EFFECTS OF SOIL WATER REGIMES ON GROWTH OF OIL PALM SEEDLING (*ELAESIS GUINEENSIS* JACQ.) IN ORLU SERIES.

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ABSTRACT
Inadequate soil moisture is a major factor limiting oil palm seedling production in Nigeria especially in the dry season. A pot experiment was carried out in a greenhouse at the Nigerian Institute for Oil Palm Research (NIFOR), main station, Benin City, Edo State Nigeria. The study lasted from October 2019 to March 2020. The purpose was to study the effects of soil water regimes on growth of oil palm seedling. The treatments consisted of six soil water regimes {(95 to 100 % (control), 70 to 75 %, 60 to 65%, 50 to 55 %, 40 to 45% and 30 to 35 % of field capacity (FC) were used}. These treatments were arranged in Completely Randomized Design (CRD) with three replications. The obtained results showed that plant highest, leaf area, base circumference and dry matter yield of oil palm seedling were highest in the control treatment (95 – 100 % FC). Above mentioned growth parameters did not differ between 95 – 100 and 70 – 75 % of FC. In addition, when soil moisture level decreased from 60 – 65 % to 30 – 35 % of FC, vegetative growth and dry matter yield of oil palm seedling were negatively affected. The result suggest that, optimum growth could be achieved by maintaining soil moisture at or above 70 – 75 % of FC thus illustrating that below this level of soil moisture may be detrimental for oil palm seedling growth in Orlu series of the study area

Keywords: Soil water regime, growth, oil palm seedlings

INTRODUCTION
Oil palm (*Elaeis guineensis* Jacq.) is one of the most important economic oil crops in Nigeria (Hartely, 1988). It is indigenous to the Nigerian coastal plain through it has migrated inland as a staple crop. Cultivation of oil palm serves as a means of livelihood for many rural families and indeed the farming culture of millions of people in the southern part of Nigeria (NIFOR, 2008). The reference to oil palm as a crop of multiple value underscore its economic importance, namely the bunches, fronds, the leaves, the trunk and the roots which are used for several purposes ranging from palm oil, palm kernel oil, palm wine, broom and palm kernel cake. Despite the importance of oil palm, production of the crop is limited under seasonal moisture fluctuations (Omerije, 2005).
The oil palm is also grown in the rain forest zone of Nigeria where the bimodal rainfall results in two distinct growing seasons – April to July and August to October. The seedlings attain sizes transplantable to the field only after 10 - 12 months growth in the nursery (Onwubuya, 1982). Consequently, the nursery phase of the oil palm seedling spans these growing season and the dry season. Fluctuations in soil moisture conditions during its growth period especially in the dry season might be expected to affect the growth of the seedling. But how fluctuations in soil moisture affects the growth oil palm seedling is not well understood especially under dry climatic conditions. In view of this, this study was conducted to determine the effects of different soil moisture regimes on growth and dry matter yield of oil palm seedlings when grown in Orlu series of NIFOR main station. It is predicted that this research will inform grower's best management practices to minimize the reduction in growth under water limitation in the nursery.

MATERIALS AND METHODS
Description of study area: This experiment was carried out in a greenhouse at the Nigerian Institute for Oil palm Research (NIFOR), near Benin City, Edo State of Nigeria. NIFOR is in the rainforest agro-ecological zone of Nigeria. The experimental site lies on longitude 5°41 and 5°87'E and latitude 6°66' and 6°60'N and altitude 149 m above sea level. The area has a bimodal rainfall pattern with two distinct seasons. The wet season is between April and October while the dry is between November and March respectively. The rainfall pattern is bimodal and falls between April and October, while the dry season is between November and March, respectively, with mean maximum temperature of 33ºC and mean minimum temperature of 21ºC. Generally, the dominant soil type in the location is ultisols, characterizes with low water holding capacity, organic matter, acidic, well drained and usually has multiple nutrient deficiencies with clay enriched subsoil. The soil in the study area has been classified as Orlu series (Ogunkunle, 1983).

Greenhouse study
Six soil moisture levels (95 – 100 %, 70 – 75 %, 60 – 65 %, 50 – 55 %, 40 – 45 % and 30 – 35 % of FC) were used as treatments. The trial was set up in Completely Randomized Design having three replications. Polybags (35 cm diameter, 40 cm height) was filled up with 11kg of sieved air dried soil. Polybag contained 11 kg soil. Soil used in the polybag was sandy loam. The soil physico – chemical

properties were as follows: 760 g kg^{-1} sand, 50 g kg^{-1} silt, 190 g kg^{-1} clay, a pH of 5.2, 8.4 g kg^{-1} organic matter, 0.4 g kg^{-1} total nitrogen, 3.47mg kg^{-1} available phosphorus, 0.08 cmol kg^{-1} exchangeable potassium and exchangeable magnesium of 0.51 cmol kg^{-1}. When pre - nursery seedling reached the third true leaf stage, they were transplanted (one seedling per polybag) on 10^{th} October 2019. Each polybag was spaced 45 cm apart. The field capacity of soil was previously determined using the direct gravimetric method (Souza *et al.* 2000). The maximum water holding capacity (field capacity) in 11 kg of soil was 1.68 L; thus, the control treatment (95 - 100 % FC) had an estimated weight (pre-fixed weight) of 12.59 - 12.68 kg with water levels of 1.60 – 1.68 L. Other treatments showed the following amounts of water and pre – fixed weight: 70 - 75 % FC = 1.18 - 1.26 L; 12.18 - 12.26 kg, 60 - 65 % FC = 1.00 - 1.09 L; 12.00 - 12.09 kg, 50 - 55 % FC = 0.84 - 0.92 L; 11.84 - 11.92 kg, 40 - 45 % FC = 0.67 - 0.76L; 11.67 - 11.76 kg, 30 - 35 % FC = 0.50 - 0.59L; 11.50 - 11.59 kg. After tranplanting, each polybag was weighed at 18.00 h each day and re-watered to the higher range of treatment (100, 75, 65, 55, 45 and 35 %), whenever the weight of the polybags fell to the lower limit established for each treatment (95, 70, 60, 50, 40 and 30 %). For each polybags, a uniform recommended dose of 28 g NPKMg 12:12:17:2 compound fertilizer was applied in 2 split doses during the study duration. The first doze was at 1 while the second doze at 4 months after transplanting. The fertilizer was applied in a ring form 7 cm away from seedling stand (Onwubuya, 1982). Polybags were hand weeded regularly to prevent weeds competition. All polybags were periodically rotated to minimize the effect of environmental heterogeneity such as light and wind

Growth measurements: Vegetative growth parameters such as plant height, leaf area, number of leaves and base circumference were collected. Five random plants per treatment and tagged to measure their growth at 2, 3, 4 and 5 months during the experimental duration. Plant height which was the distance from the soil surface to the tallest leaf was measured with a meter rule. The leaf area was estimated as its length multiplied by its maximum width of all leaves then by a correction factor of 0.05 (Harden *et al.,* 1965). At the end of the experiment (March 2020), dry matter yield was determined. Five plants per experimental units were destructively harvested and shoot and root dry weight were determined and total plant dry weight was calculated by adding the shoot and root dry weights

Laboratory methods: Particle size distribution was determined by Bouyoucos (1962) hydrometer method. Soil pH was determined in 1:2.5 soil to water ratio using pH meter (Mclean, 1965). Total nitrogen was determined by Kjeldahl method (Bremner, 1965) using selenium tablet as catalyst. Organic carbon was determined by chromic acid wet oxidation method of Nelson and Sommers (1982), while organic matter was determined by multiplying percentage organic carbon by 1.724. Available phosphorus was determined using Bray 1 method (Bray and Kurtz, 1945). Exchangeable bases (K, Na, Mg and Ca) were determined by 1N neutral NH4OAC saturation method of Grant (1982).

Statistical analysis: The nursery data collected were subjected to analysis of variance (ANOVA) using GenStat version 2008. Significant means were separated using the Duncan Multiple Range Test (DMRT) (Steel *et al.,* 1980) at $P \leq 0.05$.

RESULTS

Effect of treatment on growth oil palm seedling

Plant height: Table 1 shows that soil water regimes levels had a significant ($P < 0.05$) effect on plant height of oil palm seedling throughout the study duration. After 2 months of application of treatments, maximum values for plant height was obtained from the control treatment (95 – 100 % FC) and these values were greater than those of 40 – 45 % and 30 – 55 % of FC respectively. Decreasing soil moisture levels decreased the plant height by about 22.5 % and 24.6 % for 40 – 45 % and 30 – 55 % FC, respectively, compared with the well - watered control (95 – 100 % FC). After three months of treatment application, the control (95 – 100 % of FC) showed the maximum plant height of 44.50 cm followed by water regime of 70 – 75 % FC (43.50 cm) which was statistically similar. Decreasing soil moisture regime decreased the plant height by about 2.2 %, 13.5 %, 24.7 %, 29.2 % and 33.7 for 60 – 65 %, 50 – 55 %, 40 – 45 % and 30 – 35 % of FC, respectively compared with the control (95 – 100 % FC) (Table 1). At four months, maximum plant height was recorded at the control plot (50.50 cm) and it was higher than those of 70 – 75 %, 60 – 65 %, 50 – 55 %, 40 – 45 % and 30 – 35 % of FC respectively. Treatments 60 – 65 % and 50 – 55 % were similar likewise those of 40 – 45 % and 30 – 35 % of FC. At the end of the experiment (after 5 months of water regime), plant height significantly deceased under soil water regimes of 60 – 65 %, 50 – 55 %, 40 – 45 % and 30 – 35 % of FC by 22.9 %, 31.6 %, 34.6 % and 40.7 % respectively, compared with the control plot (95 – 100 % FC) (Table 1).

Leaf area: Leaf area of oil palm seedling at different levels soil water regimes is presented in Table 2. Leaf area decreased with decreasing soil moisture levels throughout the experiment At two months of moisture stress application, the control treatment of 95 - 100% of FC recorded the maximum leaf area of 4.23 cm^2 followed by 70 – 75 % FC (4.10 cm^2), 60 – 65 % FC (3.24 cm^2), 50 – 55 % FC (2.79 cm^2), 40 – 45 % FC (2.69 cm^2) and 30 – 35 % FC (2.37 cm^2) respectively. The control treatment (95 – 100 % FC) did not differ significantly from 70 - 75 % FC ($p>0.05$). Nevertheless decreasing soil moisture from 60 – 65 % to 30 – 35 % of FC, significantly reduced the leaf area by 23.4 %, 34.0 %, 36.4 %, and 43.9 % respectively, compared to the control plot (95 - 100 % FC). Similar decreases in leaf area were observed when soil moisture was reduced from 60 – 65 % to 30 – 35 % FC at 3, 4 and 5 months of treatment application (Table 2). At the end of the experiment (after 5 months of application of moisture stress), decreasing soil water regimes from 60 – 65 % to 30 – 35 % of FC, significantly reduced the leaf area by 34.1 %, 50.9 %, 54.7 % and 60.1 % compared with the control (95 – 100 % FC)

Base circumference

As shown in Table 3, base circumference decreased with decreasing soil moisture regime throughout the study period. At two months of treatment application, the control plant (95 - 100% of FC) had the maximum base circumference (3.45 cm) followed by 70 – 75 % FC (3.40 cm), 60 – 65 % FC (2.93 cm), 50 – 55 % FC (2.50 cm), 40 – 45 % FC (2.20 cm) and 30 – 35 % FC (1.88 cm) respectively. However there were no differences in base circumference between control (95 – 100 % FC) and 70 -75 % FC water regime. Consequently, at 60 – 65 %, 50 – 55 %, 40 – 45 % and 30 – 35 % of FC, base circumference was significantly reduced by 15.1 %, 27.5 %, 1.3 %, and 1.6 % respectively, compared to the control plot (95 - 100 % FC). At 3, 4 and 5 months of water regime application, decreases in base circumference were observed when soil moisture dropped below 70 – 75% FC (Table 3). At the end of the dry season, (after 5 months), decreasing soil moisture levels from 60 – 65 to 30 – 35 % FC, significantly decreased the base circumference by 4.3 %, 27.9 %, 34.3 % and 39.1 % respectively, compared to the control (Table 3).

Dry matter yield: At the end of the experimental period (5 months after application of treatment), root dry weight, shoot dry weigh and total dry weight of oil palm seedling decreased with decreasing soil water levels (Table 4). The control plots (95 - 100% of FC) had the highest root dry weight (2.97 g) followed by 70 – 75 % FC (2.75 g), 60 – 65 % FC (2.26 g), 50 – 55 % FC (1.62 g), 40 – 45 % FC (1.36 g) and 30 – 35 % FC (0.95 g) respectively. Treatments of 95 – 100 % and 70 – 75% of FC were significantly similar. However under 60 – 65 %, 50 – 55 %, 40 – 45 % and 30 – 35 % FC, root dry weight was significantly reduced by 23.9 %, 45.5 %, 54.2 % and 68.0 %, respectively, compared to the control (95 - 100% of FC). As for shoot dry weight, the highest value of 10. 27 g was recorded in the control plot (95 - 100% of FC) and this statistically at par with 70 – 75 % FC (9.88 g). Shoot dry weight under 60 – 65 %, 50 – 55 %, 40 – 45 % and 30 – 35 % FC, was significantly reduced by 28.6 %, 49.2 %, 59.2 % and 71.3 %, respectively as compared to the control (95 - 100% of FC). Total dry weight of oil palm seedling was affected by soil water regime during the experimental period (Table 4). Total dry weight significantly decreased under soil water regimes of 60 – 65 %, 50 – 55 %, 40 – 45 % and 30 – 35 % FC by 27.6 %, 48.3 %, 58.1 % and 70.5 % respectively, compared to the control plot (95 - 100 % FC)

Table 1: Effect of soil moisture regimes on plant height (cm) of oil palm seedling

	Months after varying soil water regimes			
Treatments	**2**	**3**	**4**	**5**
95 -100 %FC (control)	35.50[a] (0)	44.50[a] (0)	50.50[a] (0)	57.75[a] (0)
70 - 75 % FC	31.75[ab] (10.6)	43.50[a] (2.2)	47.00[b] (6.7)	56.25[a] (2.6)
60 - 65 % FC	30.25[ab] (14.8)	38.50[b] (13.5)	39.00[c] (22.7)	44.50[b] (22.9)
50 - 55 % FC	29.25[ab] (17.6)	33.50[c] (24.7)	37.00[c] (26.7)	39.50[c] (31.6)
40 - 45 % FC	27.50[b] (22.5)	31.50[cd] (29.2)	34.00[d] (32.7)	37.75[c] (34.6)
30 - 35 % FC	26.75[b] (24.6)	29.50[d] (33.7)	32.00[d] (36.6)	34.25[d] (40.7)

Means with the same letter in the same column are not significantly different using Duncan's Multiple Range Test at $P \leq 0.05$. Values in parenthesis show percentages relative to the control

Table 2: Effect of soil water regimes on leaf area (cm^2) of oil palm seedling

	Months after varying soil water regimes			
Treatments	**2**	**3**	**4**	**5**
95 –100 %FC (control)	4.23[a] (0)	5.10[a] (0)	9.45[a] (0)	11.54[a] (0)
70-75 % FC	4.10[a] (3.1)	4.92[a] (3.52)	8.70[a] (0.8)	11.13[a] (3.6)
60-65 % FC	3.24[b] (23.4)	4.37[b] (14.3)	6.28[b] (33.5)	7.61[b] (34.1)
50-55 % FC	2.79[bc] (34.0)	3.95[c] (22.5)	4.87[c] (48.5)	5.66[c] (50.9)
40-45 % FC	2.69[bc] (36.4)	3.85[c] (24.5)	4.80[c] (49.2)	5.23[cd] (54.7)
30-35 % FC	2.37[c] (43.9)	3.73[c] (26.9)	4.05[c] (57.1)	4.60[d] (60.1)

Means with the same letter in the same column are not significantly different using Duncan's Multiple Range Test at $P \leq 0.05$. Values in parenthesis show percentages relative to the control

Table 3: Effect of soil moisture regimes on base circumference (cm) of oil palm seedling

	Months after varying soil water regimes			
Treatments	**2**	**3**	**4**	**5**
95 –100 %FC (control)	3.40ᵃ (0)	4.10ᵃ (0)	5.62ᵃ (0)	6.70ᵃ (0)
70 - 75 % FC	3.30ᵃ (2.9)	3.89ᵃ (5.1)	5.43ᵃ (3.4)	6.47ᵃ (3.4)
60 - 65 % FC	2.83ᵇ (16.7)	3.43ᵇ (16.3)	5.13ᵇ (8.7)	5.74ᵇ (4.3)
50 - 55 % FC	2.50ᶜ (26.4)	3.23ᵇᶜ (21.2)	4.30ᶜ (23.5)	4.83ᶜ (27.9)
40 - 45 % FC	2.20ᶜ (25.3)	2.68ᶜ (34.6)	3.93ᵈ (30.1)	4.40ᵈ (34.3)
30 - 35 % FC	1.88ᵈ (44.7)	2.23ᵈ (45.6)	3.63ᵈ (35.4)	4.08ᵈ (39.1)

Means with the same letter in the same column are not significantly different using Duncan's Multiple Range Test at $P \leq 0.05$. Values in parenthesis show percentages relative to the control

Table 4: Effect of varying soil moisture regime on dry matter yield at the end of the experiment

Treatments	**Root dry weight ($g/plant^{-1}$)**	**Shoot dry weight ($g/plant^{-1}$)**	**Total plant dry weight ($g/plant^{-1}$)**
95 - 100 % FC (control)	2.97^{a} (0)	10.27^{a} (0)	13.24^{a} (0)
70 – 75 % of FC	2.75^{a} (7.4)	9.88^{a} (3.8)	12.63^{a} (4.6)
60 – 65 % of FC	2.26^{b} (23.9)	7.33^{b} (28.6)	9.59^{b} (27.6)
50 – 55 % of FC	1.62^{bc} (45.5)	5.22^{c} (49.2)	6.84^{c} (48.3)
40 – 45 % of FC	1.36^{cd} (54.2)	4.19^{cd} (59.2)	5.55^{cd} (58.1)
30 – 35 % of FC	0.95^{d} (68.0)	2.95^{d} (71.3)	3.90^{d} (70.5)

Means with the same letter in the same column are not significantly different using Duncan's Multiple Range Test at $P \leq 0.05$. Values in parenthesis show percentages relative to the control

DISCUSSION

It is a fact that the vegetative growth and dry matter yield of oil palm seedling grown under water deficit level of 70 – 75 % FC were significantly similar to that of the well – watered control (95 – 100 % FC), while deficits levels of 60 – 65 % to 30 – 35 of FC were significantly lower than well watered control (95 – 100 % FC). This demonstrates that optimum growth of oil palm seedling can be achieved provided soil moisture is kept at or above 70 – 75 % FC. That is to say that seedling may be affected if soil moisture drops below 70 – 75 % FC. Such increments in growth may be that the amount of plant available water retained at 70 – 75 % FC could be sufficient to improve water supply resulting in better turgidity of the cells, leading to cell enlargement and better cell wall development. The enhanced growth may also be adduced to the increased water uptake and in turn improves root function, consequently enhance nutrient uptake and metabolic processes of the plant. These findings are in line with the work of Isenmila (2003); Jaleel *et al*., (2008) and Sonal *et al.,* (2010). In contrast, the significant reductions in seedling growth under 60 - 65 to 30 – 35 % FC clearly indicated these treatments might expose oil palm seedling to excessive moisture stress in the dry season. Such reduction could be attributed to decrease in seedling cell turgor due caused by the presence of inadequate soil water. Thus, plants tend to be smaller in height, leaf area, base circumference, number of leaves and all growth processes dependent on the turgor of the plant. Boyer, (1988) and Lovisolo and Schuber, (1988) had indicated previously that the reduction in plant length in response to drought may be either due to decrease in cell elongation resulting from soil water shortage that led to a decreased in each of cell turgor, cell volume and eventually cell growth which result to the blocking up of xylem and phloem vessels thus hindering translocation through the plant vessels. Similarly, Farah (1981); Finch-Savage and Elston (1982) and Isenmila (1991) reported a decline in leaf number and leaf area with decreasing soil water availability. Tuan et al. (2019) found that the growth of oil palm seedling was significantly reduced when soil moisture dropped below 75 % of field capacity.

CONCLUSION

The current study demonstrated that soil water regime had significant effects on vegetative growth and dry matter yield of oil palm seedlings, depending on the level of soil moisture. When water regime dropped from 60 – 65 % to 35 % of FC significant reductions in growth attributes were observed. The control treatment (95 – 100 % FC) had the most favorable effect on the parameters measured but statistically similar with 70 – 75 % FC. Considering the conditions of the experimental area, it is advisable to maintain soil moisture at ≥70 – 75 % FC to prevent oil palm seedling from being subjected to excessive soil moisture stress when grown in Orlu series.

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