26.58abc	28.80ab
CRIN Tc7-100ml	19.32a	23.55ab	25.47abc	28.93abc	30.68ab
CRIN Tc7-150ml	14.53abcde	21.45abc	24.42abcd	26.88abc	28.77ab
CRIN Tc8-50ml	14.28abcde	17.97bc	25.45abc	26.80abc	28.75ab
CRIN Tc8-100ml	15.65abcd	21.55abc	24.37abcd	25.22bc	28.95ab
CRIN Tc8-150ml	20.92a	26.65a	28.48a	31.23ab	33.78ab
F3 Amazon -50ml	14.70abcd	17.88bc	20.25cd	25.68bc	29.98ab
F3 Amazon -100ml	17.02abcd	20.92abc	24.02abcd	25.50bc	28.92ab
F3 Amazon -150ml	14.65abcd	18.45bc	21.43bcd	25.72bc	28.73ab

Means with the same letter (s) in a column are not significantly different (P≤0.05). WAS-Weeks after sowing

Table 3. Response of cocoa genotypes and watering rates on stem girth development

Treatments	Stem girth (mm)				
	4 WAS	**8 WAS**	**12 WAS**	**16 WAS**	**20 WAS**
CRIN Tc1-50ml	3.36a	3.84cde	4.31abc	4.88a	5.54a
CRIN Tc1-100ml	3.78a	4.15abcde	4.56abc	5.00a	6.14a
CRIN Tc1-150ml	3.54a	3.88cde	4.37abc	4.89a	5.23a
CRIN Tc2-50ml	3.90a	4.32abcde	4.48abc	4.90a	5.74a
CRIN Tc2-100ml	4.41a	4.82abc	5.41ab	5.68a	7.02a
CRIN Tc2-150ml	3.72a	4.14abcde	4.54abc	5.36a	6.44a
CRIN Tc3-50ml	4.06a	4.24abcde	4.62abc	5.12a	5.93a
CRIN Tc3-100ml	3.77a	4.29abcde	4.88abc	5.30a	5.78a
CRIN Tc3-150ml	3.46a	4.06abcde	4.40abc	4.92a	5.63a
CRIN Tc4-50ml	3.25a	3.96bcde	4.21bc	4.54a	5.06a
CRIN Tc4-100ml	3.91a	4.21abcde	4.84abc	5.78a	7.08a
CRIN Tc4-150ml	3.25a	4.06abcde	4.47abc	4.92a	5.63a
CRIN Tc5-50ml	4.11a	4.55abcd	4.68abc	5.14a	6.69a
CRIN Tc5-100ml	4.32a	5.03a	5.44ab	6.08a	6.74a
CRIN Tc5-150ml	3.16a	4.40abcde	4.86abc	5.20a	5.72a
CRIN Tc6-50ml	3.81a	4.35abcde	4.76abc	5.53a	6.04a
CRIN Tc6-100ml	3.80a	4.22abcde	5.18abc	5.92a	6.77a
CRIN Tc6-150ml	3.80a	4.18abcde	4.84abc	5.20a	5.90a
CRIN Tc7-50ml	3.54a	4.39abcde	5.29abc	5.76a	6.55a
CRIN Tc7-100ml	3.92a	4.41abcde	5.09abc	5.82a	6.57a
CRIN Tc7-150ml	3.94a	4.46abcde	4.88abc	5.78a	6.22a
CRIN Tc8-50ml	3.94a	4.38abcde	4.94abc	5.23a	5.58a
CRIN Tc8-100ml	3.87a	4.25abcde	4.52abc	5.15a	6.19a
CRIN Tc8-150ml	4.08a	4.92ab	5.50a	5.87a	7.15a
F3 Amazon -50	2.94a	3.54e	4.44abc	5.38a	6.21a
F3 Amazon -100	3.29a	3.68de	4.07c	4.78a	6.21a
F3 Amazon -150	3.04a	3.85cde	4.38abc	4.80da	5.47a

Means with the same letter(s) in a column are not significantly different (P≤0.05). WAS-Weeks after sowing

There seems to be behavioral consistency in leaf area expansion on CRINTc varietal and watering rate as shown in table 4. The present findings indicate that from 4-16th WAS CRINTc 6 having 100 ml watering application had the largest leaf area production at p>0.05 with 52.00, 79.92, 89.20, 88.08cm respectively when compared to other treatments. More so at 20th WAS the largest leaf area value of 103.74 cm (p>0.05) having a watering rate application of 100 ml was observed in the CRINTc 5 cocoa variety (Table 4). Furthermore, in this table, at 4 and 20th WAS the results obtained in this study showed no significant difference among the varieties used on the rate of water application. This agrees with Emmanuel [24] on the small leaf size of Picralima nitida reported when the environment was water-stressed. However, Contrary to Ogunrotimi and Kayode [25] on Solanum macrocarpon and Oboho and Igharo [6] on Pycnanthus angolensis and Dauda et al. [26] reports on daily watering, leading to high leaf area production.

Among CRINTc1- 8 and F3 Amazon means shown in Table 5, the production of leaves was not significantly (p>0.05) enhanced. CRINTc 1 with a 150 ml watering rate produced the least leaves count (8.7) at 20 WAS. These results obtained should be noted as varied and equal existence between the genotype and its watering requirement in leaf production. This result support that of Emmanuel [24] who opined that the leaves of plants growing in water-stressed environment produced small size leaves in numbers. It's also in consonance with Oboho and Igharo [6] work on *Pycnanthus angolensis*, Gbadamosi [27] on *Persea americana* and Ogidan et al. [28] on *Kigelia africana* respectively.

Table 6 shows the response of fresh weight of the destructive sample parameters for CRINTc cocoa genotype seedlings and their response to watering rates. The seedlings fresh shoot weight (FSW) that recorded the highest values were obtained when 100 ml of water was applied to CRINTc5 cocoa seedlings, while CRINTc 6, 5 and 1 that has 50 ml watering application rate recoded the least values of 6.0, 6.3 and 6.7 g respectively (p>0.05). This result supports the findings of Olajuyigbe et al. [29] in their works which stated that water supply usage in plants is proportional to biomass production.

Fresh Root Weight (FSW) on the other hand shows no significant difference among the genotype on the different rates of water application used. However, this study did not take into consideration the size of the growing medium on if the use of the above material may affect root growth because it was justified by Domínguez-Caraveo et al. [30] in their report that the use of poly bags or pots produce a uniformity in root growth and development but negatively and restricted root development may occur when there is excess soil moisture according to Rahman et al. [31].

This was further buttressed in the root length enhancement where irrespective of the watering rate CRINTc 5, 8 produce a significantly longer root length (24.2 and 24.4 cm at p>0.05) compared to other varieties, with the shortest length recorded in CRINTc 2 genotype having 50 ml of water application (Table 6). However, this report varies from the report of Oloyede et al. [32] on his work on field spacing simulation using lateral root length of the cocoa CRINTc Series who observed that F3 Amazon and CRINTc 6 had the longest tap root length respectively while CRINTc 3 and CRINTc 5 had the shortest taproot length. The variations observed in these reports could be a result of different factors involved in the experiments.

The dry shoot weight (DSW) of the treatments as shown in Fig. 1 shows that treatments CRINTc 4-100 ml (5.19 g), CRINTc 5-100 ml (4.75 g) and CRINTc 8-150 ml (4.64 g) had the highest dry shoot weight respectively while CRINTc 8-50 ml (1.10g), CRINTc 5-50 ml (1.20g) and CRINTc 1-150 ml (1.28g) had the lowest dry shoot weight respectively. Generally among the treatments, no consistent trend in the result was observed. The dry root weight (DRW) of the treatments (Fig. 2) didn't follow a similar trend as dry shoot weight as shown in Fig. 1 as CRINTc 6-50 ml (2.0g), CRINTc 5-100 ml (1.85g) and CRINTc 2-100 ml (1.67g) had the highest dry root weight respectively while F3 Amazon 150ml (0.57 g), CRINTc 5-50 ml (0.70 g) and CRINTc 1-150 ml (0.74g) had the lowest dry root weight respectively. The result from Fig. 1 and Fig. 2 reveals that the dry shoot weight was greater than the dry root weight in all treatments which could be a result of the larger mass size of the shoot than the root. This trend of the result was also observed by Adejobi et al. [33] where cocoa seedling dry shoots were all greater than their corresponding dry weight [34].

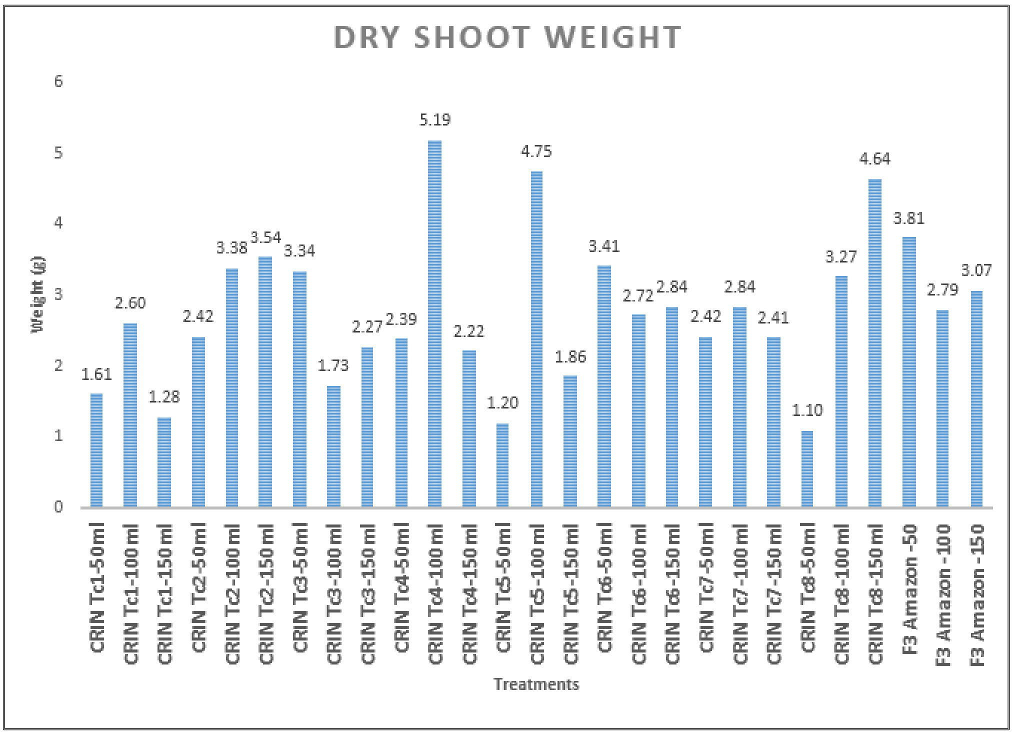

Fig. 1. Dry shoot weight of the cocoa CRINTc genotypes and watering rate treatments

Table 4. Response of cocoa genotypes and watering rates on leaf area

Treatments	Leaf Area (cm^2)				
	4 WAS	8 WAS	12 WAS	16 WAS	20 WAS
CRIN Tc1-50ml	34.97a	60.32ab	62.37a	62.75a	67.56a
CRIN Tc1-100ml	33.40a	57.86ab	61.08a	63.45a	69.72a
CRIN Tc1-150ml	37.69a	44.03ab	53.43a	69.34ab	70.36a
CRIN Tc2-50ml	25.30a	43.75ab	42.17a	57.27ab	58.68a
CRIN Tc2-100ml	26.86a	64.37ab	58.29a	66.19a	89.72a
CRIN Tc2-150ml	21.19a	43.43ab	61.30a	70.79a	73.78a
CRIN Tc3-50ml	41.61a	46.05ab	48.67a	62.15a	61.05a
CRIN Tc3-100ml	31.52a	50.87ab	57.41a	62.50a	68.05a
CRIN Tc3-150ml	45.56a	54.23ab	65.38a	74.19a	85.07a
CRIN Tc4-50ml	41.68a	52.70ab	53.66a	58.11ab	59.56a
CRIN Tc4-100ml	35.07a	53.13ab	58.18a	71.13a	78.06a
CRIN Tc4-150ml	42.52a	56.69ab	60.74a	63.67a	66.93a
CRIN Tc5-50ml	30.17a	40.03b	43.42a	49.16b	60.78a
CRIN Tc5-100ml	32.71a	51.50ab	66.1a	69.76a	103.74a
CRIN Tc5-150ml	13.29a	33.95b	39.48ab	49.34b	59.57a
CRIN Tc6-50ml	43.36a	53.40ab	60.91a	55.72a	72.74a
CRIN Tc6-100ml	52.00a	79.92a	89.20a	88.08a	90.99a
CRIN Tc6-150ml	41.38a	51.65ab	56.85a	84.49a	89.60a
CRIN Tc7-50ml	46.91a	67.23ab	69.69a	72.79a	79.68a
CRIN Tc7-100ml	40.91a	62.85ab	70.41a	89.74a	85.50a
CRIN Tc7-150ml	47.76a	70.14ab	73.03a	77.09a	78.11a
CRIN Tc8-50ml	49.06a	51.95ab	51.97a	54.55ab	59.46a
CRIN Tc8-100ml	41.62a	65.19ab	75.38a	82.16a	80.35a
CRIN Tc8-150ml	45.30a	56.03ab	61.92a	69.40a	72.91a
F3 Amazon -50	44.09a	53.45ab	54.78a	56.34a	59.32a
F3 Amazon -100	37.38a	51.82ab	59.63a	60.01a	61.98a
F3 Amazon -150	40.72a	44.31ab	59.28a	60.01a	60.32a

Means with the same letter (s) in a column are not significantly different (P≤0.05). WAS-Weeks after sowing

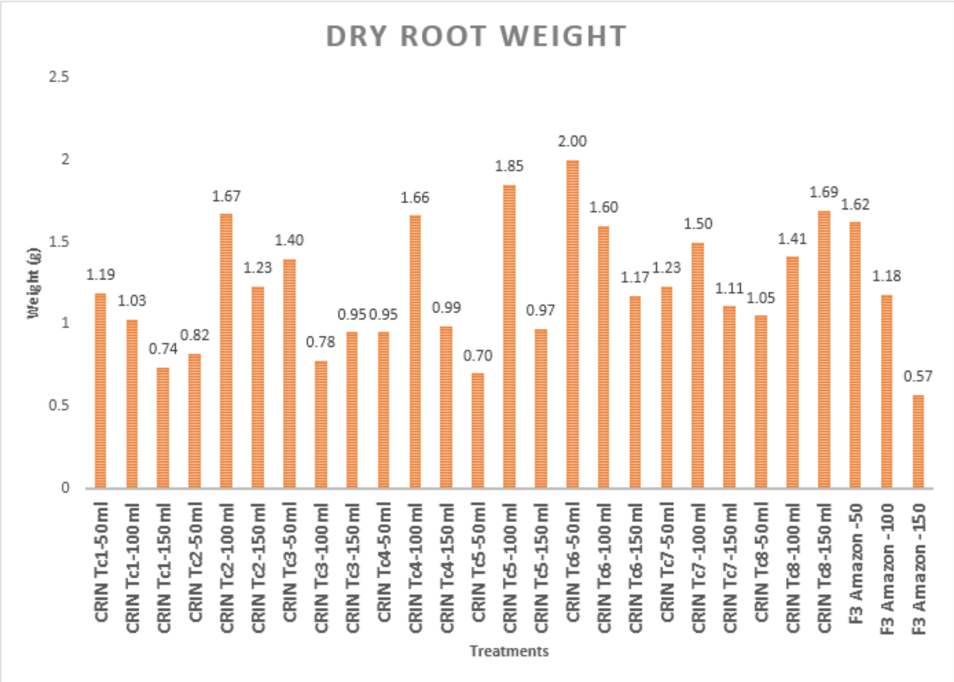

Fig. 2. Dry root weight of the cocoa CRINTc genotypes and watering rate treatments

Table 5. Response of cocoa genotypes and watering rates on leaves number

Treatments	No. of Leaves (NOL)				
	4 WAS	**8 WAS**	**12 WAS**	**16 WAS**	**20 WAS**
CRIN Tc1-50ml	3.2a	7.7a	7.8a	10.0a	10.3a
CRIN Tc1-100ml	3.3a	7.3a	8.7a	14.2a	14.7a
CRIN Tc1-150ml	4.0a	8.0a	8.7a	8.7a	8.7a
CRIN Tc2-50ml	1.6b	7.0a	10.0a	15.5a	15.5a
CRIN Tc2-100ml	2.3a	7.0a	7.7a	10.5a	11.0a
CRIN Tc2-150ml	2.0a	6.7a	9.5a	13.3a	17.8a
CRIN Tc3-50ml	3.5a	8.7a	9.2a	14.2a	17.0a
CRIN Tc3-100ml	1.8b	5.8a	5.8a	8.9a	9.2a
CRIN Tc3-150ml	4.17a	7.8a	8.0a	9.5a	10.3a
CRIN Tc4-50ml	2.8a	9.3a	10.2a	13.2a	14.3a
CRIN Tc4-100ml	3.5a	9.7a	12.2a	14.5a	15.7a
CRIN Tc4-150ml	3.0a	7.5a	7.8a	9.5a	10.7a
CRIN Tc5-50ml	4.5a	8.5a	9.0a	9.3a	11.5a
CRIN Tc5-100ml	2.5a	7.5a	8.2a	15.3a	16.8a
CRIN Tc5-150ml	1.8b	8.0a	9.7a	10.3a	13.0a
CRIN Tc6-50ml	4.2a	8.0a	10.a	12.8a	13.0a
CRIN Tc6-100ml	3.7a	8.7a	8.8a	10.0a	10.3a
CRIN Tc6-150ml	4.2a	7.8a	8.0a	9.5a	9.8a
CRIN Tc7-50ml	3.7a	6.2a	7.8a	8.8a	9.7a
CRIN Tc7-100ml	4.5ab	8.3a	8.5a	11.0a	11.2a
CRIN Tc7-150ml	4.5ab	8.2a	9.7a	10.7a	11.7a
CRIN Tc8-50ml	5.5a	10.7a	11.0a	11.3a	11.3a
CRIN Tc8-100ml	4.33a	7.8a	8.5a	9.5a	11.2a
CRIN Tc8-150ml	4.5a	7.8a	10.3a	14.8a	18.5a
F3 Amazon -50	4.0a	6.8a	10.5a	14.0a	14.3a
F3 Amazon -100	3.7a	8.3a	8.5a	11.2a	11.8a
F3 Amazon -150	2.7a	7.7a	7.8a	9.3a	11.0a

Means with the same letter(s) in a column are not significantly different (P≤0.05). WAS-Weeks after sowing

Table 6. Response of cocoa genotypes and watering rates on fresh weight parameters

Treatments	FSW (g)	FRW (g)	TRL (cm)
CRIN Tc1-50ml	6.7b	4.7a	14.5abc
CRIN Tc1-100ml	10.0ab	4.0a	16.8abc
CRIN Tc1-150ml	8.0ab	4.0a	13.8bc
CRIN Tc2-50ml	8.3ab	4.0a	12.6c
CRIN Tc2-100ml	12.3ab	4.3a	15.0abc
CRIN Tc2-150ml	16.3ab	5.0a	17.5abc
CRIN Tc3-50ml	12.7ab	5.3a	18.1abc
CRIN Tc3-100ml	8.3ab	5.0a	15.0abc
CRIN Tc3-150ml	8.0ab	4.3a	19.7abc
CRIN Tc4-50ml	8.0ab	4.0a	14.3abc
CRIN Tc4-100ml	20.0ab	6.3a	18.3abc
CRIN Tc4-150ml	8.3ab	4.0a	16.6abc
CRIN Tc5-50ml	6.3b	4.3a	15.9abc
CRIN Tc5-100ml	21.0a	7.3a	24.2a
CRIN Tc5-150ml	7.0b	4.0a	14.3abc
CRIN Tc6-50ml	6.0b	4.3a	14.9abc
CRIN Tc6-100ml	11.0ab	7.0a	19.9abc
CRIN Tc6-150ml	8.7ab	6.7a	15.9abc
CRIN Tc7-50ml	10.7ab	4.0a	21.0abc
CRIN Tc7-100ml	13.0ab	6.3a	15.7abc
CRIN Tc7-150ml	8.7ab	4.0a	13.7bc

Treatments	FSW (g)	FRW (g)	TRL (cm)
CRIN Tc8-50ml	12.7ab	7.3a	24.4a
CRIN Tc8-100ml	9.7ab	4.7a	17.6abc
CRIN Tc8-150ml	16.7ab	6.0a	23.4ab
F3 Amazon -50	12.0ab	6.7a	21.5abc
F3 Amazon -100	12.0ab	4.0a	14.6abc
F3 Amazon -150	7.3ab	4.3a	17.2abc

Means with the same letter(s) in a column are not significantly different (P≤0.05). Fresh Shoot Weight (FSW), Fresh Root Weight (FSW) and Tap Root Length (TRL)

4. CONCLUSION

The application of the 3 watering levels 50ml, 100ml and 150ml didn’t make any considerable difference on the emergence of the cocoa CRINTc 1-8 genotypes and the F3 Amazon, though 50 ml watering rate had more 100% emergence followed by 100 ml and 150 ml who had same but lesser occurrence of 100% emergence than when 50ml watering rate was applied after 4 weeks.

The watering levels influenced the morphological traits, fresh and dry weight of the shoot and root parameters of the cocoa CRINTc 1-8 genotypes and the F3 Amazon at some levels and peroids of the experiment. Generally putting all the CRINTc 1-8 genotypes and F3 Amazon into consideration, 100 ml watering rate performed best, followed by 150 ml and lastly 50ml watering rate. As a follow up to this study, the performance of these cocoa seedlings on the field should be examined after transplanting.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the contributions of the staff of the Nursery Sections of Cocoa Research Institute of Nigeria and also the effort of Mr. Adesanya K.A. and Dr. Mrs. Olorundare O.B during the data collection phase of this experiment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. International Cocoa Organization. Annual Report. ICCO. 2007:23-25.
2. Agele S, Famuwagun B, Ogunleye A. Effects of shade on microclimate, canopy characteristics and light integrals in dry season field-grown cocoa (*Theobroma cacao* L.) seedlings. Journal of Horticulture. 2016;11(1):47-56.
3. Daba MH, Tadese AE. Estimation of optimum water requirement and frequency of watering for different tree seedlings at Bako Agricultural Research Center nursery site. Journal of Health and Environmental Research. 2017;3(6):90-97.
4. Mhango J, Akinnifesi FK, Mng’omba SA, Sileshi G. Effect of growing medium on early growth and survival of *Uapaca kirkiana* Müell Arg. seedlings in Malawi. African Journal of Biotechnology. 2008; 7(13).
5. Mng’omba SA, Akinnifesi FK, Sileshi G, Ajayi OC, Nyoka BI, Jamnadass R. Water application rate and frequency affect seedling survival and growth of *Vangueria infausta* and *Persea americana*. African Journal of Biotechnology. 2011;10(9):1593-1599.
6. Oboho EG, Igharo B. Effect of pregermination treatments on germination and watering regimes on the early growth of *Pycnanthus angolensis* (Welw) Warb. Journal of Agriculture and Veterinary Science. 2017;10(3):62-68.
7. Morrison J, Morikawa M, Murphy M, Schulte P. Water scarcity & climate change: Growing risks for businesses and investors. A Ceres Report, Ceres, Boston; 2009.
8. Aderounmu AF, Onilude QA, Oladele AT. Diversity and growth characteristics of tree species in the botanical gardens, University of Ibadan, Nigeria. Journal of Forests. 2017;4(2):27-34.
9. Rosenzweig C, Iglesius A, Yang XB, Epstein PR, Chivian E. Climate change and extreme weather events-implications for food production, plant diseases, and pests; 2001.
10. Blum A. Crop response to drought and the interpretation of adaptation. Plant Growth Regul. 1996;20:135–148.
11. Chaitanya KV, Sundar D, Jutur PP, Ramachandra A. Water stress effects on photosynthesis in different mulberry

cultivars. Plant Growth Regul. 2003;40: 75–80.

12. Shao HB, Chu LY, Lu ZH, Kang CM. Main antioxidants and redox signaling in higher plant cells. Int. J. Biol. Sci. 2008;44:12–18.
13. Bae H, Kim S, Kim MS, Sicher RC, Lary D, Strem MD, Natarajan S, Bailey BA. The drought response of *Theobroma cacao* (cacao) and the regulation of genes involved in polyamine biosynthesis by drought and other stresses. Plant Physiology and Biochemistry. 2008;46: 174188.
Available:http://dx.doi.org/10.1016/j.plaphy.2007.10.014
14. Raja Harun RM, Hardwick K. The effect of different temperatures and water vapour pressure deficits on photosynthesis and transpiration of cocoa leaves. Proceeding of the 10th International Cocoa Research Conference, Santo Domingo, Dominican Republic, 1723 May. 1987:211214.
15. Ayegboyin KO, Akinrinde EA. Effect of water deficit imposed during the early developmental phase on photosynthesis of cocoa (*Theobroma cacao* L.). Agricultural Sciences. 2016;07:11-19.
DOI: 10.4236/as.2016.71002
16. Dias PC, Araujo WL, Moraes GABK, Barros RS, Damatta FM. Morphological and physiological responses of two coffee progenies to soil water availability. Journal of Plant Physiology. 2007;164:16391647.
Available:http://dx.doi.org/10.1016/j.jplph.2006.12.004
17. Krishnan P, Meyers TP, Scott RL, Kennedy L, Heuer M. Energy exchange and evapotranspiration over two temperate semi-arid grasslands in North America. Agricultural and Forest Meteorology. 2012;153:31-44.
18. SAS Institute. The SAS system for Windows. Release 9.2.SAS.Inst., Gary, NC, USA; 2007.
19. Gush M, Moodley M. Water use assessment of *Jatropha curca*s. In: *Jatropha curcas* in South Africa: An assessment of its water use and bio-physical potential; 2007.
20. Tolulope OB, Joshua K. Effects of watering regimes on germination and early seedling development of *Dioscoreophyllum cumminsii*. SCIREA Journal of Biology. 2018;3(1):16-25.
21. Olajide O, Oyedeji AA, Tom GS, Kayode J. Seed germination and effects of three watering regimes on the growth of *Dialium guineense* (wild) seedlings. Am. J. Plant Sci. 2014;5:3049-3059.
22. Buriro M, Sanjrani AS, Chachar QI, Chachar NA, Chachar SD, Buriro B, Mangan T. Effect of water stress on growth and yield of sunflower. Journal of Agricultural Technology. 2015;11(7):1547-1563.
23. Agele SO, Osaigbovo AU, Ogedegbe SA, Nwawe AK. Effects of watering regime, organic manuring and mycorrhizal inoculation on the growth and development of Shea butter (*Vitellaria paradoxa* C.F. Gaertn) seedlings. International Journal of Agricultural Policy and Research. 2015; 4(3):35-45.
24. Emmanuel GA. Effect of watering regimes and water quantity on the early seedling growth of *Picralima nitida* (stapf). Sustainable Agric. Res. 2014;3:35-43.
25. Ogunrotimi DG, Kayode J. Effect of watering regimes on early seedling growth of *Solanum macrocarpon* L. (solanaceae). Journal of Applied Sciences. 2018;18:79-85.
26. Dauda TO, Asiribo OE, Akinbode SO, Saka JO, Salahu BF. An assessment of the roles of irrigation farming in the millennium development goals. Afr. J. Agric. Res. 2009;4:445-450.
27. Gbadamosi AE. Effect of watering regimes and water quantity on the early seedling growth of *Picralima nitida* (Stapf); 2014.
Available:http://dx.doi.org/10.5539/sar.v3n2p35
28. Ogidan OA, Olajire-Ajayi BL, Adenuga DA. Assessment of watering regimes on seedling growth performance of *Kigelia africana* (Lam) Benth. Biodiversity Conservation and National Development Potentials and Challenges. Proceedings of 6th Nigeria Chapter of Society for Conservation Biology (NSCB). Biodiversity Conference. 2018:341-345.
29. Olajuyigbe S, Tobin B, Saunders M, Nieuwenhuis M. Forest thinning and soil respiration in a sitka spruce forest in Ireland. Agricultural and Forest Meteorology. 2012;157:86-95.
30. Domínguez-Caraveo H, et al. Emergency and survival of blue grama with biosolids under greenhouse conditions. J. Arid Environ. 2010;74:87-92.
31. Rahman MN, Hangs R, Schoenau J. Influence of soil temperature and moisture on micronutrient supply, plant uptake, and biomass yield of wheat, pea, and canola.

Journal of Plant Nutrition. 2020;43(6):823-833.

32. Oloyede AA, Olaniyi OO, et al. Simulating cacao hybrids field spacing's based on some morphological variables in the nursery. Proceedings of the 9th annual conference of the Horticultural Society of Nigeria (Hortson) CRIN; 2021. Available:https://crin.gov.ng/wp-content/uploads/2022/02/Proceedings-of-39th-Annual-Conference-of-the-Horticultural-Society-of-Nigeria-HORTSON-CRIN-2021.pdf Pg. 1353- 1356

33. Adejobi KB, Akanbi OS, Ugioro O, Adeosun SA, Mohammed I, Nduka BA, Adeniyi DO. Comparative effects of NPK fertilizer, cowpea pod husk and some tree crops wastes on soil, leaf chemical properties and growth performance of cocoa (*Theobroma cacao* L.). African Journal of Plant Science. 2014;8(2):103-107.

34. Bhatt RM, Srinivasa NK. Influence of pod load on response of okra to water stress. Indian J. Plant Physiol. 2005;10: 54–59.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/98999