

Effects of shading, irrigation and mycorrhizal inoculation on growth and development of oil palm *Elaeis guineensis* Jacq. (Magnoliophyta: Arecaceae) seedlings in the nursery

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Abstract. Experiments were conducted to examine the growth and development of oil palm *Elaeis guineensis* Jacq. (Magnoliophyta: Arecaceae) seedlings subjected to shading, irrigation regimes and mycorrhizal inoculation in the dry season. Treatments were 2 x 2 x 2 factorial combination consisting of shade and no-shade (open sun), 7 and 14 day irrigation intervals and mycorrhizal inoculation or non-inoculation. Seedlings that were grown under shade and irrigated weekly produced highest number and length of fronds, and shoot, leaf and frond weights in addition to taller plants compared to open sun (unshaded) seedlings. Across irrigation treatments, un-shaded seedlings had lower weights of leaf, frond and shoot biomass. The effects of shade treatments were significant on plant height and frond length from 2 to 20 weeks after planting. The seedlings irrigated fortnightly produced longer roots compared with the unshaded and weekly irrigated. Fortnight irrigation enhanced root development compared with weekly irrigation. Shading and weekly irrigation significantly enhanced soil moisture contents and seedling water use efficiency compared with the unshaded. Shaded seedlings irrigated weekly used larger amount of water compared with fortnight irrigation. Significant interactions were obtained between shade and irrigation regimes for most of the growth parameters measured. Mycorrhizal inoculation, shaded and weekly irrigated seedlings were more vigorous compared with the unshaded and non-inoculated.

Keywords: Seedling; Survival; Growth; Water use; Shade; Irrigation; inoculation.

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Introduction

The oil palm *Elaeis guineensis* Jacq. (Magnoliophyta: Arecaceae) is a perennial monocotyledonous plant which belongs to the Family Arecaceae. It originates from West Africa (Corley, 2009, Omoti, 2001). The pulp and nut that provide palm oil and kernel oil, respectively, make oil palm a high yielding oil-producing crop (Henderson and

Osborne, 2000). At present, palm oil production is second only to that of soybean oil in terms of world vegetable oil production and the demand for palm oil is expected to increase in future (Ho et al., 2007; Yusof, 2007; Corley, 2009; Bateman et al., 2010). It is an evergreen crop that may be used to conserve the environment. Palm oil accounts for 21% and 47% of the global oil and fats production and trade. Malaysia is the world's largest palm oil producer

(84%) while Indonesia is the largest exporters (Corley and Tinker, 2003).

Corley and Tinker (2003) stated that Nigeria was once the largest producer of palm oil but lost her position to the Far East producers like Malaysia. In recent years, Nigeria produces about one-tenth of the Malaysia output. Omoti (2001) hinted that the annual production of oil palm in Nigeria is 960,000 tonnes per year and this is consumed within the country, Omereji (1995) confirmed that Nigeria imports palm oil as local demand is over 1 million tonnes annually. Compared with major oilseed crops (soyabean, rapeseed and sunflower), oil palm is considered the most environmentally friendly with respect to land and energy use efficiency and productivity, and inputs of fertilizers and pesticides and pollution potential. It contributes positively to climatic change effects through effective carbon sequestration and it is not a genetically modified plant. The oil obtained from processed fruits of the oil palm plant called palm oil, is an important food and a major source of lipids.

The oil palm is allogamous and is propagated via seeds. Healthy oil palm seedling is a pre-requisite for a successful establishment of plantation in the field. In the nursery the production of oil palm seedlings covers a period of twelve months from the date the germinated seeds are planted to when seedlings are ready for field planting. Transplanting of oil palm seedlings to the field is usually done at the onset of the rains (NIFOR, 2009).

However, the effect of mycorrhizal inoculation on growth and drought tolerance of oil palm is yet to be assessed. The mutualistic association sets up a strategy to improve the nutritional status of both partners, the fungi receive fixed carbon compounds mainly in the host plant, whilst the plant benefits from the association by increased nutrient uptake especially phosphate (Ezawa et al., 2002) and nitrogen and water (Agele et al., 2016).

Traditional agricultural system involves a fallow period where vegetation and standing trees are left on the farmlands (Boffa, 1999). However increasing

deforestation coupled with intensive agriculture threatens this system (Dhillon and Gusta, 2004). These farmlands are degrading steadily resulting in loss of nutrients that can be improved with the use of arbuscular mycorrhizal (AMF) (Agele et al., 2016) that arbuscular mycorrhizal when used improved fitness and growth of plants through widespread mutualistic symbiosis between the plant and fungi of the Phylum Glomeromycota.

Improved agronomic production packages are required in order to attain improvement in growth, establishment and yield of oilpalm from seedlings to fruit bearing on the field. Such packages are capable of enhancing survival oil palm of the harsh weather conditions following out-planting on the field in the dry season. This study examined the effects of irrigation and shade regimes and mycorrhizal inoculation on the growth, development and survival of seedlings of oil palm seedlings in the nursery during the dry season.

The study will generate information which will serve as useful inputs in the development and improvement of silvicultural practices required for enhanced field survival, establishment and growth of oil palm seedlings in the dry season.

The objectives of this study are to examine the effects of shade, irrigation regimes and mycorrhizal inoculation on the growth and development of the oil palm *E. guineensis* seedlings in the nursery and the pattern of water use by oil palm seedlings.

The main objective of the study is to evaluate the effects of densities of plantain shade (moderate and dense shades) and irrigation regimes (5 and 10 days interval) for enhancing survival, field establishment, flowering and pod production of cacao seedlings on the field.

Materials and methods

Experimental site and environmental conditions

The study was conducted at the Nursery Unit of the Nigerian Institute for Oil Palm Research (NIFOR), Benin City, Edo State, Nigeria, the Rainforest Zone of Nigeria. The average annual rainfall in the

study area is 1,500 mm. The average temperature ranges between 22.5 °C to 32.8 °C, relative humidity between 62.5% and 79.1% in dry and rainy seasons, respectively. NIFOR is located between latitude 06° 33' N and longitude 05° 37' E. The average pH of the soil is 5.5 (slightly acidic). Two trials were conducted in the NIFOR main nursery during the dry season (December-April) of 2011/2012 and 2012/2013, respectively.

Preparation of substrates and sowing

Soil samples were collected from top soil under five-year fallow vegetation and were sieved to remove stones and pebbles. Black polythene bags (5,000 mL) were filled with 6 kg of the soil and arranged in rows 90 cm both in the open sun and in the shade. The drip lines were placed along the rows after ten days. Two months old oil palm seedlets (Tenera) were obtained from NIFOR pre-nursery and transplanted into the filled pot in the open

sun and in the shade. Three shades measuring 6 x 6 m was constructed using bamboo sticks, while palm fronds were used to cover the top and sides. Gravity drip irrigation system was adopted using 200 L capacity bucket placed on a 1.5 m wooden stand; drippers were installed to apply water (2 L/oil palm seedling at each application). Two thermometers each were installed one in the shade and the second in the open sun for the measurement of air temperature weekly and fortnightly intervals.

Experimental design and data collection

The experiment consisted of 2 x 2 x 2 factorial combinations of shade, irrigation regimes and mycorrhizal inoculation arranged in a split plot design replicated three times. Shade or no shade (open sun) constituted the main plots, while irrigation intervals (7 and 14 days) and mycorrhizal inoculation (or not) were the sub plot treatments. The treatments consisted of:

Open Sun X 14 days irrigation interval	x	Mycorrhizal inoculation
Open Sun X 7 days interval watering	x	Mycorrhizal inoculation
Open Sun X 14 days interval watering	x	Non-Mycorrhizal inoculation
Open Sun X 7 days interval watering	x	Non-Mycorrhizal inoculation
Shade X 14 days interval watering	x	Mycorrhizal inoculation
Shade X 7 days interval watering	x	Mycorrhizal inoculation
Shade X 14 days interval watering	x	Non Mycorrhizal inoculation
Shade X 7 days intervals watering	x	Non Mycorrhizal inoculation

Soil and plant growth measurements

Data were obtained on growth parameters, pattern of leaf production and senescence, chlorophyll content of leaf tissues using SPAD Chlorophyll Meter, weekly measurement of soil moisture content using a soil moisture sensor while thermometers were installed under shade and open sun condition to measure air temperature. At the end of the experiment, 10 plants were gently uprooted and the root washed and shade dried for root measurements.

Irrigation method

Oil palm seedlings were drip-irrigated weekly and fortnightly commencing from 10 days after commencement of experiment (20 days after transplanting: DAT). For both (2012 and 2013) experiments, irrigation regimes consisted of water application weekly and fortnight intervals using gravity-drip irrigation system and 2 L of water per plant at each irrigation via point source emitters of 2 L/h discharge rate which were installed on laterals per row of crop spaced 90 cm

apart. Irrigation buckets were suspended on 1.5 m high stakes to provide the required hydraulic heads (IWMI, 2002; Agele et al., 2014). There was a two-day pre-irrigation treatment (1.5 L/day) following oil palm seedling transplanting, and thereafter, the weekly and fortnight irrigation treatments were imposed.

Peak evapotranspiration (ET_{peak}) rate for the crop under drip irrigation treatment was estimated as:

$$ET_{peak} = \frac{ET_0 \times P}{85} \quad (1)$$

where ET_{peak} is peak evapotranspiration rate for the month or period, ET_0 is the reference evapotranspiration, for the month/period (e.g. 5.1 mm/day), P is the proportion of total land area covered by the crop leaf area (cm) which is assumed 80% (after Agele et al., 2011).

$$ET_{peak} = \frac{5.1 \times 80}{85} = 4.8 \text{ mm day}^{-1}$$

The volume of water required per plant (irrigation requirement, I_R) was estimated as:

$$\text{Irrigation requirement } (I_R) = ET_{peak} \times \frac{\text{area}_{crop}}{E_n} \quad (2)$$

$$\text{Irrigation requirement} = 4.80 \times \frac{0.09}{0.94} = 0.46 \text{ L day}^{-1}$$

where E_n is emitter uniformity for drip irrigation system (0.94) and area per crop is 0.09 m² (30 x 30 crop spacing: 0.09 m²).

Maximum (management) allowable deficit (MAD) for oil palm was set at 50 %. Crop evapotranspiration (ET_a) was also estimated using the FAO method (Doorenbos and Pruitt, 1977; Allen et al., 1998) in the form:

$$ET_a = K_c ET_0 \quad (3)$$

where ET_p is reference crop evapotranspiration and K_c is the crop

coefficient (Doorenbos and Pruitt, 1977; Allen et al., 1998).

Crop coefficient (K_c) for oil palm seedling: initial (0.43) were obtained from Allen et al. (1998). Reference Potential evapotranspiration (ET_0) values for the months from December to April were computed. Data for computing Potential evapotranspiration (ET_0) was computed by the Penman-Monteith combination equation (Doorenbos and Pruitt, 1977; Allen et al., 1998) using data obtained from the agrometeorological station of NIFOR. Weather variables at site of experiment during crop growth cycle (soil and air temperatures, vapour pressure deficit (vpd), solar radiation, wind speed will be monitored from Meteorological Observatory, 500 m from site of experiment).

Data collected were subjected to analysis of variance (ANOVA). Significant treatment means were separated using the Duncan Multiple Range Test (DMRT).

Results

Effects of shade and irrigation regimes on growth parameters of oil palm seedlings

The shading treatments (open sun and shaded) significantly affected the growth characters of oil palm seedlings ($P \leq 0.05$). For the 2012 experiment, seedlings grown under shade were taller than those under open sun across the period of study (shown at 2, 8, 14 and 20 weeks after planting (WAP) respectively (Figure 1a). At the different measurements periods, it was observed that shaded seedlings were taller at 2, 8, 14 and 20 WAP compared with the unshaded seedlings. Also frond length was also affected by shade variation (Figure 2). Seedlings under shade had significantly longer fronds than counterparts in the open sun at 2 and 8 WAP. As the seedlings aged there seems to be reduced variation in the number of fronds. In fact, treatment differences were not significant at 14 and 20 WAP respectively. Irrigation regime affected height and leaf (frond production) development of oil palm seedlings (Figure 1b and 2b, respectively). Seedlings grown

under open sun had significantly higher root lengths than those under shade (Table 1). Though root weight and number of roots were not significantly different, seedlings in the open sun had higher weights and number of roots. Shaded seedlings produced higher shoot biomass than the ones under open sun. The values of shoot weight, leaf weight and front weight were significantly higher seedlings grown under shade than under open sun. Seedlings grown under shade at 2 and 20 WAP had

significantly higher number of fronds than those in the open sun but not at 8 and 14 WAP. Although seedlings under shade had more number of fronds, non-significant differences were observed at 8 and 14 WAP. Unshaded seedlings had significantly higher shoot and frond longer and heavier roots which were significantly different from shaded seedlings. Shaded seedlings had significantly higher shoot, leaf and frond weights than unshaded seedlings (Table 1).

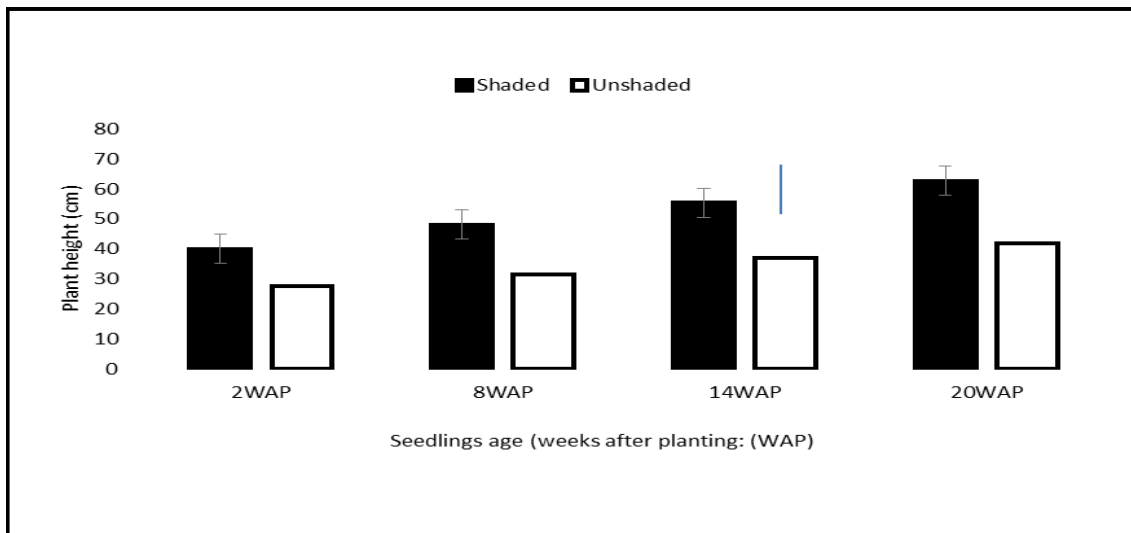


Figure 1a. Effect of shade on height of oil palm seedlings.

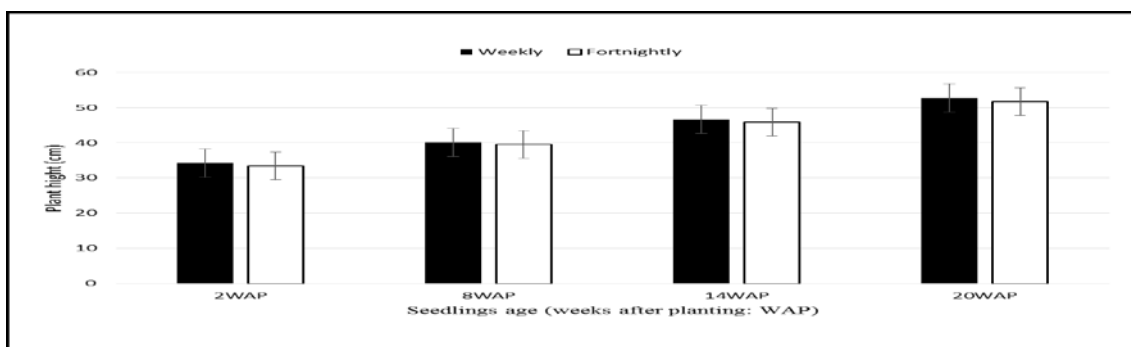


Figure 1b. Effect of irrigation intervals on height of oil palm seedlings.

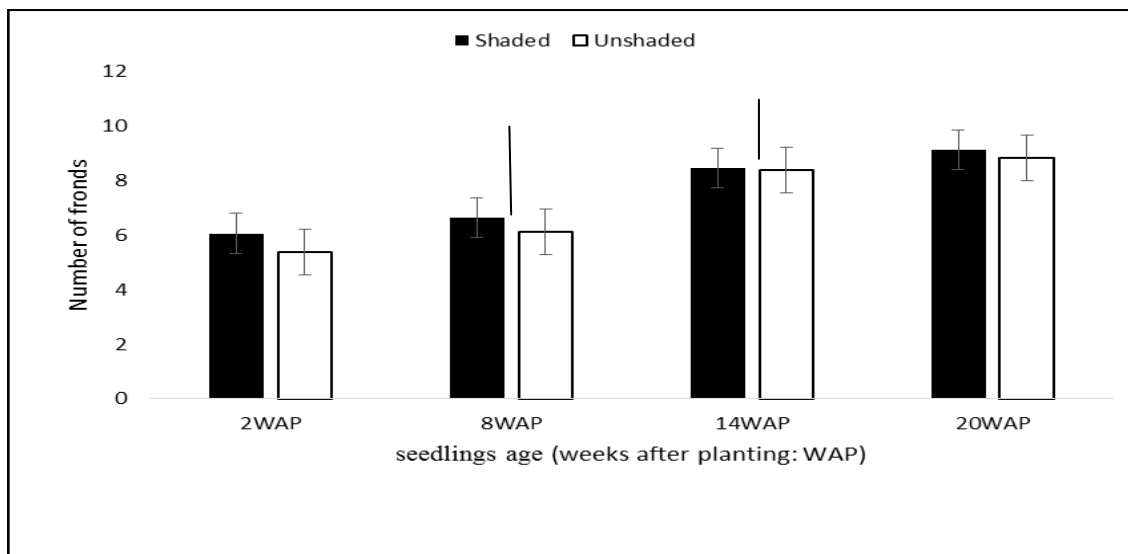


Figure 2a. Effect of shade on number of frond of oil palm seedlings.

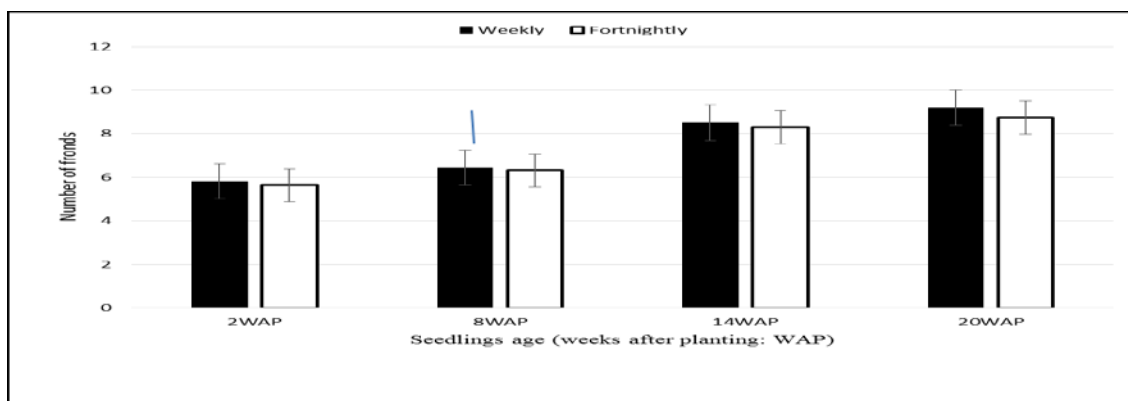


Figure 2b. Effect of irrigation intervals on number of frond of oil palm seedlings.

Table 1. Effect of shading on growth parameters of oil palms seedlings.

Treatment	Root length (cm)	Root weight (g)	Number of root	Shoot weight (g)	Root: shoot weight	Leaf weight (g)	FronD weight (g)
2012 experiment							
Shaded	42.86b	11.83a	12.13a	101.81a	0.12b	44.06a	38.43a
Unshaded	47.91a	12.34a	12.19a	63.03b	0.20a	26.01b	22.37b
2013 experiment							
Shaded	39.06b	10.30a	10.15a	94.17a	0.11b	40.76a	35.42a
Unshaded	45.10a	11.46b	11.14a	57.83b	0.20a	23.41b	20.35b

Means in a column with the same letter (s) under the same experiment are not significantly different according to DMRT (P= 0.05).

Effects of irrigation on growth parameters of oil palm seedlings

The growth parameters of oil palm seedlings as affected by irrigation regimes are presented in Table 2. Although, weekly irrigated oil palm seedlings were taller than those irrigated fortnightly, no significant difference was observed among irrigation regimes. Also, irrigation regimes did not significantly affect number of fronds. Fortnightly irrigation significantly increased root length (Table 2). However, non-significant differences were observed

for total root weight, number of roots, frond length and weights of shoot and leaf. Seedlings that were irrigated weekly were taller than those grown under fortnight irrigation, seedlings irrigated fortnightly had significantly longer roots and heavier root biomass than those irrigated weekly although, values of these parameters were not significantly different. Weekly irrigation favours biomass development which was evidenced in significantly higher shoot, leaf and frond weights than those irrigated fortnightly.

Table 2. Effects of irrigation interval on growth parameters of oil palm seedlings.

Treatment	Root length (cm)	Root weight (g)	Number of roots	Shoot weight (g)	Root: shoot weight	Leaf weight (g)	Frond weight (g)
2012 experiment							
Weekly	41.87b	12.61a	11.87a	85.28a	0.15a	36.73a	30.61a
Fortnightly	48.87a	11.56a	12.44a	79.56a	0.15a	33.34a	30.20a
2013 experiment							
Weekly	44.81b	12.61b	91.28a	0.14b	39.15a	35.10a	11.37a
Fortnightly	56.72a	16.64a	65.56b	0.25a	32.54b	28.40b	12.24a

Means in a column with the same letter (s) under the same experiment are not significantly different according to DMRT (P= 0.05).

Effects of shade and irrigation on soil moisture content

Soil moisture content under shade was significantly higher than under open sun at 2, 8 and 14 WAP respectively (Figure 3a and 3b). However, irrespective of shade treatments, there seems to be reduction in percentage soil moisture content as seedlings grow older. Weekly irrigation regime had higher soil moisture

contents than fortnight irrigation regime across the measurement period (Figure 3b). The effects of shade and irrigation regimes on the consumptive water use of oil palm seedlings (Figure 4) showed that seedlings that were irrigated fortnightly and unshaded consumed less water than open sun. The results also showed that seedlings irrigated weekly use more moisture than those irrigated fortnightly under shaded and open sun treatments (Figure 4).

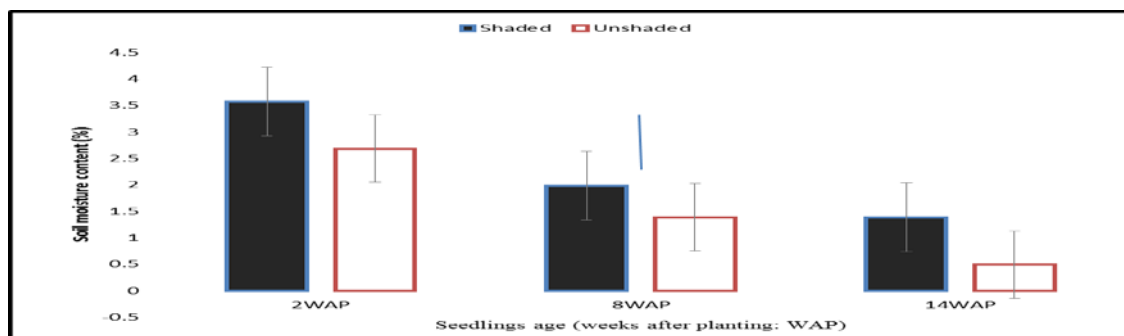


Figure 3a. Soil moisture content for shaded and unshaded treatments.

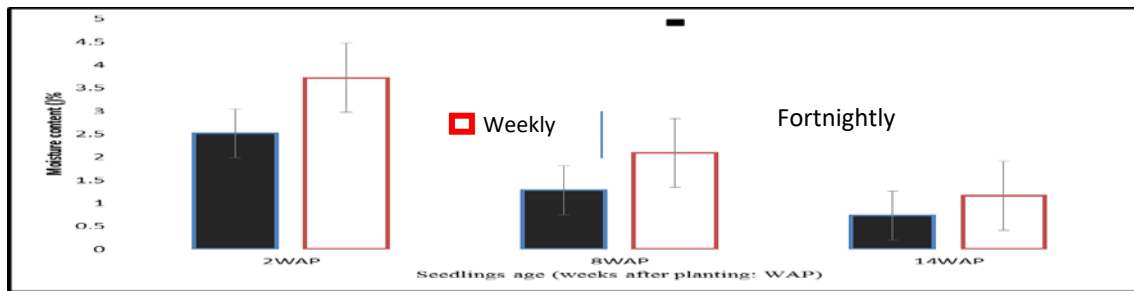


Figure 3b. Soil moisture content for weekly and fortnight irrigation regimes.

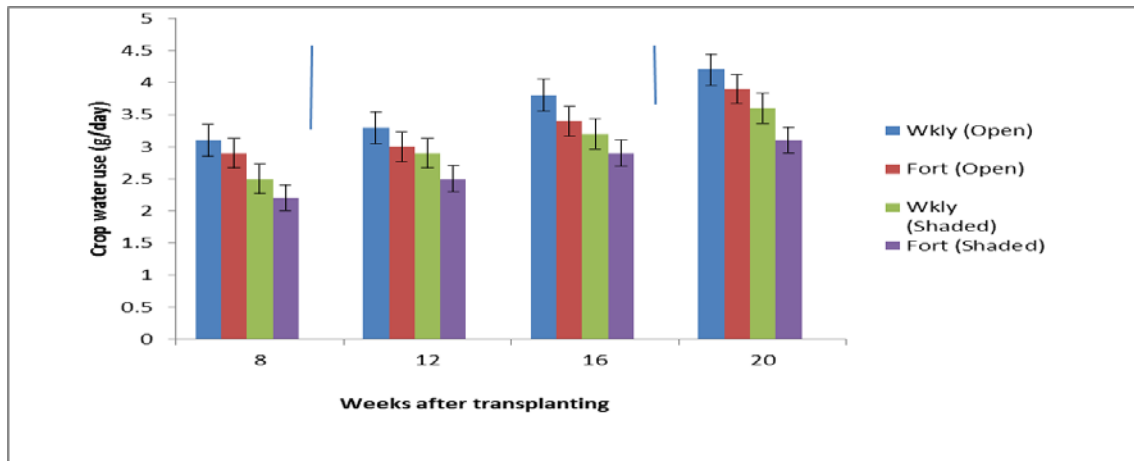


Figure 4. Interaction effects between irrigation regime and shading on crop water use.

Effects of mycorrhizal inoculation on growth and development of oil palm seedlings

Effects of mycorrhizal inoculation on the growth parameters of oil palm seedlings are presented in Table 3. The results showed that significant differences ($P < 0.05$) were obtained for leaf and root length, leaf and frond weight only. Seedlings that were inoculated with mycorrhizal fungi had shorter root, higher number and weights of roots than non-inoculated. In addition, inoculated seedlings had higher

weights of shoot, leaf and frond than the non-inoculated. The results of the effects of mycorrhizal inoculation on height increase and fronds production are presented in Figure 5a and 5b. There were significant differences for height increase and frond production for the AMF inoculated and non-inoculated treatments. Mycorrhizal inoculated seedlings produced longer roots and heavier root biomass than those irrigated weekly although, values of these parameters were not significantly different (Table 4).

Table 3. Effect of mycorrhizal inoculation on growth parameters of oil palm seedlings.

Treatments	Root length (cm)	Root weight (g)	Shoot weight (g)	Root: shoot weight	Leaf weight (g)	Frond weight (g)	Number of root
2012 experiment							
Inoculated	42.35b	13.42a	89.04a	0.15a	37.24a	32.73a	12.81a
Non-inoculated	48.42a	10.76a	75.79a	0.14a	33.82b	28.08b	11.50a
2013 experiment							
Inoculated	42.91b	12.41b	89.68a	89.68a	34.54a	29.90a	11.76a
Non-inoculated	55.72a	16.04a	58.66b	58.66b	28.46b	23.46b	12.01a

Means in a column with the same letter (s) under the same experiment are not significantly different according to DMRT (P= 0.05).

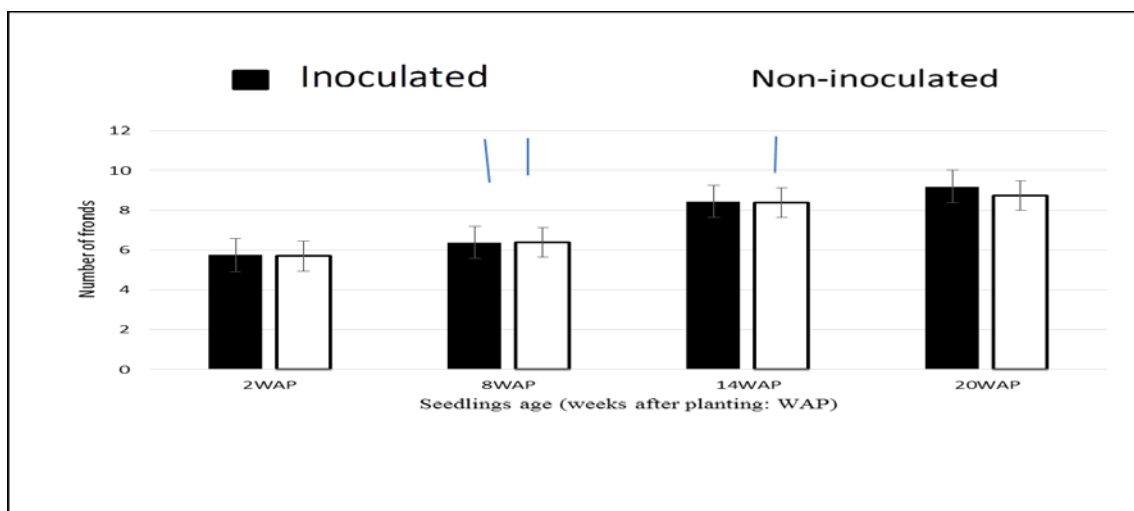
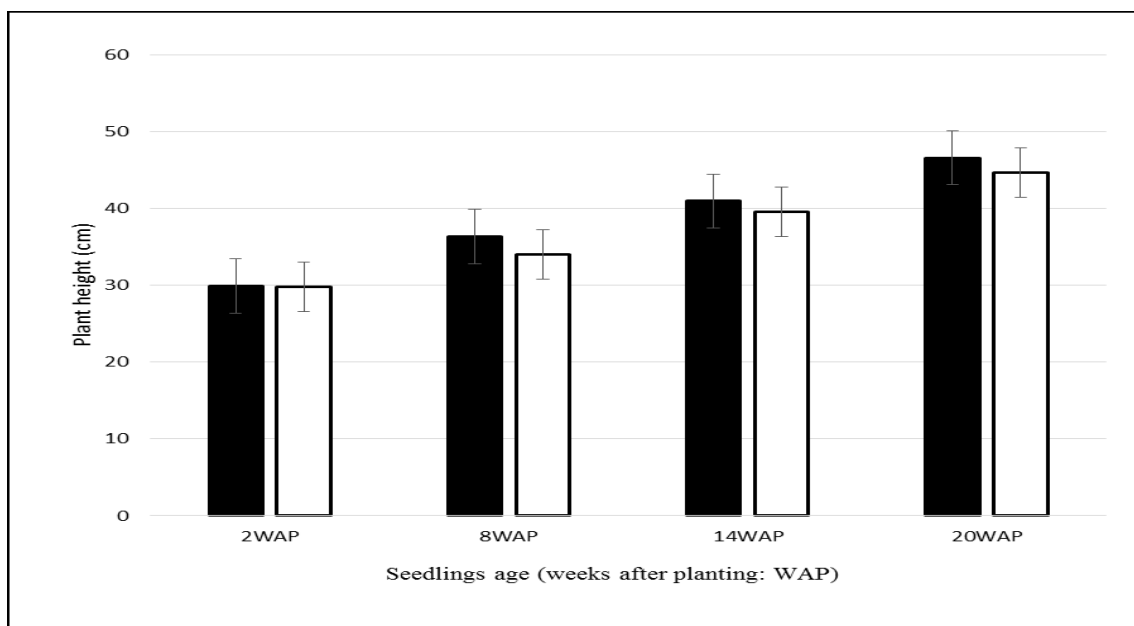
**Figure 5b.** Effect of AMF inoculation of number of fronds of oilpalm seedlings.**Figure 5a.** Effect of AMF inoculation on height of oilpalm seedlings.

Table 4. Interaction effects between irrigation regime and shade on oil palm seedlings.

Shade	Irrigation	Plant height (cm)	Number of fronds	FronD length (cm)	Root length (cm)	Root weight (g)	Shoot weight (g)	Root: shoot weight	Leaf weight (g)	FronD weight (g)	Number of root
2012 experiment											
Shaded	Weekly	62.2	9.38	51	43	13.15	109.3	0.12	47.57	39.1	11.62
	Fortnightly	63.1	8.88	54.5	42.7	10.51	94.3	0.11	40.55	37.75	12.62
Unshaded	Weekly	43.3	9.38	34.3	40.8	12.07	61.3	0.19	25.89	22.13	12.12
	Fortnightly	40.3	9.38	33.4	55	12.61	64.8	0.2	26.13	22.65	12.25
2013 Experiment											
Shaded	Weekly	65.41	9.13	38.43	46.2	14.55	96.5	0.15	49.46	45.42	11.52
	Fortnightly	52.32	8.5	31.69	49.7	10.51	97.5	0.11	43.65	39.98	11.92
Unshaded	Weekly	37.24	8.75	20.98	42.98	17.17	58.7	0.29	23.92	23.34	12.04
	Fortnightly	27.61	8.13	20.03	61.1	12.61	65.75	0.19	28.33	25.76	12.25

Interaction effects between irrigation, shade and AMF inoculation on growth of oil palm seedlings

Significant interactions ($P \leq 0.05$) were obtained between irrigation and shade regimes for plant height, number of fronds, frond length, root length, shoot weight, leaf weight and frond weight (Table 4). Non-significant difference was obtained for root weight and number of roots. The interaction between shade and weekly irrigation significantly increased the seedling height and enhanced the number and length of fronds. The unshaded seedlings that were irrigated fortnightly had longer roots than seedlings irrigated weekly either shaded or unshaded and for fortnight irrigation plus shading. Seedlings irrigated weekly and under shade produced higher weights of shoot, leaf and fronds than those irrigated fortnightly and under in the open sun. Consistently unshaded seedlings had lower weights of shoot, leaf and frond than shaded irrespective of irrigation regimes. Significant interactions ($P \leq 0.05$) were observed between irrigation regimes and shade treatment for most of the parameters measured on oil palm seedlings (Table 4). Seedlings under shade and weekly irrigation were taller than those under open sun. Irrespective of irrigation regimes the plant heights of seedlings were not significant different from each other as long they were under the same shade treatment. The interaction between shade and weekly irrigation was significant for length of fronds. As well, root length was significantly increased by the interaction

between fort for fortnight irrigation and open sun treatments. Seedlings irrigated fortnightly and under shade had heavier shoots, leaves and fronds than those irrigated fortnightly and under open sun. Consistently, seedlings under open sun had less shoot, leaf and frond weights than those under shade irrespective of irrigation regimes.

Discussion

Effects of shading and irrigation regimes on growth and development of oil palm seedlings

The results of this study showed that the measured growth variables of oil palm seedlings responded to the shading and irrigation regimes imposed. Weekly irrigation increased plant height, stem girth and number of leaves due to an enhanced status and availability of moisture in the crop rootzone. This observation is consistent with reports of Henson et al. (2005) and Majumder (2010), who stated that when adequate water is available, plant cells remain turgid and plants retain their form and structure. The measured growth variables of oil palm seedlings were statistically superior under weekly irrigation and shading. This implies that the oil palm seedlings require consistent moist rootzone environment and modified microclimate offered by shading (Henson et al., 2007). The oil palm seedlings that were irrigated weekly were taller than those irrigated at fortnight interval. This result further confirms how essential water is to growth

and development of oil palm seedlings, a crop that is known to be very sensitive to a soil water deficiency (Henson et al., 2005; Majumder, 2010).

Adequacy of soil moisture promotes leaf development as was obtained for seedlings that were irrigated weekly. Adequately available moisture in crop rootzone will enhance optimum plant water use (crop evapotranspiration). Adequate soil and plant water status is critical to the survival of seedlings during establishment on the field (Mimano et al., 2006). The results of this study confirmed that oil palm seedlings cannot withstand soil moisture deficit stress as was obtained for seedlings that were irrigated fortnightly especially in the open sun. The terminal drought (dry spell) situation of the dry season is characterized by high intensity of soil and air moisture deficits and temperatures, these conditions have implications for survival and establishment of seedlings on the nursery and field. When plants grow under soil water deficit conditions, previous research had attributed poor vigour of growth to limitations of stomatal (closure) function and negative plant water status (low leaf water potential and relative water content) (Henson and Harun 2007; Oyun et al., 2010).

Effects of mycorrhizal inoculation on growth and development of oil palm seedlings

The seedling batch that was subjected to weekly watering regime without mycorrhizal inoculation had significantly higher ($P < 0.05$) survival than fortnightly irrigation regime. Seedlings inoculated with mycorrhizae fungi and subjected to weekly and fortnight irrigation intervals were more vigorous going by the measured growth parameters of oil palm. Nevertheless, there were no significant differences for most of the measured parameters between weekly and fortnight irrigation for mycorrhizal inoculated seedlings.

Drought stress reduces leaf area and number of leaves in tree species (Tiaz and Zeiger, 1998; Agele et al., 2016). Pellegrino et al. (2005) and Henson and

Harun (2007) reported that leaf emergence rate as the most sensitive parameter to drought stress. Awotoye et al. (1992) reported that mild water stress and mycorrhizal inoculation enhanced growth than the non-mycorrhizal (control). The findings of the present study were similar to the report of Osundina (1995) that mycorrhizal inoculation enhanced leaf number, increased collar diameter and shoot biomass in *Parkia biglobosa*. The author concluded that mycorrhizal infection of plant roots brought about increases plant growth and drought tolerance. The effect of the interaction between mycorrhizal inoculation and irrigation was enhancement of growth performance of oil palm seedlings. Application of AMF supported the growth of oil palm seedlings in the nursery with more leaves, thickness of the roots. It is not out of place to say that AMF is a bio-fertilizer. The presence of AMF as black dots on roots of oil palm seedlings signifies presence of mycorrhizal hyphae, and played functional role in oil palm growth. Mycorrhizae fungi form symbiosis (mutualistic) association between plants and soil fungi. The transport of nitrate via mycorrhizal fungi hyphae to the host plant has been demonstrated preferentially under drought when nitrate diffusion in the soil is reduced. The growth of oil palm seedlings plants in this study was promoted by mycorrhizal inoculation. As observed by Agele et al. (2016), oil palm plants inoculated with mycorrhizal exhibit superior growth which is attributable to high mycorrhizal colonization of seedling roots compared with the non-inoculated. In another study, plant height and stem diameter of coffee seedlings were significantly increased by single super phosphate fertilizer and mycorrhizal inoculation (Ibiremo et al. 2011) which corroborates the findings in the study. In mycorrhizal-Acacia relationships, plant responses were greater from endomycorrhizal than ectomycorrhizal inoculation (Oyun et al., 2010).

The weekly irrigation plus mycorrhizal inoculation produced wider stem girth and greater number of leaves. The enhancement of growth characters

under this treatment combination may be due to the activity of the mycorrhizal fungi in enabling the oil palm seedlings to explore a greater volume of soil for increased nutrient absorption. This is consistent with report by Ibiremo *et al.* (2011) that mycorrhizal inoculation increased shoot biomass of tree crops. It is probable that mycorrhizal root colonization increased the ability of the seedlings to take up nutrients which increased their vegetative growth. Levy and Kirkum (1983) as well as Read and Boyed (1986) noted that mycorrhizal inoculated plants had enhanced soil water extraction and root hydraulic conductivity. The findings from this study support earlier observations by Oyun *et al.* (2010) that mycorrhizal inoculation and watering twice weekly enhanced growth and seedling survival of oil palm seedlings. However, the mycorrhizal inoculated seedlings had higher chlorophyll content than the non-inoculated. This infers that mycorrhizal inoculation is needed to increase chlorophyll concentration of oil palm seedlings.

Mycorrhizal inoculation enhanced oilpalm seedling growth than the non-inoculated, and weekly watering of seedlings enhanced plant height compared with fortnightly irrigation. At 16 WAP, some seedlings both the inoculated and non-inoculated that were subjected to fortnight irrigation wilted while those subjected to weekly irrigation had significantly higher growth and survival in the field. However, mycorrhizal inoculated seedlings had higher growth and survival in the field than the non-inoculated. The total chlorophyll content gradually increased with the age of the seedlings. Within the same treatment, total chlorophyll content of the leaves of mycorrhizal inoculated seedlings irrigated weekly was significantly higher than that obtained from the other treatments. Based on the measured growth parameters of oil palm seedlings, shading and weekly irrigation had better vigour of growth than fortnightly and open sun (unshaded) treatments. Mycorrhizal inoculation of oil palm seedlings, shade and

weekly irrigation are recommended. These treatments enhanced vigour, growth and reduce mortality of oil palm seedlings in the nursery in the dry season.

Conflicts of interest

Authors declare that they have no conflict of interests.

References

- Agele, S. O.; Osaigbovo, A. U.; Ogedegbe, S. A.; Nwawe, A. K. 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**, v. 4, No. 3, p. 35-45, 2016. Available from: <<https://journalissues.org/wp-content/uploads/2016/03/Agele-et-al.pdf>>. Accessed on: Jul. 23, 2016.
- Agele, S. O.; Agbona, I. A.; Ewulo, B. S.; Anifowose, A. Y. Drip irrigation scheduling for optimizing productivity of water use and yield of dry season pepper (*Capsicum annum* L.) in an inland valley swamp in a humid zone of Nigeria. **International Journal of Plant and Soil Science**, v. 4, No. 2, p. 171-184, 2014.
- Agele, S. O.; Iremiren, G. O.; Ojeniyi, S. O. Evapotranspiration, water use efficiency and yield of rainfed and irrigated tomato in the dry season in a humid rainforest zone of Nigeria. **International Journal of Biology & Agricultural Sciences** v. 13, p. 469-476, 2011.
- Allen, R. G.; Pereira, L. S.; Raes, D.; Smith, M. **Crop evapotranspiration: guideline for computing crop water requirement**. Rome: Food and Agriculture Organisation of the United Nations, 1998. (FAO Irrigation and Drainage Paper, 56).
- Awotoye, O. O.; Atayese, M. O.; Osonubi, O.; Mulongoy, K.; Okali, D. U. V. Response of some tropical nitrogen-fixing woody legumes to drought and inoculation with mycorrhiza. In: Mulongoy, K.; Gueye, M.; Spencer, D. S. C. (Eds.). **Biological Nitrogen fixation and sustainability of Tropical Agriculture**. New York: Wiley and Sons, 1992. p. 67-77.
- Bateman, I. J.; Fisher, B.; Fitzherbert, E.; Glew, D.; Naidoo, R. Tigers, market and palm oil: market potential for conservation. **Oryx**, v. 44, p. 230-234, 2010.

- Bello, A. G.; Ambursa, A. S. Indigenous knowledge of gum arabic (*Acacia senegal* L.) wild production in North-Western Nigeria. 31st. Annual Conference of Forestry Association of Nigeria, 2005.
- Boffa, J. M. Agro forestry parkland systems in Sub-Saharan Africa. Rome: Food and Agriculture Organisation of the United Nations, 1999. (FAO conservation guide, 34).
- Corley, R. H. V.; Tinker, P. B. **The oil palm**. 4 ed. World Agriculture Series, 2003. p. 19-28.
- Corley, R. H. V. How much oil palm do we need? **Environmental Science Policy**, v. 12, p. 134-139, 2009.
- Doorenbos, J.; Pruitt, W. O. **Crop water requirements**. Rome: Food and Agricultural Organization of the United Nations, 1977. (FAO Irrigation and Drainage Paper, 24).
- Dhillon, S.; Gustad, G. Local management practices influence on the viability of the baobab (*Adansonia digitata* Linn.) in different land use types. Ginazana, Mpali. **Agriculture and Ecosystem**, v. 101, p. 84-103, 2004.
- Ezawa, T.; Smith, S. E.; Smith, F. A. P. Metabolism and transport in AM fungi. **Plant Soil**, v. 244, p. 221-230, 2002.
- Henderson, J.; Osborne, D. J. The oil palm in our lives: how this came about. **Endeavor**, v. 24, No. 2, p. 63-68, 2000. [https://doi.org/10.1016/S0160-9327\(00\)01293-X](https://doi.org/10.1016/S0160-9327(00)01293-X)
- Henson, I. E.; Noor, M. R. M. D.; Harun, M. H.; Yahya, Z.; Mustakim, S. N. A. Stress development and its detection in young oil palms in North Kedah, Malaysia. **Journal of Oil Palm Research**, v. 17, p. 11-26, 2005. Available from: <<http://palmoilis.mpob.gov.my/publications/jopr17june-ms11.pdf>>. Accessed on: Jul. 26, 2016.
- Henson, I. E.; Harun, M. H.; Chang, K. C.; Mohammed, A. T. Predicting soil water status, evapotranspiration growth and yield of young oil palm in a seasonally dry region of Malaysia. **Journal of Oil Palm Research**, v. 19, p. 398-415, 2007.
- Ho, C. L.; Kwan, Y. Y.; Choi, M. C.; Tee, S. S.; Ng, W. N.; Lim, K. A.; Lee, Y. R.; Ooi, S. E.; Lee, W. W.; Tee, J. M.; Tan, S. H.; Kulaveerasingam, H.; Alwee, S. S. R. S.; Abdullah, M. O. Analysis and functional annotation of expressed sequence tags (ESTs) from multiple tissues of oil palm (*Elaeis guineensis* Jacq). **BMC Genomics**, v. 381, p. 1-12, 2007.
- Ibiremo, O. S.; Daniel, M. A.; Oloyede, A. A.; Iremiren, G. O. Growth of coffee seedlings as influenced by arbuscular mycorrhizal inoculation and phosphate fertilizer in two soils in Nigeria. **International Research Journal of Plant Science**, v. 2, No. 6, p. 160-165, 2011.
- IWM - International Water Management Institute. Annual Reports. IWMI Thailand. 2002.
- Levy, Y.; Krikum, J. Effects of irrigation, water and salinity and root-stock on the vertical distribution of vesicular arbuscularmycorrhiza on citrus roots. **New Phytol.**, v. 15, p. 397-403, 1983.
- Majumder, A. L.; Sengupta, S.; Goswami, L. Osmolyte regulation in abiotic stress. In: Pareek, A.; Sopory, S. K.; Bohnert, H.; Govindjee (Eds.). **Abiotic stress adaptation in plants**. Physiological, Molecular and Genomic Foundation, 2010. p.349-370.
- Mimano, L. N.; Macharia, C. W.; Wasilwa, L. A. Micro-propagation: a useful tool for rapid multiplication of oil palm (*Elaeis guineensis*) hybrids in Kenya. Proceedings of 10th Kenyan Agricultural Research Institute Biennial Scientific Conference, 2006. v. 1.
- NIFOR. A manual of oil palm production. Nigerian Institute for Oil Palm Research. 2009.
- Niinemets, U. Global-scale climatic controls of leaf dry mass per area, density, and thickness in trees and shrubs. **Ecology**, v. 82, p. 2390-2401, 2001.
- Omereji, G. O. Meeting Nigeria's oil needs: small holders or large scale plantation approach. Proc. 1993 PORIM International Palm oil Congress, Kuala Lumpur, 1995.
- Omoti, U. Recent development in the oil palm industry in Nigeria. Paper presented at conference. "The future of the oil palm industry in Africa and strategies for development", 12th September. African Oil Palm Development Association/African Development Bank. Abijan, (2001).
- Osundina, M. A. Responses of seedlings of *Parkia biglobosa* to drought and inoculation with vesicular-arbuscular mycorrhiza. **Nigeria Journal of Botany**, v. 8, p. 1-10, 1995.
- Oyun, M. B.; Adeduntan, S. A.; Suberu, S. U. Influence of watering regimes and mycorrhizae inoculations on the physiology and early growth of *Acacia senegal* (L.). Wild. **African Journal of Plant Science**, v. 4, No. 7, p. 210-216, 2010.

Pellegrino, T.; Lebon, E.; Simmonneau, T.; Wery, J. Towards a simple indicator of water stress in grapevine (*Vitis vinifera* L.) based on the differential sensitivity of vegetative growth component. **Australian Journal of Grape and Wine Research**, v. 11, p. 306-315, 2005.

Read, D. J.; Boyd, R. C. Water Relations of mycorrhizal fungi and their host plant. In: Ayres, P. C.; Boddy, L. (Eds). **Water, fungi and plants**. Cambridge, U.K.: Cambridge University Press, 1986.

Tiaz, L.; Zeiger, E. **Plant physiology**. 2. ed. Massachusetts: Sinauer Associates Inc., 1998.

Yusof, B. Palm oil production through sustainable plantations. **European Journal of Lipid Science Technology**, v. 109: p. 289-295, 2007.