EFFECT OF SOIL MOISTURE LEVEL ON NUTRIENT UPTAKE BY OIL PALM SEEDLING IN A SANDY LOAM SOIL

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ABSTRACT
Information about optimum soil water content for efficient use of nutrients is essential for higher crop yield. The aim of this work was to determine the effect of different soil moisture levels on nutrient uptake by oil palm seedling when grown in a sandy loam soil. The study was conducted at the Nigerian Institute for Oil palm Research, (NIFOR), near Benin City, from October 2018 - September 2019. Pre - nursery seedling (at 3 – leaf stage) was transplanted in polybags and subjected to six soil moisture regimes as follows: one well – watered (95 – 100 %) and five reduced soil moisture treatments {70 -75 %, 60 - 65%, 50 - 55 %, 40 - 45% and 30 - 35 % of field capacity (FC).These treatments were laid out in Completely Randomized Design (CRD) with three replications. Each soil moisture level was maintained by weighing polybags and plant daily and then compensating the water loss through evapo-transpiration by adding an equivalent amount of water. Results showed that significant reductions in nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg) uptake by oil palm seedling were observed when soil moisture levels decreased from 95 – 100 to 30 -35 % FC. However, total N, P and K uptake by oil palm seedling did not differ significantly ($P<0.05$) between the control (95 - 100 %) and reduced soil water level of 70 – 75 % of FC.There were significant reductions in vegetative growth (plant height, leaf area and number of leaves) when soil moisture levels decreased from 60 – 65 % to 30 – 35 % of FC. The study showed that revealed that nutrient uptake and good growth of oil palm seedling in dry period could be maintained provided soil moisture is maintained on or above 70 - 75 % FC in Orlu series of the study area

Key words: Soil moisture, nutrient uptake, oil palm seedling

INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.) is one of the most important economic oil crops in Nigeria. It is indigenous to the Nigerian coastal plain through it has migrated inland as a staple crop (Hertely, 1988). Cultivation of oil palm serves as a means of livelihood for many rural families and indeed the farming culture of millions of people especially in the southern part of Nigeria. The reference to oil palm as a crop of multiple value underscore its economic importance, namely the bunches, 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 (NIFOR ,2008). Despite the importance of oil palm, production of the crop is limited due to soil water stress (Omerije, 2005; NIFOR, 2008). In Nigeria, oil palm seedling is grown by farmers under rainfed conditions; inadequate or unpredictable rainfall may limit its growth and development (Isenmila and Babalola 1989). Erratic rainfall distribution during growth exposes plants to soil moisture deficits stress especially in the dry season and this has been reported to be the main factor limiting oil palm production in Nigeria (Hartley, 1988; NIFOR, 2008).

Oil palm seedling places a high demand on nutrients to attain adequate growth and vigour, which is necessary for optimum field establishment (Onwubuya, 1982). Some of these essential nutrient elements needed for optimum productivity are N, P, K and Mg (Ughah, 2005).Decrease in soil moistureespeciallyim the dry seasonmay cause nutrient deficiencies due to reduced nutrient uptake via decrease in mass movement/diffusionof nutrient elements to plant roots (Cramer, *et al.,* 2009, Waraich*et al.,* 2011; Deepesh, *et al.*, 2018). Although the effect of varying soil moisture levels on growth and yield of oil palm is well documented(Isenmila and Babalola, 1989; Isenmila, 1991; 2003; Tuan, *et al.*, 2019), but little is known aboutits effect on nutrient uptake..As the oil palm seedlings is widely grown under rainfed conditions, imposition of experimental soil moisture deficits can help to understand how limited soil moisture during drought can affect nutrient uptake by the crop for better management decitions.Therefore the aim of this work was to determine the threshold when soil moisture starts to decrease nutrient uptake by oil palm seedling when grown in Orlu Series of NIFOR main station

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 patternis 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. The soil in the study area has been classified as Orlu series (Ogunkunle, 1983).

Greenhouse study:

Six soil moisture levels viz., 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. Soil used in the polybag was sandy loam. The soil pH was 5.2, the organic matter was 8.4 g kg^{-1}, the total nitrogen was 0.4 g kg^{-1}, the available phosphorus was 3.47mg kg^{-1}, the exchangeable potassium 0.08 cmol kg^{-1} and exchangeable magnesium (Mg) was 0.51 cmol kg^{-1} respectively. When pre - nursery seedling reached the third true leaf stage, they were transplanted (one seedling per polybag). 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. The decreased soil water treatments levels had 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. Thereafter, 1.68, 1.26, 1.09, 0.92, 0.76 and 0.59 L of irrigation water was added in each polybag to bring the soil moisture at the higher range of each treatment (100, 75, 65, 55, 45 and 35 %). For the nursing of desired soil water regimes, the polybags were weighed daily and irrigation water was applied when the soil moisture came down to the lower levels (95, 70, 60, 50, 40 and 30 %). I.e when the weight of polybags reached 12.59, 12.18, 12.00, 11.84, 11.67 and 11.50 kg respectively. The estimated amount of water added was done to maintain soil moisture level to the higher range of each treatment throughout the study. Consequently polybag weight at lower level of moisture was subtracted from that at the higher range to give the estimated amount of water applied. For each polybags, a uniform recommended dose of 42 g NPKMg 12:12:17:2 compound fertilizer was applied in 3 split doses during the growth period (Ugbah, 2005). The first doze was at the time of transplanting (3 months after plantig) while second and third dozes at 5 and 8 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.

Plant nutrient uptake: The uptake of N, P, K and Mg in plant parts (root and shoot) were evaluated at the end of the study (12 months after varying soilmoisture levels). From each experimental unit, five plants were harvested. Plant parts were partitioned into roots and shoots. Plant parts were oven-dried at 70ºC to constant weight before grinding them separately with a Wiley mill before passing through a 0.5 mm sieve. The samples were chemically analyzed to determine their contents of nitrogen, phosphorus, potassium and magnesium. Concentrations of all nutrients were expressed on a dry weight basis and the nutrient uptakes were calculated using the respective plant dry weights. The total nitrogen concentration was determined by the micro-Kjeldahl method (Bremner, 1965). For the determination of the remaining elements (plant samples were first subjected to wet digestion (Mehlich, 1984). From the digest various elements were read using the relevant procedures. P contents were determined colorimetrically using a spectrophotometer. The procedure involved the use of Vanado-molybdate yellow method (Murphy and Riley, 1962). A flame photometer was used for the determination of K in plant tissue (Heald, 1965). Atomic adsorption spectrophotometer was used to determine Mg (Pratt, 1965).

Calculation of plant nutrient uptake: The uptake of N, P, K and Mg by the seedlings was determined following the method of Fahim*et al.,* (2012) as follows: Shoot nutrient uptake (mg/plant) = shoot dry weight (g) x N, P, K Mg concentration (mgg^{-1}). Root nutrient uptake (mg/plant) = root dry weight (g) x N, P, K Mg concentration (mgg^{-1}). Total nutrient uptake (mg/plant) = (shoot nutrient uptake + root nutrient uptake)

Growth measurements: Growth parameters including were plant height, leaf area and number of leaves were collected. Six random plants per treatment were tagged to measure their growth at 4, 8 and 12 months after transplanting. Plant height which was the distance from the soil surface in the polybag 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). Number of leaves was determined by counting all expanded and live leaves on each plant.

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's New Multiple Range Test (DMRT) (Steel *et al.,* 1980) at $P \leq 0.05$

RESULTS

Effect of treatment on nutrients uptake

N uptake: There was a general decrease in root, shoot and total N uptake by oil palm seedling when soil moisture level dropped from the control (95 – 100 % FC) to 30 – 35 % FC (Table 1). Root N uptake under 60 – 65, 50 – 55, 40 – 45, and 30 – 35 % FC was significantly lower than that of the control (95 – 100 % FC) with 6.7 %, 20.6 %, 50.8 % and 78.6 %, respectively. The root N uptake in the control (95 – 100 % FC) and 70 – 75 % FC were similar. In addition, shoot N uptake significantly decreased with 7.1 %, 38.8 %, 51.3 % and 78.9 % under 50 – 55 %, 40 – 45 % and 30 – 35 % of FC compared to the control plot (95 – 100 % FC). Compared with the control (95 – 100 % FC), total N uptake under reduced soil moisture levels of 60 – 65 %, 50 – 55 %, 40 – 45 % and 30 – 35 % of FC was significantly reduced by 6.8 %, 35.1%, 51.2.% and 78.8 %) (Table 1).

P uptake: Data illustrated in Table 2 showed that reduced soil water caused a decrease in root, shoot and total P uptake by oil palm seedling in the order 95 – 100 % > 70 – 75 % > 60 – 65 % > 50 – 55 % 40 – 45 % > 30 – 35 % of FC. It was observed that root P uptake under 60 – 65 %, 50 – 55 %, 40 – 45 % and 30 – 35 % of FC was significantly lower than that of the control (95 – 100 % FC) with 9.9 %, 30.4 %, 33.0 % and 58.2 % respectively. In addition, there were significant reductions in shoot P uptake under 50 – 55 %, 40 – 45 % and 30 – 35 % of FC compared to the control treatment (95 – 100 % FC). Compared to the control treatment (95 – 100 % FC) deceasing soil water levelsfrom 50 – 55 % to 30 – 35 % FC caused significant reductions in total P uptake respectively (Table 2).

K uptake: Results presented in Table 3 showedthatsoil moisture levels of 70 – 75, 60 – 65, 50 – 55, 40 – 45 and 30 – 35 % FC reduced K uptake in root and shoot of oil palm seedlings compared to unstressed control plant (95 – 100 % FC). Maintaining soil moisture at 60 – 65 %, 50 – 55 %, 40 – 45 % and 30 – 35 % of field capacity, significantly decreased the root K uptake by 36.6 %, 43 %, 45.7 % and 64.5 % compared to the control plot (95 – 100 % FC). At 50 – 55 %, 40 – 45 % and 30 – 35 % of field capacity shoot K uptake was significantly reduced by 17.4 %, 47.3 % and 55.4 % respectively compared to the control plot (95 – 100 % FC). Total K uptake was significantly reduced when soil water level dropped from 60 – 65 % to 30 – 35 % of FC(Table 3).

Mg uptake Data in Table 4 showed thatsoil moisture levels of 60 – 65 %, 50 – 55 %, 40 – 45 % and 30 – 35 % of field capacity, significantly reduced Mg uptake by 19.9 %, 46.5 %, 54.5 %, and 73.4 % compared to the control plot (95 – 100 % FC). In addition, shoot Mg uptake was significantlyreduced when soil water level dropped from 50 – 55 % to 30 – 35 % of FC when compared to the control plot (95 – 100 % FC). Compared to the control treatment (95 – 100 % FC) maintaining soil water levels from 60 – 65 % to 30 – 35 % FC caused significant reduction in total Mg uptake by oil palm seedling that varied from 15.6 to 67.2 % respectively (Table 4).

Table 1: Nitrogen uptake by oil palm seedlings under decreasing soil moisture levels

	Nitrogen uptake (mg/plant)		
Treatments	Root	Shoot	Total
95 - 100 % FC (control)	42.21^{a} (0)	164.60^{a} (0)	206.81^{a} (0)
70 – 75 % of FC	40.85^{a} (3.2)	163.90^{a} (0.4)	204.75^{a} (0.1)
60 – 65 % of FC	39.38^{b} (6.7)	152.98^{a} (7.1)	192.78^{b} (6.8)
50 – 55 % of FC	33.51^{b} (20.6)	100.70^{b} (38.8)	134.21^{c} (35.1)
40 – 45 % of FC	20.76^{b} (50.8)	80.10^{c} (51.3)	100.86^{d} (51.2)
30 – 35 % of FC	9.05^{d} (78.6)	34.70^{d} (78.9)	43.75^{e} (78.8)

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 percentage reductions relative to the control

Table 2: Phosphorus uptake by oil palm seedlings under decreasing soil moisture levels

	Phosphorus uptake (mg/plant)		
Treatments	Root	Shoot	Total
95 - 100 % FC (control)	7.54[a] (0)	25.08[a] (0)	33.62[a] (0)
70 – 75 % of FC	7.35[a] (2.5)	23.89[a] (4.7)	31.24[a] (7.1)
60 – 65 % of FC	6.79[b] (9.9)	22.04[a] (28.1)	28.83[a] (16.0)
50 – 55 % of FC	5.25[b] (30.4)	12.68[b] (49.4)	17.93[b] (46.7)
40 – 45 % of FC	5.05[b] (33.0)	10.90[c] (56.5)	15.95[b] (53.5)
30 – 35 % of FC	3.15[c] (58.2)	5.86[d] (76.6)	9.01[c] (73.20)
±SEM	0.57	0.85	1.22

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: Potassium uptake by oil palm seedlings under decreasing soil moisture levels

Treatments	Potassium uptake (mg/plant)		
	Root	Shoot	Total
95 - 100 % FC (control)	10.09[a] (0)	26.77[a] (0)	36.86[a] (0)
70 – 75 % of FC	9.41[a] (6.71)	26.51[a] (0.9)	35.92[a] (2.6)
60 – 65 % of FC	6.39[b] (36.6)	24.41[a] (8.8)	30.08[b] (18.4)
50 – 55 % of FC	5.75[bc] (43.0)	22.12[b] (17.4)	27.87[c] (24.4)
40 – 45 % of FC	5.48[c] (45.7)	14.10[c] (47.3)	19.25[d] (47.8)
30 – 35 % of FC	3.58[d] (64.5)	11.94[d] (55.4)	15.52[e] (57.9)
±SEM	0.48	0.63	0.83

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 percentage reductions relative to the control.

Table 4: Magnesium uptake by oil palm seedlings under decreasing soil moisture levels

	Magnesium uptake (mg/plant)		
Treatments	Root	Shoot	Total
95 - 100 % FC (control)	10.05[a] (0)	20.70[a] (0)	30.75[a] (0)
70 – 75 % of FC	9.21[a] (8.4)	20.52[a] (0.7)	29.73[ab] (3.3)
60 – 65 % of FC	8.05[b] (19.9)	17.90[b] (13.5)	25.95[b] (15.6)
50 – 55 % of FC	5.38[c] (46.5)	16.49[b] (20.3)	21.87[c] (28.8)
40 – 45 % of FC	4.57[c] (54.5)	10.22[c] (50.6)	14.26[d] (53.6)
30 – 35 % of FC	2.67[d] (73.4)	7.41[d] (64.2)	10.08[d] (67.2)
±SEM	0.58	0.68	0.58

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 percentage reductions relative to the control

Growth components

Plant height: Data in Table 5 show that plant height of oil palm seedling decreasing soil moisture levelsfrom the control (95 – 100 % FC) to 30 – 35 % FC throughout the growth period. After four months of treatment application, the control treatment (95 – 100 % FC) had the tallest plant height (52.28 cm) followed by 70 – 75 % (50.76 cm), 60 – 65 % (46.30 cm), 50 – 55 % (46.70 cm), 40 – 45 % (44.80 cm) and 30 – 35 % of FC (42.60 cm) respectively. There were no significant differences in the plant height in the 70 – 75 % and 95 – 100 % FC (p<0.05). Consequently at 60 – 65 %, 50 – 55 %, 40 – 45 % and 30 – 35 % of FC plant height was significantly reduced by11.4 %, 10.7 %, 14.3% and 18.5 % compared to the control plot (95 – 100 % FC). A similar trend was observed when soil moisture dropped below 70 – 75 % FC at 8 and 12 months of treatment application. At the end of the growth period (i.e., after 12 months), the plant height were significantly lower than that in control (95 – 100 % FC) by 20%, 27.9 %, 27.9 % and 43.1 % respectively (Table 5)

Leaf area: The effect of various soil moisturelevels on leaf area of oil palm seedling is presented in Table 6. At four months of treatment application, water stress treatment of 60 – 65 %, 50 – 55 %, 40 – 45 % and 30 – 35 % of FC significantly reduced the leaf area by 28.4 %, 29.4 %, 34.6 % and 36.3 % compared to the control plot (95 – 100 % FC). Significant decreases in leaf area were observed whensoil moisture levels droppedbelow 70 – 75% FC at 8 and 12 months of treatment application. At the end of the growth period (12 months of varying soil moisture), leaf area under soil moisturelevels of 60 – 65 %, 50 – 55 %, 40 – 45 % and 30 – 35 % of FC was significantly lower than that in control (95 – 100 % FC) with 37.1 %, 52.1 %, 53.1 % and 61.5 % respectively. (Table 6).

Number of leaves: Number of leaves of oil palm seedling decreased with decreasing soil moisture levels (Table 7). At four months of treatmentapplication,soil moisture levelsof 40 – 45 % and 30 – 35 % of FC significantly reduced number of leaves by 12.2 % and 12.4 % compared to the control plot (95 – 100 % FC). After 8 months of treatment application, soil moisture levels of 50 – 55 %, 40 – 45 % and 30 – 35 % of FC, number of leaves were significantly lower by 25.5 %, 30.9 % and 47.3 % respectively, compared to the control (95 – 100 % FC). At the end of the experiment (after 12 months), soil water treatments of 60 – 65 %, 50 – 55 %, 40 – 45 % and 30 – 35 % of FC significantly reduced the number of leaves by 14.8 %, 27.9 %, 31.1 % and 54.2 % compared to the control (95 – 100 % FC) (Table 7)

Table 5: Plant height (cm) of oil palm seedlings under decreasing soil moisture levels

Treatments	4	8	12
95 - 100 % FC (control)	52.28^{a} (0)	83.00^{a} (0)	103.50^{a} (0)
70 – 75 % of FC	50.76^{a} (2.9)	82.60^{a} (0.5)	101.60^{a} (1.8)
60 – 65 % of FC	46.30^{b} (11.4)	66.60^{b} (19.0)	82.70^{b} (20.0)
50 – 55 % of FC	46.70^{b} (10.7)	66.40^{b} (20.0)	74.60^{c} (27.9)
40 – 45 % of FC	44.80^{b} (14.3)	61.20^{b} (26.3)	74.60^{c} (27.9)
30 – 35 % of FC	42.60^{b} (18.5)	52.80^{d} (36.4)	58.90^{d} (43.09)
±SEM	1.34	2.47	2.29

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 reduction relative to the control

Table 6: Leaf area (cm^2) of oil palm seedlings under decreasing soil moisture levels

Treatments	4	8	12
95 - 100 % FC (control)	9.51a (0)	20.40^{a} (0)	48.21^{a} (0)
70 – 75 % of FC	8.73^{a} (8.2)	20.60^{a} (1.7)	46.88^{a} (2.8)
60 – 65 % of FC	6.81^{b} (28.4)	15.54^{b} (18.9)	30.31^{b} (37.12)
50 – 55 % of FC	6.71^{b} (29.4)	15.55^{b} (23.7)	23.10^{c} (52.1)
40 – 45 % of FC	6.22^{b} (34.6)	15.37^{bc} (24.7)	22.63^{bc} (53)
30 – 35 % of FC	6.06^{b} (36.3)	12.39^{c} (39.3)	18.53^{c} (61.5)
±SEM	0.41	1.03	1.27

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 reductions relative to the control

Table 7: Number of leaves of oil palm seedlings under decreasing soil moisture levels

Treatments	4	8	12
95 - 100 % FC (control)	7.40^{a} (0)	11.00^{a} (0)	12.20^{a} (0)
70 – 75 % of FC	7.20^{ab} (4.1)	10.60^{a} (3.6)	11.70^{a} (4.1)
60 – 65 % of FC	7.10^{ab} (4.0)	10.00^{a} (9.1)	10.40^{b} (14.8)
50 – 55 % of FC	6.70^{ab} (9.5)	8.20^{b} (25.5)	8.80^{c} (27.9)
40 – 45 % of FC	6.50^{b} (12.2)	7.60^{b} (30.9)	8.40^{c} (31.1)
30 – 35 % of FC	6.48^{b} (12.4)	5.80^{c} (47.3)	5.59^{d} (54.2)
±SEM	0.18	0.55	0.59

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

Nutrient uptake: Mineral nutrients are essential for plant growth and development through their fundamental role in plant metabolism. Results of this experiment showed that decreasing soil moisture levelsfrom 60 – 60 % to 30 – 35 % of field capacity resulted in significant reductions in nutrient uptake by the seedling. These suggest that 70 - 75 % FC was the threshold water stress level for maintaining nutrient uptake by the oil palm seedling when grown in Orlu series. The reason for such decreasewith decreasing soil moisture levels could be attributed to decrease nutrient transport by diffusion and mass flow rates to the oil palm seedling root surfaces and nutrient adsorption by root. The decrease in nutrient uptake may also be attributed to a decreased stomata opening and transpiration stream, to transport the nutrients from roots to shoots (Pinkerton and Simpson 1986). Sharma *et al.* (2015) had reported decreased uptake of N, P and K under limited soil moisture conditions. Similarly, Umar, (2006) also indicated that that under progressive soil moisture stress levels, the nutrient film around the soil particle became thin; whereby the distance for movement of P and K ions increased resulting in poor diffusion of these ions into the plant roots. In a similar study, Schier and McQuattie (2000) concluded that N, P and K concentrations in the leaves of pitch pine were decreased under moisture stress conditions. They attributed this phenomenon to less availability and mobility of these elements to the plant under low soil moisture condition. Furthermore, Guiterrez-Boen and Thomas (1999) reported that the decrease in soil water availabilityinhibitsthe rate of diffusion of many plant nutrients and finally their composition and concentration.

Growth attributes: It is a fact that soil moisture levels of 60 - 65 % to 30 – 35 % of field capacity caused significant reductions in growth attributes (plant height, leaf area and number of leaves) of oil palm seedling. This is an indication that the growth of oil palm seedling was impaired when soil moisture levels fell below 70 - 75 % FC when raised in Orlu seriesof NIFOR mainstation. These reductions in growth below this level of soil moisture could be attributed to decrease in cell turgor due to insufficient soil moisture levels. Thus,plants tend to be smaller inheight, 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 moisture status.

CONCLUSION

The current study demonstrated that decreasing soil moisture level had significant effects on nutrient uptake and growth of oil palm seedlings, depending on the level of reduction. Soil moisture levels of60 – 65 % to 35 % of FCsignificantly reducted N. P, K and Mguptake by oil palm seedling. The growth attributes of oil palm seedlings were also impacted under these watering regines. The control treatment (95 – 100 % FC) had the most favorable effect on the parameters measured but was not significantly different from 70 – 75 % FC. The study showed that maintaining soil moisture at 70 -75% FC was considered critical for improving nutrient uptake and growth of oil palm seedling when raised in a sandy loam soil of NIFOR mainstation.

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