MORPHO-PHYSIOLOGICAL ASSESSMENT OF OIL PALM (*Elaeis guineensis* Jacq.) SEEDLINGS EXPOSED TO SIMULATED DROUGHT CONDITIONS

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ABSTRACT

Elaeis guineensis *Jacq. (oil palm) production is threatened by drought due to climate change and anthropogenic deforestation. This study aims to understand how drought conditions contribute to changes in foliar nitrate-nitrogen concentration as well as the effects on the growth and development of oil palm seedlings. Seventy oil palm seedlings were maintained in a screen house and subjected to simulated drought conditions. There was a significant reduction in the number of leaves with increased drought exposure from 10 to four per plant. Oil palm leaves exposed to higher drought levels had less broad leaves, with leaf area ranging from 133.25-172.22 cm² compared to the control (383.73 cm²). The foliar yield per plant was low in plants exposed to extreme drought condition (2.27 g), compared to 71.98 g in the control. Moreover, total drought-exposed oil palm seedlings had the highest concentration of nitrate-nitrogen.* E. guineensis *exposed to no-drought conditions had more roots (18 roots) than those exposed to total or partial drought (6-10 roots per plant). Overall, there was a decrease in height, leaf area and the number of leaves for most of the seedlings exposed to drought condition, which might be detrimental to their photosynthetic ability and growth.*

INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.), is a monocotyledonous tropical palm tree, which belongs to the family Arecaceae and is believed to have originated in West Africa (Poku, 2002). It is the major source of edible and industrial oil in west, east and central parts of Africa and Madagascar. *Elaeis guineensis* is also domesticated in Sri Lanka, Indonesia, Malaysia, Madagascar, Central America,

along with many other island states in the Indian and Pacific Oceans. It is a close relative of the American oil palm [*Elaeis oleifera* (Kunth.) Cortes] and a distant relative of maripa palm [*Attalea maripa* (Aubl.) Mart.] found in the Caribbean (Hormaza *et al.*, 2012). Human use of oil palms dates as far back as 5000 years in West Africa. Three cultivars of oil palm are common in Nigeria; namely *Dura, Pisifera* and *Tenera* (FAO, 2002; Okolo *et al.*, 2019). The preferred variety among oil palm farmers in Nigeria is the hybrid cultivar, *Tenera*; which is a crossbreed of *Dura* (female) and *Pisifera* (male). *Tenera* seedlings are produced by the Nigeria Institute for Oil Palm Research (NIFOR) and largely used in extension works to promote oil palm cultivation (Iankova *et al.*, 2016). In terms of comparison, the fruit of the *Tenera* contains 25% oil (by weight), whereas it is 18% in *Dura*. Oil palm is common in Edo State, Nigeria where climate change events are becoming more frequent (Ogwu *et al.*, 2014; Ogwu, 2019).

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Uptake of nutrients is low during the first year in oil palm but increases steeply between year one and three (when harvesting commences) and stabilises around year five to six (Woittiez *et al.*, 2017). Early applications of fertiliser, better planting material and more rigid culling have led to a dramatic increase in early yields in the third to sixth year after planting. Nitrogen, which mostly enters the plant as soluble nitrate ion, is a building block for tissue growth. Nitrogen is an integral part of most essential components including in chlorophyll and nucleic acids. Without nitrogen, there might be limited to no growth and yield. Nitrogen deficiency first shows up as discolouration of young oil palm fronds, which lose their healthy dark green colour and turn yellow (chlorosis). Nitrogen deficiency is caused by some factors including poor drainage and waterlogged soil; inherently infertile soils exhausted by previous agricultural activities, excessive competition from weeds (Hartley, 1988; Lai *et al.*, 2019). In regions without a significant drop in rainfall, yields of over 25 t of fresh fruit bunches (FFB) per hectare have been achieved in the second year of harvesting. On the other hand, drought stress results when water loss from the plant exceeds the ability of roots to absorb water and when the plant's water content is reduced enough to interfere with normal plant processes. Water is a universal solvent needed by plants to grow and is a major constituent of plant cells, without which, photosynthesis and consequently, growth processes may be hampered (Carr, 2011; Safitri *et al.*, 2019).

This study aims to understand how drought conditions contribute to changes in foliar nitrate-nitrogen concentration as well as the effects on the growth and development of oil palm. The combined use of morphology and other traits to characterise plant germplasm is increasingly commonplace (Osawaru *et al.*, 2013; 2014a; 2014b). Drought stress may take time to become visible in plants and depends on the water holding capacity (WHC) of the soil, environmental conditions, stage of plant growth and plant species. Moreover, poorly established plants are more susceptible to drought stress because of the limited root system (low root-shoot ratio). During drought conditions, there is a shortage of water for plant use. Hence, given the obvious challenges posed by recent trends in climate change, it is pertinent to assess drought stress in oil palm seedlings.

MATERIALS AND METHODS

Plant Materials and Growth Conditions

Seventy palm samples, all of which were six months old where selected randomly from a pool of oil palm nursery at NIFOR, Benin City, Nigeria. The oil palm seedlings were held in black polyethene nursery bags and maintained in a screen house to shield the palms from rainfall. It is in the screen house that different water treatments were applied to the oil palm seedlings. The experiment was initiated in July 2018, but the application of treatments started in August 2018, which was enough time for the oil palm seedlings to get acclimatised to the screen house. Measurements of experimental parameters took place six months after sowing.

Collection of Topsoil Used in the Study

Topsoil (0-15 cm) was collected from NIFOR and pooled to obtain composite samples. The soil was sun-dried to constant weight. Thereafter 7.50 kg was measured each into perforated nursery bags. A total of 70 bags were arranged in the screen house for the experiment.

Water Holding Capacity (WHC) of the Soil

The experiment relied on the restricted application of water and the WHC of the soil was determined before commencing the experimental procedures. About 1.00 kg of sun-dried soil was placed in a funnel initially lined with Whatman's filter paper (A). Water was poured unto it to completely saturate the soil. This was left overnight in a darkroom. The next morning, the weight of the saturated soil was taken (B) and the difference (B-A) was expressed in mL per kg. The WHC of the soil was determined to be 480 mL kg^{-1}. This amounted to 3600 mL per nursery bag.

Simulation of Drought

The drought conditions for the experiment was a factor of the WHC. There were six levels comprising of control, total drought, 0.05% WHC, 0.10% WHC, 0.50% WHC, 1.00% WHC and 5.00% WHC (*Table 1*).

Application of Treatment

Initially, the entire nursery bags received 3600 mL of water, which represented the WHC of the entire 7.50 kg soil. Thereafter, the oil palm seedlings were transplanted and left in the screen house for two weeks. Subsequently, the seedlings were divided into seven groups, comprising 10 per group and randomised within the experimental block. Each group received the designated amount of water as presented in *Table 1*.

Determination of Plant Growth Characteristics

Some plant growth characteristics including the number of leaves as well as dry weight of the total number of leaves (hereafter referred to as

foliar yield). Number of roots were also physically counted. In the experiment, the prominent roots were defined as those roots that were significantly larger and longer than the other roots. The lengths of these prominent roots were determined. Similar to foliar yield, root yield per plant was calculated as dry weight of all physically removed roots.

Determination of Nitrate-Nitrogen

This was carried out according to Smith (1974) and summarised here - test plant was oven-dried at 65°C for 24 hr and then ground to 40-mesh sized powder. The ground sample was re-dried in an oven at 70°C. A measure of 100 mg of ground sample was suspended in deionised water and incubated at 45°C for 1 hr. The incubated suspension was then mixed and centrifuged at 5000 xg for 15 min to sediment tissue residues. The supernatant was decanted and kept for analysis.

Preparation of Stock Nitrate Solution

Potassium trinitrate (V) (KNO_3) was oven dried for 24 hr at 105°C and then 1.63 g of the dried salt was weighed into 250 mL flask and dissolved with distilled water. The solution was transferred into 1-L flask made to the mark with distilled water to obtain 1000 ppm of stock KNO_3 solution.

Preparation of Standard Nitrate Solution

Using a 100 mL measuring cylinder, 50 mL of the stock solution was measured into 500 mL flask and made to the mark with water. This was carefully swirled to mix to obtain 100 mg L^{-1} of the stock. From the 100 mg L^{-1} standards concentrations of 80-10 mg L^{-1} was prepared by serial dilution.

Preparation of 2N Solution of Sodium hydroxide (NaOH)

Exactly 40 g of NaOH pellets were introduced into a 250 mL beaker and dissolved with distilled water. The solution obtained was transferred into a 500 mL flask and made up to the mark.

Preparation of Salicylic Acid Solution

Five grams of salicylic acid was dissolved in concentrated sulphuric acid (H_2SO_4) and diluted to 100 mL with the same acid. The solution obtained was stored in amber bottles.

Calibration and Estimation of Nitrate-N in Plant Tissue

Aliquots (0.1 mL) of working standards solution in 30.0 mL tube were mixed thoroughly with 0.4 mL salicylic acid solution. After 20 min at room temperature, 9.5 mL 2N sodium hydroxide (NaOH) solution was slowly added to obtain 0.1-1.0 mg L^{-1} NO_3-N solutions. The plant extract was analysed for Nitrate-N by mixing 5 g plant extract, 0.8 mL concentrated H_2SO_4, 19.0 mL of NaOH and 0.4 mL of salicylic acid solution. A similar mixture of the plant extract (without salicylic acid) was used as blank. The nitrosalicylic acid complex formed was read at maximum absorption of 412 nm using a spectrophotometer.

For this determination, seven different water rates were applied to oil palm seedlings; control, total drought, 0.05% WHC, 0.1% WHC, 0.5% WHC, 1% WHC and 5% WHC. Each treatment was replicated 10 times namely; A, B, C, D, E, F, G, H, I, J, culminating in 70 experimental units. The experimental units were then laid out in the completely randomised design in the NIFOR screen house.

Statistical Analysis

Data obtained from the study were analysed using statistical package for social sciences (SPSS) statistical software version 21. Results were presented as the mean of 10 replicates and separated at 95% confidence interval.

TABLE 1. EXPERIMENTAL TREATMENTS TO SIMULATE DROUGHT CONDITIONS

Treatments	Treatment factor per 7.5 kg soil	Quantity of water applied to soil (7.5 kg) per week
Control	Soil was watered normally	Frequent soil wetting as soon as soil moisture was reduced
Total drought	No water applied at all	0.36 mL applied to soil weekly
0.05% WHC	0.005 x 3600 = 1.8 mL	1.8 mL applied to soil on a weekly basis
0.1% WHC	0.0001 x 3600 = 3.6 mL	23.6 mL applied to soil on a weekly basis
0.5% WHC	0.0001 x 3600 = 18.0 mL	18.0 mL applied to soil on a weekly basis
1% WHC	0.0001 x 3600 = 36.0 mL	36.0 mL applied to soil on a weekly basis
5% WHC	0.0001 x 3600 = 180.0 mL	180.0 mL applied to soil on a weekly basis

Note: WHC - water holding capacity.

RESULTS AND DISCUSSION

The present study explored the assimilation of nitrogen in oil palm seedlings exposed to drought stress. Some morphological parameters of the palm seedlings at six months after sowing are presented in *Table 2*. Results showed a significant reduction in the number of leaves with increased drought exposure from 10 to four per plant. Similarly, leaves that were exposed to higher drought levels had less broad leaves, with leaf area ranging from 133.25-172.22 cm^2, compared to the control with a leaf area of 383.73 cm^2. The foliar yield per plant was significantly low in the plant with the total drought treatment (2.27 g), compared to 71.98 g in the control. Altogether, these results suggest the importance of water supply in oil palm production as earlier suggested by Carr (2011). Moreover, this also supports the findings of Caliman and Southworth (1998), which highlighted the effects *El Nino*-induced droughts in oil palm cultivation region of Southeast Asia.

There was a general decrease in the height of most of the seedlings exposed to drought condition. It was observed that the height of oil palm seedlings at Week 4 was 31.10 cm and 36.40 cm at Week 16 in T1, which showed less than 15% increase in height compared to the control group. Height of seedling increased from 27.5 cm at Week 4 to 57.1 cm in control, which showed over 50% increase with respect height of seedlings. The difference is clearly because the control oil palm seedlings were not subjected to physiological (and other) stress and therefore performed normal metabolic functions needed for its growth and development. In the same way, Gupta *et al*. (2001) also observed a slow progression in height of their test plants, which they attributed to low water potential elicited by drought condition. Further, this may

have raised the osmotic potential in the test plant, thus, prompting the expression of genes that code for traits essential for survival without a significant increase in height (Delperee *et al*., 2003; Zgallai *et al*., 2006). Neilson *et al*. (2015) used advanced high-throughput screening platforms equipped with an automated irrigation system to measure a wide range of morpho-physiological variables in a large number of genotypes of cereal crops to support their view that plants have the capacity to down-regulate genes for certain metabolic activities under drought stress. The age of the oil palm seedlings and the duration of the drought period are important factors in the present study. However, plants can respond properly to drought stress with enhanced growth-promoting hormones like auxin (Mshelmbula *et al.,* 2015; Ogwu, 2018; Ogwu *et al*., 2015).

The number of necrotic leaves on oil palm seedlings at six months after planting are presented in *Table 3*. The effects of drought was noticed in all the test plants as leaf necrosis began to appear after four weeks and progressed over time. There were 4.80 necrotic leaves at Week 4 in the total drought-exposed oil palm seedlings and increased to 5.08 by Week 14. In oil palm seedlings exposed to soils with 0.1% WHC, the number of necrotic leaves were 4.85 at Week 4 and 5.03 at Week 14, whereas the number of necrotic leaves in the control group remains significantly negligible compared to the test plants subjected to drought stress. Observably, although oil palm seedlings exposed to soils with 0.5% WHC showed similar evidence of drought stress with evidence of necrosis like other test plants, the number of necrotic leaves in the plant had remained fairly the same throughout the study. The work of Ikhajiagbe and Anoliefo (2011) suggest that plant tolerance to drought can be enhanced by using soil amendments.

TABLE 2. MORPHOLOGICAL ASSESSMENT OF DROUGHT-EXPOSED OIL PALM SEEDLINGS AT SIX MONTHS AFTER SOWING

Treatments	Plant height (cm)	*No. of leaves	Leaf area (cm^2)	Foliar yield/ plant (g)	Percentage senescence (%)	Stem girth (cm)
Total drought	35.8 ± 2.3[a]	5 ± 2[a]	166.27 ± 45.32[a]	2.27 ± 1.08[a]	25.36 ± 9.02[ab]	4.40 ± 0.92[a]
0.05% WHC	33.4 ± 3.4[a]	6 ± 2[a]	133.25 ± 52.14[a]	4.37 ± 1.65[a]	43.39 ± 11.37[b]	4.58 ± 1.01[a]
0.1% WHC	36.4 ± 2.7[a]	6 ± 2[a]	142.76 ± 27.22[a]	5.46 ± 2.01[a]	22.21 ± 9.11[ab]	4.75 ± 0.65[a]
0.5% WHC	36.5 ± 3.2[a]	4 ± 2[a]	160.76 ± 75.06[a]	4.77 ± 1.88[a]	33.37 ± 8.02[b]	4.03 ± 0.42[a]
1% WHC	34.4 ± 4.1[a]	5 ± 3[a]	152.42 ± 66.93[a]	5.88 ± 2.66[a]	37.52 ± 9.02[b]	4.20 ± 0.73[a]
5% WHC	43.2 ± 2.9[b]	7 ± 2[ab]	172.22 ± 55.11[a]	20.13 ± 8.42[b]	11.10 ± 7.14[a]	5.63 ± 1.12[a]
Control	49.7 ± 2.3[c]	10 ± 3[b]	383.73 ± 85.73[b]	71.98 ± 19.02[c]	0.00[c]	9.30 ± 1.82[b]
p-value	<0.001	0.034	<0.001	<0.001	<0.001	<0.001

Note: *Means and standard error have been provided to the nearest whole number. The concentrations of water applied to soil were based on soil's initial water holding capacity. Values on same column with similar alphabetic superscripts are not significantly different from one another (*p*>0.05). FL/Plant = No. of foraged leaves/plant; PFC - percentage foliar chlorosis; WHC - water holding capacity.

Leaf area is affected during drought stress conditions in plants, as plants tend to reduce the possibility of losing more water in addition to the prevalent condition. There were general increases in the leaf areas in all the experimental plants irrespective of the treatment. Nonetheless, the increase in leaf area was lower in all the oil palm seedlings subjected to drought conditions compared to that of control group. This could probably be due to the restrained metabolic processes necessary to promote leaf enlargement in the plant and also reduce evapotranspiration, which could hasten the death of drought-stressed plant through acute dehydration (Parker and Pallardy, 1985; Puértolas et al., 2017). As the stress condition intensified, the plant may resort to drastic steps to increase its chances of survival under the prevailing unsupportive environment and this may be effective by the production of metabolites that cause leaf senescence resulting from stress and not from age. This explains the reduction in the number of leaves observed in oil palm seedlings after exposure to drought stress in the present study (Table 3). This view is in line with the outcome of previous investigations including those of Kabiri (2010); Kafi and Mahdavi-Damghani (1999); Kavar et al. (2007).

Nitrate concentration was assayed in oil palm seedlings during the present study and results showed that total drought-exposed oil palm seedlings had the highest concentration of nitrate-nitrogen (Table 4). Nitrate concentration was 3.17 mg kg^{-1} dry weight (DW) of oil palm seedling in the total drought-exposed oil palm seedlings whereas it was 0.88 mg kg^{-1} DW in the oil palm seedlings exposed to 0.5% WHC, and it was 1.64 k kg^{-1} DW and 1.62 mg kg^{-1} DW in oil palm seedlings exposed to 0.1% WHC and 1% WHC respectively. Symptoms of drought in oil palm include general paling and stiffening of the pinnae, which lose their glossy lustre. The report of Al-Amin et al. (2011) suggests that drought lower the yield of FFB in oil palm up to 26.30%. The decline of oil palm yield is a direct effect of inhibition of the photosynthetic rate of oil palm (Jafaar and Ibrahim, 2012; Russell et al., 2017). Increasing nitrogen utilisation in the face of environmental stress can also improve plant performance (Ikhajiagbe et al., 2020).

TABLE 3. NUMBER OF LEAVES WITH NECROTIC LESIONS OF DROUGHT-EXPOSED OIL PALM SEEDLINGS AT SIX MONTHS AFTER SOWING

	Weeks after transplanting						
Treatments	4	6	8	10	12	14	16
Total drought	4.8 ± 0.44[ab]	5.45 ± 0.98[a]	5.75 ± 0.83[a]	5.70 ± 0.93[c]	4.6 ± 0.52[a]	5.08 ± 0.83[a]	4.40 ± 0.52[a]
0.05% WHC	4.47 ± 0.65[a]	4.72 ± 1.01[a]	4.88 ± 0.73[a]	4.9 ± 0.74[bc]	4.1 ± 0.99[a]	4.75 ± 1.22[a]	4.58 ± 0.73[a]
0.1% WHC	4.85 ± 0.83[ab]	5.25 ± 0.93[a]	5.58 ± 1.06[a]	5.23 ± 0.41[bc]	4.8 ± 0.73[a]	5.03 ± 0.734[a]	4.75 ± 1.01[a]
0.5% WHC	4.8 ± 0.81[ab]	4.40 ± 1.01[a]	5.18 ± 0.99[a]	4.35 ± 0.44[b]	5.6 ± 1.04[a]	4.60 ± 1.42[a]	4.03 ± 0.55[a]
1% WHC	5.5 ± 0.38[b]	4.67 ± 0.85[a]	5.28 ± 0.75[a]	4.68 ± 0.39[b]	5.1 ± 0.79[a]	5.18 ± 2.02[a]	4.20 ± 0.92[a]
5% WHC	5.2 ± 0.42[ab]	5.12 ± 0.73[a]	4.58 ± 1.03[a]	4.8[b] ± 0.31[c]	5.9 ± 1.15[a]	5.70 ± 1.55[a]	5.63 ± 1.15[a]
Control	1.1 ± 0.33[c]	1.23 ± 0.18[c]	1.32 ± 0.78[c]	1.24 ± 0.66[a]	1.2 ± 0.78[b]	1.18 ± 0.64[b]	1.30 ± 0.56[b]
p-value	0.323	0.415	0.776	0.004	0.004	0	0
F-value	1.248	1.062	0.535	4.531	4.495	11.97	32.906

Note: The concentrations of water applied to soil were based on soil's initial water holding capacity (WHC). Values on the same column with similar alphabetic superscripts do not differ from one another (*p*>0.05).

TABLE 4. CONCENTRATION OF NITRATE IN THE LEAVES OF DROUGHT-EXPOSED OIL PALM SEEDLINGS AT SIX MONTHS AFTER SOWING

Treatments	Foliar nitrate concentration (mg kg^{-1} DW)
Total drought	3.17 ± 1.04[b]
0.05% WHC	1.36 ± 0.78[ab]
0.1% WHC	1.64 ± 0.65[ab]
0.5% WHC	1.26 ± 0.82[ab]
1% WHC	1.62 ± 0.79[ab]
5% WHC	0.88 ± 0.23[a]
Control	1.07 ± 0.64[a]
F-value	1.73 x 10^6
***p*-value**	1.84 x 10^6

Note: The concentrations of water applied to soil were based on soil's initial water holding capacity (WHC). Values on the same column with similar alphabetic superscripts are not significantly different from one another (*p*>0.05).

Below ground parameters of the test plants showed that plants exposed to non-drought conditions had significantly more roots (18 roots) than those exposed to total or partial drought (6-10 roots per plant) (*Table 5*). There were between two and four prominent roots across the experiment, irrespective of drought conditions. However, root yield per plant, which was determined in the study as the dried weight of entire roots obtained per plant, was higher in the control (11.46 g) than in the drought-exposed plants (3.50-6.53 g). The low stomatal conductance decreases the rate of carbon dioxide (CO_2) diffusion so that the photosynthetic activity of oil palm is inhibited (Henson and Harun, 2007). Other factors that inhibit the rate of photosynthesis in drought conditions are the relatively low water content (Fahramand *et al.*, 2014; Zain *et al.*, 2014), low chlorophyll *a/b*, and reduced nitrogen and phosphorus contents in leaf tissue of plants (Ashraf and Harris, 2013; Zlatev and Lindon, 2012).

Morphological description of drought-exposed oil palm seedlings at six months after sowing are presented in *Table 6*. Results showed that plants that were exposed to total drought showed dried-out leaves and most of them folded upwards. Leaves of the control plants were green, with no signs of chlorotic or necrosis; only two leaves showed signs of foliar scorching. During periods of drought, nutrient deficiency and changes in metabolism are common in oil palm (Silva *et al.*, 2018). Our results support the recent findings by Corley *et al.* (2018) that the future of the oil palm industry will depend on the successful breeding of drought-resistant species.

CONCLUSION

In conclusion, drought stress leads to poor growth and development in oil palm seedlings, which may lower production in oil palm. Drought causes stomatal conductance of oil palm leaves to decline rapidly as more stomata close, which may also be detrimental to the photosynthetic ability and growth of the plant. Oil palm is very sensitive to drought and countries where products are greatest are highly vulnerable to this climate change effect. Therefore, if current trends are left unchecked, in a few decades climate change-induced drought might significantly affect the global output of oil palm. Agronomic approaches can be taken to reduce the sensitivity of oil palm to drought including planting drought-resistant varieties and adopting

TABLE 5. NUMBER OF ROOTS AND LENGTH OF PROMINENT ROOT OF DROUGHT-EXPOSED OIL PALM SEEDLINGS AT SIX MONTHS AFTER TRANSPLANTING

Treatments	No of roots	*No. of prominent roots	Length of prominent roots	Total root weight (g DW)
Total drought	10 ± 3[b]	2 ± 1[a]	23.4 ± 8.3[c]	3.504 ± 1.032[a]
0.05% WHC	7 ± 3[b]	4 ± 2[a]	27.1 ± 7.1[c]	3.195 ± 1.109[a]
0.1% WHC	10 ± 2[b]	3 ± 1[a]	27.7 ± 6.8[c]	3.054 ± 1.047[a]
0.5% WHC	6 ± 3[b]	2 ± 1[a]	35.5 ± 7.4[bc]	4.832 ± 0.092[a]
1% WHC	7 ± 3[b]	3 ± 1[a]	24.4 ± 9.3[c]	4.194 ± 0.432[a]
5% WHC	9 ± 3[b]	2 ± 1[a]	70.5 ± 11.1[a]	6.532 ± 0.509[b]
Control	18 ± 4[a]	3 ± 1[a]	57.5 ± 9.4[ab]	11.458 ± 2.093[c]
p-value	0.002	0.643	0.015	<0.001

Note: *Means and standard error have been provided to the nearest whole number. The concentrations of water applied to soil were based on soil's initial water holding capacity (WHC). Values on the same column with similar alphabetic superscripts are not significantly different from one another (*p*>0.05).

TABLE 6. MORPHOLOGICAL DESCRIPTION OF DROUGHT-EXPOSED OIL PALM SEEDLINGS AT SIX MONTHS AFTER SOWING

Treatments	Morphological description
Total drought	Leaves were totally dry and most of them were folded upwards
0.05% WHC	All of its leaves had dried up and two out of the five leaves where folded
0.1% WHC	Leaves were necrotic (dried up)
0.5% WHC	Leaves were brown and the whole seedling was dry
1% WHC	Leaves were necrotic with one out of its five leaves twisted
5% WHC	Signs of foliar necrosis. An additional leaf showed partial necrosis
Control	Leaves were fresh and green, only two leaves showed signs of foliar scorching

Note: WHC – water holding capacity.

sustainable irrigation practices. The findings from this study suggest that drought produces variable growth and developmental response in *E. guineensis* seedlings such as a decrease in height, leaf area, number of leaves and roots for most of the seedlings exposed to drought condition. An important caveat to the findings reported here is a potential birch effect resulting from the drying of experimental soil. However, many oil palm cultivation regions around the world are currently having prolonged dry seasons without rain.

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