Assessment of water stress tolerance in juvenile oil palm genotypes (*Elaeis guineensis* Jacq.) through the measurement of morphological and physiological parameters

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ABSTRACT (Arial, Bold, 11 font, left aligned, caps)

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| The oil palm industry holds significant importance in Ivorian agriculture. Côte d’Ivoire is the second largest producer and the foremost exporter of palm oil in Africa. The purpose is to augment palm oil production by expanding the cultivable area in non-traditional agricultural zones characterised by water scarcity. Nevertheless, the existing oil palm genotypes have not been chosen based on their resistance to water scarcity. This research seeks to find genotypes that are likely to withstand water scarcity. The experiment was carried out in a greenhouse at the CNRA of La ME (Abidjan region), with a factorial block design with three replications. The water regime component comprises two levels of water supply (RH100%, RH0%) alongside the genotype factor, which includes 23 genotypes. The trial endured for 45 days within a greenhouse. Observations were conducted on the plants of 23 genotypes under water stress circumstances by assessing morphological and physiological parameters to identify those with enhanced resistance to water deficit. The examined parameters were influenced by the water deficit. Statistical analysis indicated that on the control diet (500 ml/d), all examined genotypes exhibited normal parameter values, which were somewhat uniform overall. Conversely, in the extreme deficit diet of 0 ml of water, the reduction in the values of the examined parameters compared to the control was minimal for genotypes 1, 5, 7, 9, 10, and 23, and moderate for genotypes 6, 11, 14, 17, and 22. The reduction was significant for genotypes 2, 3, 4, 8, 12, 13, 15, 16, 18, 19, 20, and 21. This nursery research, designed to distinguish sensitive genotypes from resistant ones under water stress, represents a significant advancement in validating drought-tolerant genotypes in a natural setting. |

*Keywords:* oil palm seedlings, water stress, climate change, Côte d’Ivoire

1. INTRODUCTION (Arial, Bold, 11 font, left aligned, caps)

The oil palm (*Elaeis guineensis* Jacq.) serves as a significant economic asset due to the fruits and nuts from which palm oil and palm kernel oil are derived (Konan et al., 2024a). Palm oil is the most extensively produced and consumed vegetable oil globally, according to Adon et al, (2021). This oil is regarded as the second most significant food sector following rice, for food security and income in west Africa region (Carrère, 2010). Indonesia accounts for 58% of the oil production, while Malaysia contributes 26% (Chew et al., 2021). Côte d'Ivoire emerges as a viable alternative for palm oil supply in tropical Africa. According to the USDA (2024), Côte d'Ivoire produces 650 000 tons of crude palm oil annually, positioning it as the 10th largest producer worldwide. It is the foremost exporter of palm oil and the second largest producer in Africa, following Nigeria (Niamketchi et al., 2024). In addition to generating more than 500 billion CFA francs in revenue, the oil palm business is responsible for the employment of about one million people. In West Africa, where demand for palm oil is steadily rising each year, Côte d'Ivoire is seen as a feasible option due to the high quality and genetic improvement of its plant material (Tano et al., 2019). As a result, it is necessary to increase its production in order to meet its own needs and resolve the oilseed shortage (Konan et al., 2024b). As noted by Brou et al, (2005), N'diaye et al. (2007) and Yehouessi et al. (2020), the persistent decline in rainfall and its uneven distribution caused by climate change are adversely impacting production. Consequently, research initiatives are being conducted to provide producers with high-performance plant materials that are optimal for the production environment. This is in accordance with N’guetta et al. (2010) and Nodiacho et al. (2011).

The vegetative and productive capacity of the oil palm is most significantly improved by water and the environmental component. To maintain normal production, the palm tree necessitates 1800 to 2400 mm of water annually, which must be evenly distributed throughout the year (Wang et al., 2020; Bayona-Rodríguez et al., 2024). The primary constraint constraining the output of oil palm tree is water supply, as noted by Montoya et al. (2024) and Wang et al (2020). Nevertheless, Côte d'Ivoire, like other sub-Saharan African nations, is facing the unpredictable effects of climate change. The oil palm genotypes that are currently available have not been chosen based on their ability to withstand water deficits (Gogoue et al., 2020). It is therefore imperative to identify the material in the germplasm of the National Centre for Agronomic Research (CNRA) that possesses a water deficit tolerance heritage to reproduce it in seeds and make it accessible to the agricultural community (Gogoue et al., 2020). Consequently, the aim of this investigation is to identify oil palm genotypes that are resistant to water stress during the nursery phase by analysing their agromorphological and physiological characteristics.

2. material and methods

**2.1 Research location**

The experiment was carried out in a greenhouse at the National Centre for Agronomic Research (CNRA) of La Mé Research Station, situated in the southeastern region of Côte d'Ivoire, at 5° 26' North Latitude and 3° 50' West Longitude. The greenhouse facilitated the regulation of climate variables, rendering water deficiency as the sole stressor. A humidity sensor in the greenhouse facilitated the establishment of optimal temperature and humidity conditions for palm plants, maintaining an average hourly temperature between 28° and 38°C and humidity levels ranging from 80% at night to 50% at daytime.

**2.2 Plant materials**

The plant material consisted of 23 genotypes of six-month-old oil palm seedlings (DXP) (Figure 1). The genotypes are derived from three categories of oil palm: C1001F, C2501F, and J1942F, which were artificially pollinated at the Mé Research Station (Table 1). The seeds are renowned for their exceptional productivity in the field and their ability to tolerate Fusarium disease, the most devastating diseases affecting oil palm in Africa (Diabaté et al., 2009).

**2.3. Experimental designs**

Three-month-old seedlings from a pre-nursery were transplanted into black polyethylene bags with an average capacity of 7.85 dm³and arranged in a seedling nursery. The seedlings were nurtured for 3 months to ensure the development of robust and vigorous plants, after which a water stress test was conducted at the 6-month mark (Figure 2).

The experiment was executed using a fully randomised block factorial design (two factors) with three repetitions. The genotype component has 23 modalities, while the water stress treatment factor consists of 2 modalities. The 100% water regime, characterised by a continuous drip irrigation system delivering 500 ml per day, and the 0% water regime, which entails no water supply. Each block or repetition comprised 46 elementary plots (23 genotypes x 2 water regimes) or 138 elementary plots (46 plots x 3 repetitions) for the entire experiment. The quantity of plants per elementary plot was five, resulting in a total of 414 plants for the trial (138 plots x 3 plants). Before the experiment started, all the 23 genotypes seedlings, possessing 5 to 6 leaves, were irrigated routinely prior to the imposition of stress. The experiment endured for 60 days within a greenhouse.

**Table 1. Various genotypes of the C1001F, C2501F, and J1942F categories of oil palm evaluated**

|  |  |  |
| --- | --- | --- |
| **Categories** | **Genotypes** | **Total** |
| C1001F | LM 8 023 (G1) | 18 |
| LM 12 165 (G2) |
| LM 16 578 (G3) |
| LM 17 114 (G4) |
| LM 18 443 (G5) |
| LM 18 775 (G6) |
| LM 18 783 (G7) |
| LM 19 016 (G8) |
| LM 19 121(G9) |
| LM 18 801(G10) |
| LM 19 175 (G11) |
| LM 21 256 (G12) |
| LM 24 382 (G13) |
| LM 18 805 (G14) |
| PO 6 531(G15) |
| PO 6 637 (G16) |
| PO 7 259 (G17) |
| PO 7 974 (G18) |
| C2501F | LM 11076 (G19) | 4 |
| LM 19 622 (G20) |
| LM 20 258 (G21) |
| LM 21 181 (G22) |
| J1942F | LM 23 543 (G23) | 1 |



**Figure 1. Plants of different genotypes in nursery**

*Une image contenant bâtiment, serre, plein air, plante

Description générée automatiquementUne image contenant ciel, plein air, nuage, arbre

Description générée automatiquement*

**Figure 2. View of the greenhouse (1), and plants of different categories in the greenhouse (2)**

**2.4 Vegetative measurements**

Measurements were conducted biweekly on three plants per elementary plot. The agromorphological metrics were plant mortality, vegetative growth, bole or collar diameter, leaf production per plant, and physiological parameters such as chlorophyll and nitrogen content. These characteristics are associated with water deficiency, as noted by Maillard et al. (1974), Adjahoussou (1983), and Nouy et al. (1999). Mortality assessment consisted of periodically enumeration of deceased plants categorised by genotype, treatment, and replication. The vegetative growth of the plant was assessed with a tape measure. The bole diameter was measured using a calliper. The quantity of leaves generated was quantified. The chlorophyll and nitrogen content of the leaves were assessed using a plant nutritional analysis instrument (Chlorophyll fluorometer PAM-2500). Chlorophyll content measurements are presented on the device's screen during measurement in SPAD (Soil Plant Analysis Development) units. The nitrogen content of the leaves was quantified in mg/g using the same procedure and measurement instrument.

**2.5 Data analysis**

All data collected were subjected to an analysis of variance (ANOVA) with SAS 9.4 software. In case of a significant difference between the treatments, the comparison of the means was carried out by the Newman-Keuls multiple comparison test at the α threshold of 5%. Hierarchical clustering (HCA) was used to classify individuals with similar behavior on a set of variables using XLSTAT 2023 version.

3. results and discussion

3.1 Results

The analysis of variance showed a significant difference in the values of the studied parameters of the 23 genotypes, (P < 0.001) at each water regime. Control plants exhibited superior morphological and physiological metrics compared to those that were not irrigated following a two-month period of water scarcity.

**3.1.1 Effect of water deficit on the morphological parameters of the 23 oil palm genotypes.**

***3.1.1.1 Effect of water deficit on the mortality rate of plants***

Following two months of water stress in the greenhouse, the effects of water deficiency on the survival of each tested genotype were observed by the mortality rate of oil palm plants (Table 2). Genotypes LM18443 (G5), LM23543 (G23), LM8023 (G1), LM21543 (G22), LM19121 (G9), and LM18801 (G10) exhibited reduced mortality rates ranging from 20% to 40%. Conversely, the genotypes PO7074 (G18), PO6637 (G16), LM19175 (G11), PO6531 (G15), and LM21256 (G12) exhibited significantly elevated mortality rates, ranging from 46% to 70% (Table 2).

**Table 2: Mortality status and classification of plant genotypes following two months of stress**

|  |  |  |  |
| --- | --- | --- | --- |
| Genotypes | Number of plants in the trial | Observed mortalities | Mortalities (%) |
| LM 8 023 (G1) | 15 | 3 | 20 |
| LM 12 165 (G2) | 15 | 6 | 40 |
| LM16578 (G3) | 15 | 6 | 40 |
| LM17114 (G4) | 15 | 7 | 46 |
| LM18443 (G5) | 15 | 3 | 20 |
| LM18775 (G6) | 15 | 6 | 40 |
| LM18783 (G7) | 15 | 5 | 33 |
| LM19016 (G8) | 15 | 6 | 40 |
| LM19121 (G9) | 15 | 5 | 33 |
| LM18801 (G10) | 15 | 5 | 33 |
| LM19175 (G11) | 15 | 8 | 53 |
| LM21256 (G12) | 15 | 7 | 46 |
| LM24382 (G13) | 15 | 6 | 40 |
| LM18805 (G14) | 15 | 7 | 46 |
| PO6531 (G15) | 15 | 7 | 46 |
| PO6637 (G16) | 15 | 9 | 60 |
| PO7974 (G17) | 15 | 6 | 40 |
| PO7074 (G18) | 15 | 10 | 66 |
| LM11062 (G19) | 15 | 7 | 46 |
| LM19258 (G20) | 15 | 7 | 46 |
| LM20187 (G21) | 15 | 6 | 40 |
| LM21543 (G22) | 15 | 4 | 26 |
| LM23543 (G23) | 15 | 3 | 20 |

*LM : La Mé ; PO : Pobé ; G : Genotype*

***3.1.1.2 Effect of water deficit on vegetative growth***

The statistical analysis of vegetative growth data for the 23 oil palm genotypes indicates that under normal water conditions (RH100%), the growth of the control plants varied between 245.41 cm and 279.18 cm. The genotypes LM 8 023 (G1), LM18801 (G10), LM11062 (G19), and LM23543 (G23) exhibited the greatest plant vegetative growths. Under the stressed regime, the plant vegetative growth of the genotypes varied from 207.40 cm to 268.55 cm. Genotypes LM23543 (G23), LM18801 (G10), and LM8023 (G1) exhibited the greatest heights under stress conditions. Analysis of the vegetative growth variation between control and stressed plants indicates that the genotypes LM18783 (G7), LM18443 (G5), LM23543 (G23), LM18801 (G10), LM20187 (G21), and LM8023 (G1) exhibit the minimal decrease in vegetative growth from control to stressed conditions (Table 3). Nevertheless, the genotypes LM11062 (G19), LM18805 (G14), and PO7074 (G18) exhibit the most significant reduction in vegetative growth relative to their control, as indicated in Table 3.

**Table 3: Variation in the vegetative growth of oil palm plants according to treatments**

|  |  |  |  |
| --- | --- | --- | --- |
| Genotypes | Witness | Stressed | Variation between witness and stressed plants |
| LM 8023 (G1) | 276.08 ±35.55 a | 258.08 ± 39.15 a | 18.00c |
| LM 12165 (G2) | 261.26 ± 33.12 ab | 223.63 ± 32.75 abcd | 37.63b |
| LM16578 (G3) | 257.30 ± 30.93 bc | 233.05 ± 23.79 abcd | 24.25bc |
| LM17114 (G4) | 249.50 ± 30.61de | 223.94 ± 24.77 abcd | 25.56bc |
| LM18443 (G5) | 255.31 ± 34.28 bc | 247.90 ± 26.08 a | 7.41d |
| LM18775 (G6) | 256.31 ± 29.67 bc | 232.53 ± 30.10 abcd | 23.78bc |
| LM18783 (G7) | 253.81 ± 35.47 cd | 249.65 ± 26.10 a | 4.16d |
| LM19016 (G8) | 257.90 ± 35.15 ab | 237.25 ± 33.03abc | 20.65bc |
| LM19121 (G9) | 247.11 ± 39.16 de | 226.61 ± 29.35 cde | 20.05bc |
| LM18801 (G10) | 279.58 ± 34.70 a | 268.43 ± 37.59 a | 11.15c |
| LM19175 (G11) | 260.18 ± 30.88 ab | 231.88 ± 34.84 ab | 28.30b |
| LM21256 (G12) | 256.51 ± 44.42 bc | 233.21 ± 40.41 ab | 23.30bc |
| LM24382 (G13) | 263.60 ± 34.20 ab | 237.38 ± 29.40 ab | 26.22b |
| LM18805 (G14) | 273.71 ± 33.08 ab | 230.86 ± 35.56 ab | 42.85a |
| PO6531 (G15) | 265.26 ± 39.42 ab | 240.66 ± 32.58 a | 24.60bc |
| PO6637 (G16) | 263.13 ± 35.01 ab | 224.30 ± 29.10 cd | 38.83b |
| PO7974 (G17) | 255.51 ± 30.18 bc | 235.33 ± 29.19 ab | 20.18bc |
| PO7074 (G18) | 249.88 ± 31.00 ab | 207.40 ± 27.37 e | 42.48a |
| LM11062 (G19) | 277.98 ± 32.83 a | 231.68 ± 30.48 ab | 46.30a |
| LM19258 (G20) | 271.21 ± 37.93 ab | 239.10 ± 32.23 ab | 32.11b |
| LM20187 (G21) | 245.41 ± 31.53 de | 228.00 ± 27.10 bc | 17.41c |
| LM21543 (G22) | 268.18 ± 34.37 ab | 240.40 ± 31.66 a | 27.78b |
| LM23543 (G23) | 279.18 ± 33.66 a | 268.55 ± 46.65 a | 10.63c |
| *F* | *4.96* | *6.9* | *3.64* |
| *P* | *< 0.001* | *< 0.001* | *< 0.001* |

*Means followed by the same letter in the same column do not show a significant difference (P ≥ 0.05). F: F-statistic associated with the test and P: the probability; LM: La Mé ; PO : Pobé ; G : Genotype*

***3.1.1.3 Effect of water deficit on the number of leaves emitted by plants***

Table 4 presents the average number of leaves produced by the 23 genotypes of plants under various water regimes, together with their corresponding variations. The statistical study indicates that under normal water conditions, the average number of leaves produced by control plants varies from 15.09 to 17.40. The genotypes LM19016 (G8), LM19258 (G20), LM20187 (G21), LM18775 (G6), LM8023 (G1), and LM11062 (G19) had the highest leaf production values. Under stress, the average number of leaves produced by plants of the genotypes ranged from 10.40 to 15.8, primarily characterised by a decline. The genotypes LM8023 (G1), LM18443 (G5), LM18783 (G7), LM18802 (G10), PO7974 (G17), LM21543 (G22), and LM23543 (G23) had the greatest mean values for the number of leaves produced by stressed plants. The analysis of the variation in leaf count between control and stressed plants indicates that the genotypes LM8023 (G1), LM23543 (G23), LM18783 (G7), LM18443 (G5), LM18802 (G10), and LM21543 (G22) exhibit the least variation in leaf production from stress to control conditions (Table 4).

**Table 4. Variation in leaf count of genotypes according to treatments**

|  |  |  |  |
| --- | --- | --- | --- |
| Genotypes | Witness | Stressed | Variation between witness and stressed plants |
| LM 8 023 (G1) | 16.02 ± 1.50 a | 15.88 ± 1.91 a | 0.14d |
| LM 12 165 (G2) | 15.09 ± 1.46 b | 12.65 ± 2.03 gh | 2.44a |
| LM16578 (G3) | 15.68 ± 1.26 a | 12.85 ± 2.09 bc | 2.83a |
| LM17114 (G4) | 15.33 ± 1.58 b | 12.18 ± 2.06 h | 3.15a |
| LM18443 (G5) | 15.18 ± 1.40 ad | 14.13 ± 1.71 a | 1.03d |
| LM18775 (G6) | 16.05 ± 1.37 a | 11.06 ± 2.11 cd | 4.99a |
| LM18783 (G7) | 15.25 ± 1.77 c | 14.23 ± 2.08 a | 1.02d |
| LM19016 (G8) | 17.40 ± 1.99 a | 13.03 ± 1.93 cd | 4.37a |
| LM19121 (G9) | 15.86 ± 2.06 ab | 14.68 ± 2.55a | 1.18cd |
| LM18801 (G10) | 16.00 ± 1.93 a | 14.93 ± 2.36 a | 1.07d |
| LM19175 (G11) | 15.55 ± 1.83 bc | 12.11 ± 1.94 bc | 3.44a |
| LM21256 (G12) | 15.43 ± 2.13 bc | 12.86 ± 1.88 bc | 2.57a |
| LM24382 (G13) | 15.23 ± 1.97 cd | 13.73 ± 1.53 bc | 1.50ab |
| LM18805 (G14) | 15.08 ± 1.42 cd | 12.38 ± 1.65 bc | 1.70b |
| PO6531 (G15) | 15.41 ± 1.72 ab | 11.10 ± 1.95 bc | 4.31a |
| PO6637 (G16) | 15.95 ± 1.79 a | 10.48 ± 1.47 bc | 5.47a |
| PO7974 (G17) | 15.66 ± 1.56 a | 14.51 ± 1.57a | 1.15cd |
| PO7074 (G18) | 15.96 ± 1.98 ab | 10.40 ± 1.66 cd | 5.56a |
| LM11062 (G19) | 16.01 ± 1.82 a | 12.35 ± 1.98 bc | 3.66a |
| LM19258 (G20) | 16.15 ± 2.18 a | 12.37 ± 1.76 bc | 3.78a |
| LM20187 (G21) | 16.08 ± 2.88 a | 13.35 ± 2.15 b | 2.73a |
| LM21543 (G22) | 15.68 ± 3.08 a | 14.60 ± 2.37 a | 1.08d |
| LM23543 (G23) | 15.35 ± 3.34 bc | 14.55 ± 1.94 a | 0.80d |
| *F* | 3.60 | 8.73 | 2.54 |
| *P* | *< 0.001* | *< 0.001* | *< 0.001* |

*Means followed by the same letter in the same column do not show a significant difference (P ≥ 0.05). F: F-statistic associated with the test and P: the probability; LM: La Mé; PO: Pobé; G: Genotype*

***3.1.1.4 Effect of water deficit on the collar circumference of plants***

The average collar circumference values per plant for the 23 genotypes, categorised by water regimes and their variations, are presented in Table 5. The statistical analysis of these values indicates that under normal water conditions, the collar circumference of the control plants ranges from 5.03 to 6.33 cm. The genotypes LM21543 (G22), LM23543 (G23), LM11062 (G19), and LM20187 (G21) exhibit the largest collar circumference values among control plants (Table 5). Under the stressed environment, the collar circumference of the plant genotypes ranged from 3.29 to 5.17 cm, primarily characterised by a reduction in values. The genotypes LM23543 (G23), LM19121 (G9), LM18443 (G5), LM21543 (G22), LM8023 (G1), LM18801 (G10), and PO7974 (G17) exhibited the greatest collar circumference values among stressed plants (Table 5). An examination of the collar circumference variations between control and stressed plants indicates that the genotypes LM23543 (G23), LM19121 (G9), LM18443 (G5), LM21543 (G22), and LM8023 (G1) exhibit minimal reductions in collar circumference values of stressed plants compared to control plants (Table 5).

**Table 5: Variation in Circumference of Oil Palm Genotypes Based on Treatments**

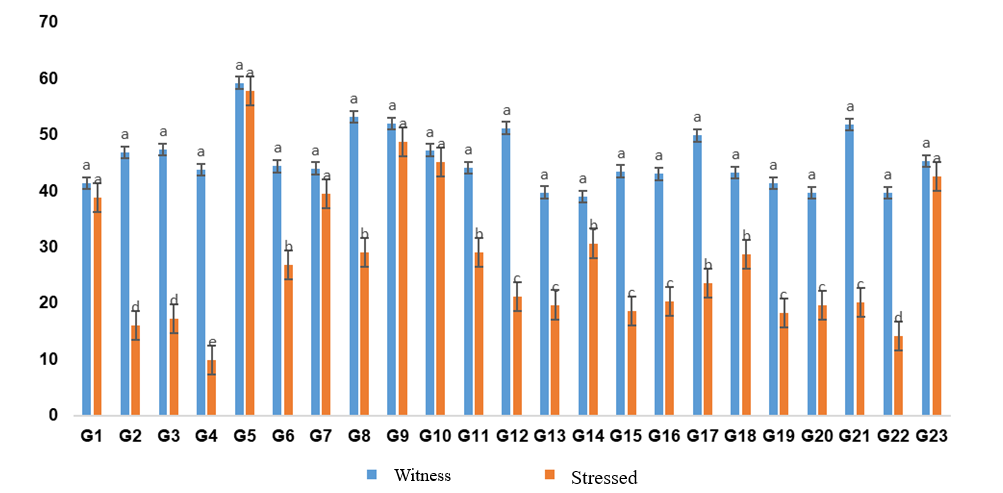
|  |  |  |  |
| --- | --- | --- | --- |
| Genotypes | Witness | Stressed | Variation between witness and stressed plants |
| LM 8 023 (G1) | 6.03 ± 1.32 a | 4.80 ± 1.22 a | 1.23d |
| LM 12 165 (G2) | 5.74 ± 1.08 bc | 3.67 ± 0.92 b.d. | 2.07a |
| LM16578 (G3) | 5.45 ± 0.81 bc | 4.05 ± 1.02 cd | 1.40ab |
| LM17114 (G4) | 5.33 ± 0.92 c | 3.77 ± 0.97 cd | 1.56b |
| LM18443 (G5) | 5.03 ± 1.19 c | 3.95 ± 1.01 cd | 1.08d |
| LM18775 (G6) | 5.65 ± 0.88 bc | 3.08 ± 0.95 cd | 2.57a |
| LM18783 (G7) | 5.64 ± 1.14 bc | 4.17 ± 1.29bcd | 1.47ab |
| LM19016 (G8) | 5.54 ± 1.06 c | 3.91 ± 1.23 cd | 1.63a |
| LM19121 (G9) | 5.57 ± 1.35 bc | 4.54 ± 1.28 a | 1.03d |
| LM18801 (G10) | 5.80 ± 1.11a | 4.55 ± 1.33 a | 1.25d |
| LM19175 (G11) | 6.10 ± 0.93 a | 4.36 ± 1.22 abcd | 1.30c |
| LM21256 (G12) | 5.70 ± 1.19 b | 4.03 ± 1.28 cd | 1.67a |
| LM24382 (G13) | 5.68 ± 0.94 b | 4.03 ± 0.88 cd | 1.65a |
| LM18805 (G14) | 5.60 ± 1.14 b | 4.11 ± 1.21 abcd | 1.49ab |
| PO6531 (G15) | 5.72 ± 0.97 ab | 4.13 ± 1.03 abcd | 1.59b |
| PO6637 (G16) | 5.31 ± 0.85 c | 3.83 ± 0.86 cd | 1.48ab |
| PO7974 (G17) | 5.76 ± 0.99 b | 4.48 ± 1.06 abcd | 1.28d |
| PO7074 (G18) | 5.65 ± 0.85 bc | 3.29 ± 1.08 abcd | 2.36a |
| LM11062 (G19) | 6.22 ± 1.00 a | 4.45 ± 1.06 abcd | 1.77a |
| LM19258 (G20) | 6.08 ± 0.91 a | 4.76 ± 1.15 a | 1.32c |
| LM20187 (G21) | 6.11 ± 0.91 a | 4.59 ± 1.04 ab | 1.52b |
| LM21543 (G22) | 6.33 ± 0.80 a | 5.12 ± 1.08 a | 1.21d |
| LM23543 (G23) | 6.19 ± 0.95 a | 5.17 ± 1.19 a | 1.02d |
| *F* | 7.46 | 4.58 | 3.80 |
| *P* | *< 0.001* | *< 0.001* | *< 0.001* |

*Means followed by the same letter in the same column do not show a significant difference (P ≥ 0.05). F: F-statistic associated with the test and P: the probability; LM: La Mé; PO: Pobé; G: Genotype*

**3.1.2 Effect of water deficit on the physiological parameters of the 23 oil palm genotypes**

**3.1.2.1 *Effect of water deficit on Chlorophyll content***

Figure 3 presents the average chlorophyll content values of the plants throughout the 23 genotypes in relation to the water regimes. The statistical analysis of these findings indicates that under typical water conditions, the chlorophyll content of the control plants varies between 40 and 60 SPAD units. The genotypes LM18443 (G5), LM19016 (G8), LM19121 (G9), LM21256 (G12), PO7974 (G17), and LM23543 (G23) have the maximum chlorophyll content per plant (Figure 3). Under stress, the chlorophyll content of the plant genotypes varied from 10 to 58 SPAD units, primarily marked by a reduction in values. The genotypes LM23543 (G23), LM19121 (G9), LM18443 (G5), LM8023 (G1), LM18801 (G10), and LM18783 (G7) exhibited the maximum chlorophyll content among the 23 stressed genotypes (Figure 1). The analysis of chlorophyll content variations from control to stressed plants indicates that genotypes LM19121 (G9), LM18801 (G10), LM23543 (G23), LM18443 (G5), and LM8023 (G1) exhibit the least losses in chlorophyll content relative to their irrigated controls. The most significant reductions in chlorophyll content are observed in genotypes LM 12165 (G2), LM 16578 (G3), LM 17114 (G4), LM 21256 (G12), LM 20187 (G21), and LM 11062 (G22).

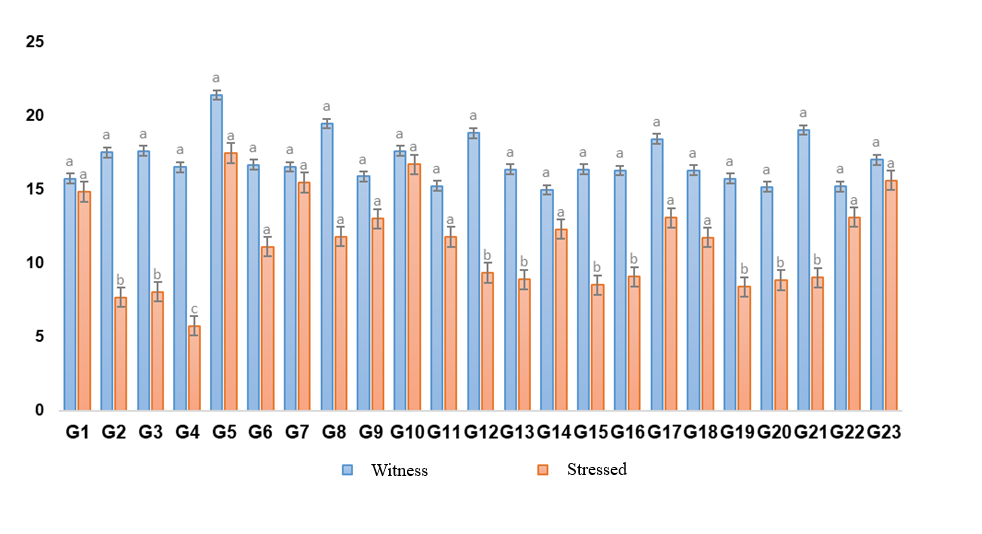


**Figure 3: Variation of chlorophyl content by treatments and genotypes**

*Histograms topped with the same value are statistically identical at the 5% threshold - Newman-Keuls test (Mean ± standard error)*

**3.1.2.2 *Effect of water deficit on Nitrogen (N) content***

Figure 4 presents the average nitrogen content values of the plants across the 23 genotypes, categorised by water regimes. The statistical analysis indicates that under typical water conditions, the nitrogen concentration in the control plants varies between 15 and 22 mg/g. The genotypes LM18443 (G5), LM19016 (G8), LM21256 (G12), PO7974 (G17), and LM20187 (G21) exhibit the highest nitrogen content among the control plants (Figure 2). Under stress, the nitrogen concentration in the plant genotypes varied from 07 to 18 mg/g, primarily marked by a decline in values. The genotypes LM18801 (G10), LM8023 (G1), LM23543 (G23), and LM18801 (G10) exhibited the highest nitrogen content values among the 23 genotypes (Figure 4). The analysis of nitrogen content variations from control to stressed plants indicates that the genotypes LM8023 (G1), LM18783 (G7), LM18801 (G10), and LM23543 (G23) exhibited the least reduction in nitrogen content relative to the controls. The most significant decrease in nitrogen content is observed in genotypes LM17114 (G4), LM21256 (G12), and LM20187 (G21) (Figure 4).



**Figure 4: Variation of water stress on the nitrogen concentration in oil palm foliage**

*Histograms topped with the same value are statistically identical at the 5% threshold - Newman-Keuls test (Mean ± standard error)*

**3.1.3 Classification of the genotypes examined based on tolerance levels, according to the variation in values of several parameters from control to stressed conditions.**

Statistical analysis reveals a substantial difference (P < 0.001) among genotypes regarding the average fluctuation in values from control to stressed conditions across the many parameters examined (Table 6). The research categorised all the genotypes into three (03) tolerance classes (Figure 5). The genotypes of class 3 (C3) exhibited minimal variation in the parameters examined from control to stress conditions (G1, G5, G7, G9, G10, and G23), indicating a high tolerance to water deprivation (Table 6). Conversely, the genotypes of class 2 (C2), namely G6, G11, G14, G17, and G22, exhibited an average fluctuation in the parameters analysed from control to stressed conditions, categorising them as moderately tolerant (Table 6). The remaining genotypes, G2; G3; G4; G8; G12; G19; G20; and G21, belong to class 1 (C1) and are classified as weakly tolerant, as they exhibit significant fluctuation in the examined parameters from control to stress conditions (Table 6).

**Table 6: Classification of the genotypes examined by tolerance group, based on the variation in parameter values from control to stressed conditions**.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Genotypes | F | C | H | N | PR | CH | Class | Means |
| G1 | 1.14 | 1.23 | 18 | 1 | 0.04 | 0.1 | C3 | 3.58c |
| G2 | 2.44 | 2.07 | 37.63 | 7.4 | 0.06 | 29.8 | C1 | 13.23a |
| G3 | 2.83 | 1.4 | 24.25 | 6.9 | 0.09 | 32.7 | C1 | 11.36a |
| G4 | 3.15 | 1.56 | 25.56 | 9.03 | 0.08 | 38.1 | C1 | 12.91a |
| G5 | 1.03 | 1.08 | 7.41 | 2.23 | 0.04 | 0.17 | C3 | 1.99c |
| G6 | 4.99 | 2.57 | 23.78 | 5.43 | 0.08 | 19.1 | C2 | 9.32b |
| G7 | 1.02 | 1.47 | 4.16 | 1.8 | 0.05 | 0.7 | C3 | 1.53c |
| G8 | 4.37 | 1.63 | 20.65 | 7.09 | 0.09 | 26.7 | C1 | 10.08a |
| G9 | 1.18 | 1.03 | 20.05 | 2.4 | 0.03 | 0.52 | C3 | 4.19c |
| G10 | 1.07 | 1.25 | 11.15 | 1.07 | 0.03 | 0.45 | C3 | 2.5c |
| G11 | 3.44 | 1.3 | 28.3 | 4.72 | 0.07 | 15.8 | C2 | 8.93b |
| G12 | 2.57 | 1.67 | 23 | 8.43 | 0.06 | 34.2 | C1 | 11.65a |
| G13 | 1.5 | 1.65 | 26.22 | 8.49 | 0.07 | 23.2 | C1 | 10.18a |
| G14 | 1.7 | 1.49 | 42.85 | 2.01 | 0.07 | 9.71 | C2 | 9.63b |
| G15 | 4.31 | 1.59 | 24.6 | 7.51 | 0.07 | 23.8 | C1 | 10.31a |
| G16 | 5.47 | 1.48 | 38.83 | 7.46 | 0.06 | 23.9 | C1 | 12.86a |
| G17 | 1.15 | 1.28 | 20.18 | 3.78 | 0.08 | 31.2 | C2 | 9.61b |
| G18 | 5.56 | 2.36 | 42.48 | 5.78 | 0.1 | 13.1 | C1 | 11.56a |
| G19 | 3.66 | 1.77 | 46.3 | 6.49 | 0.1 | 24.5 | C1 | 13.8a |
| G20 | 3.78 | 1.32 | 32.11 | 7.12 | 0.07 | 21.3 | C1 | 10.95a |
| G21 | 3.73 | 1.52 | 17.41 | 10.27 | 0.07 | 30 | C1 | 10.5a |
| G22 | 1.08 | 1.21 | 27.78 | 1.76 | 0.05 | 26.7 | C2 | 9.76b |
| G23 | 0.8 | 1.02 | 10.63 | 1.02 | 0.03 | 0.13 | C3 | 2.27c |



**Discussion**

Climate change presents considerable problems with oil palm production, as its yield can be directly influenced by abiotic stress, particularly drought. This research aimed to examine the impact of water stress regimes on the morphology and physiology of 23 oil palm seedling genotypes from the La Mé Research Station. The results demonstrated the impact of water deficiency on the morphological and physiological development of genotypes evaluated. Ceasing irrigation of juvenile oil palm specimens resulted in postponing vegetative development and mortality of plants to varying degrees across all 23 genotypes, in contrast to the irrigated controls (Najihah et al., 2019; Suharyanti et al., 2020).

At 100% water supply (RH100%), all examined genotypes exhibited normal growth. Genotypes G1, G3, G8, G10, G12, G17, and G21 from category C1001F, along with G21 and G22 from category C2501F, exhibited the most favorable growth and physiological parameters assessed. These findings align with those of Gogoue et al. (2020), who observed that plants of genotypes within these groups exhibit robust growth under conditions of adequate water availability. The significant reduction in the water regime from 100% to 0% resulted in a delay in plant growth by diminishing vegetative and physiological parameters (plant growth, leaf count, collar diameter, chlorophyll content, nitrogen content) and led to the mortality of the 23 oil palm genotypes. This tendency, observed across all analysed genotypes, indicates that water availability is the primary limiting factor in oil palm growth (Maillard et al., 1974; Quencez, 1996; Reis de Carvalho, 1991; Nouy et al., 1999; Jazayeri et al., 2015; Rivera-Mendes et al., 2016; Idris et al., 2024; Montoya et al., 2024). A limiting factor denotes an element that, because of its insufficient value, hinders or restricts the efficacy of a physiological function, despite all other conditions being favorable. The diminishment of vegetative development in plants under water stress may be attributed to decreased cell elongation and expansion resulting from reduced turgor pressure, as plant cell growth is the most sensitive physiological activity affected by water deficiency (Najihah et al., 2019). Furthermore, Young oil palm seedlings in nurseries frequently do not recuperate even after water is reintroduced following episodes of severe water stress (Jazayeri et al., 2015).

Water is the quintessential solvent for substances within the cell and contributes to the structural integrity of the entire plant by inducing cellular turgor. Without water, the plant is unable to absorb minerals from the soil or perform photosynthesis, which is essential for sap production. The water deficit results in a diminished requirement for water uptake in stressed plants. This results in a decline of vegetative and physiological characteristics, ultimately leading to the plant's demise. Under the 0% water supply regime, the genotypes LM8023 (G1), LM18443 (G5), LM18783 (G7), LM19121 (G9), LM18801 (G10), LM21543 (G22), and LM23543 (G23) exhibited the highest tolerance, demonstrating average mortalities and sustained development under this stress condition. During water scarcity, each oil palm genotype has a specific adaptive approach to sustain development despite water limitations. This enables the differentiation of genotypes from one another. Wang et al. (2020) achieved analogous results with oil palm *Tenera* seedlings. These authors observed morphological changes in leaves and roots of oil palm seedlings under drought stress with a period of 14 days. The water scarcity variously affected the morphological and physiological parameters of the 23 genotypes. The predominant tolerant genotypes belong to the C1001F and C2501F categories, aligning with Gogoue et al. (2019) findings who observed that these categories demonstrate significant tolerance in a state of substantial deficiency. The marginal reduction in the vegetative and physiological parameters of genotypes G1, G5, G7, G9, G10, G22, and G23 under both water stress and normal conditions (control) relative to other genotypes indicates the genetic specificity among the evaluated oil palm genotypes. A similar trend has also been reported by Corley et Tinker (2016), where authors showed that genetic improvement in drought-tolerant oil palm cultivars could mitigate the effects of climate change on the crop and optimize oil palm yield.

4. Conclusion

This study sought to ascertain the resistance of 23 genotypes from categories C1001F, C2501F, and J1942F of oil palm to water deficit during the nursery period by evaluating morphological and physiological parameters under conditions of 100% and 0% water availability. The results indicated that the morphological and physiological parameters of the plants fluctuated based on water stress and the genetic characteristics of the various oil palm genotypes. A cessation of water supply resulted in a marked decline in the morphological and physiological parameters of the plant genotypes. Nevertheless, in certain genotypes, the reduction in the values of morphological and physiological indicators relative to the control was minimal. In some instances, it was small, however in most genotypes, this reduction was substantial. The genotypes exhibiting favorable resistance to water deprivation are LM8023 (G1), LM18443 (G5), LM18783 (G7), LM19121 (G9), LM18801 (G10), LM21543 (G22), and LM23543 (G23). To validate the water deficit tolerance of the evaluated genotypes, it is essential to conduct field tests in a water-scarce region.

AcknowledgEments

This work was financially supported by the Interprofessional Association of Oil Palm (AIPH) and The Interprofessional Fund for Agricultural Research and Consulting (FIRCA) through the project AIPH/FIRCA/CNRA 3445 “premature detection of drought-resistant oil palm genetic material”. Authors thank also the technicians at CNRA for their assistance during data collection

Competing interests

The authors declare no conflict of interest in this paper.

Authors’ Contributions

This work was carried out in collaboration among all authors. Author GDO designed the study, wrote the protocol, fitted the data and wrote the first draft of the manuscript. Authors NGL and ABC checked the first draft of the manuscript and achieved the submitted manuscript. Authors OKM performed the statistical analysis and assisted the implementation of experiments. Author BHM expertized the results interpretations. All authors read and approved the final manuscript.

References

Adjahossou D.F. (1983). Contribution à l’étude de la résistance à la sécheresse chez le palmier à huile (*Elaeis guineensis* Jacq.). Thèse de doctorat, université Paris VII, Franc. 79 p.

Adon B., Konan J. N., Cochard C., Flori A., Diabaté S., Bakoumé C., Sokouri D. P. (2021). Agronomical Performances of Angolan Natural Oil Palm Accessions and Interests for Oil Palm Selection in Côte d’Ivoire. *Journal of Agricultural Science, 13*(11), 64-73. <https://doi.org/10.5539/jas.v13n11p64>

Bayona-Rodríguez, C.; Romero, H.M. Drought Resilience in Oil Palm Cultivars: A Multidimensional Analysis of Diagnostic Variables. *Plants* 2024, *13*, 1598

Brou Y. T., Akindes F., Bigot S. (2005). La variabilité climatique en Côte d’Ivoire : entre perceptions sociales et réponses agricoles. Cahiers Agricultures, 14 (6) 533-540

Carrère R. (2010). Oil palm in Africa: the past, the present and the future. World Rainforest Movement. Book, Series No. 15 of the World Rainforest Movement (WRM) on Plantations, .70 p.

Chew C. L., Ng C. Y., Hong W. O., Wu T. Y., Lee Y.-Y., Low L. E., Kong P. S., Chan E. S. (2021). Improving sustainability of palm oil production by increasing oil extraction rate: a review. *Food and Bioprocess Technology, 14 :573–586.* [*https://doi.org/10.1007/s11947-020-02555-1*](https://doi.org/10.1007/s11947-020-02555-1)

Corley R.H.V.; Tinker P. *The Oil Palm*, 5th ed.; Wiley Blackwell: Hoboken, NJ, USA, 2016; ISBN 9781405189392.

Diabaté S., Konan K. E., Allou D., Coulibaly O. A., De Franqueville H. (2009). Performance de deux techniques d’extraction des phénols racinaires pour l’évaluation du marquage de la tolérance à la fusariose des clones de palmier à huile (*Elaeis guineensis* Jacq.). *Sciences & Nature*, 6(2): 117 - 123.

Gogoue D. O., Konan N.T., Lekadou T. T. and Sekou D. (2020). Study of the use of NPK fertilizer complexes in root and vegetative improvement of the C1001F category of oil palm (*Elaeis guineensis* Jacq.) in times of water deficit. *Agricultural Science Research journal*, 10(6) 150 – 153.

Gogoue D.O., Sekou D.,Ballo K., Kouassi A. (2019). Study of the morphological behavior under water deficit of categories of oil palm (*Elaeis guineensis* Jacq) in the juvenile phase. *Agronomie Africaine*, 8 : 49-67

Idris S., Sung B. T. C., Zaibon S., Cheak S. C. (2024). Climate variability and water stress effects on oil palm (*Elaeis guineensis* Jacq.) productivity in Malaysia**.** *Journal of Oil Palm Research, DOI:* [*https://doi.org/10.21894/jopr.2024.0054*](https://doi.org/10.21894/jopr.2024.0054)

Jazayeri S.M., Rivera Y., Camperos-Reyes J., Romero H.M. (2015). Physiological effects of water deficit on two oil palm (*Elaeis guineensis* Jacq.) genotypes. Agron. Colomb. 33, 164-173. Doi: 10.15446/agron.colomb.v33n2.49846.

Konan J.-N., Fofana V. P., Fofana I. J., Niamketchi G. L., N’Guessan A. H., Soumahoro M. (2024b). Improvement the bunch and oil yields of oil palm (*Elaeis guineensis* Jacq.) by introducing material of Yocoboué origin into the selection scheme in Côte d'Ivoire. *Journal of Experimental Agriculture International, 46(1):103-114. DOI: 10.9734/JEAI/2024/v46i12299*

Konan J-N, Soumahoro M., Niamketchi G. L., Boye M. A.-D., Fofana V. P. (2024a). Assessment of the acidity of progenies from crosses between double self-fertilized DA115D AF AF × LM2T AF AF oil palm (*Elaeis guineensis* Jacq) progenitors in Côte d’Ivoire. *Journal of Agricultural Science, 16(3) :1-9.* <https://doi.org/10.5539/jas.v16n3p1>

Maillard G., Daniel C., Ochs R. (1974). Analyse des effets de la sécheresse sur le palmier à huile. *Oléagineux,* 29(8–9) : 397–404

Montoya C., Daza E., Mejía-Alvarado F.S., CaicedoZambrano A.F., Ayala-Díaz I., Ruiz Romero R., Romero H.M. Photosynthetic performance of oil palm genotypes under drought stress. *Plants* 2024, *13*, 2705. <https://doi.org/10.3390/> plants13192705

Najihah S. T., Ibrahim M. H., Razak A. A., Nulit R., Wahab P. E. M. (2019). Effects of water stress on the growth, physiology and biochemical properties of oil palm seedlings. *AIMS Agriculture and Food,* 4(4): 854-868. DOI: 10.3934/agrfood.2019.4.854

Ndiaye O., Diouf O., Adon B., Braconnier S. (2007). Critères physiologiques discriminants au jeune âge pour la sélection de génotypes de palmier à huile (*Elaeis guineensis* Jacq.) tolérants à la sècheresse. *Agronomie Africaine*,19 (1) : 1-12

N'guetta R.Y., Kamagate D.K. (2010). Production du palmier à huile et taux d'extraction dans des conditions climatiques marginales au Nord-Est de la Cote D'ivoire. Agronomie Africaine 22(2) : 149-16.

Niamketchi G. L. 1, Konan J.-N., Adolphe M. G., N’guessan A. H. 1, Adou B. C., Kablan B. M. A., Gouai A. (2024). Quality assessment of artisanal palm oil from smallholders in the department of Man, western region of Côte d'Ivoire. *World Journal of Advanced Research and Reviews*, 24(01), 846–856. DOI: <https://doi.org/10.30574/wjarr.2024.24.1.2765>

Nodichao, L., Chopart, J.-L., Roupsard, O., Vauclin, M., Aké, S., Jourdan, C., 2011. Genotypic variability of oil palm root system distribution in the field. Consequences for water uptake. Plant Soil 341, 505–520. <https://doi.org/10.1007/s11104-010-0663-0>

Nouy, B., Baudouin, L., Djegui, N., Omore, A., 1999. Oil palm under limiting water supply conditions. Plant. Rech. Dév. 6, 31-45.

Quencez P. (1996). La culture du palmier à huile en Afrique Intertropicale : les conditions du milieu physique. OCL 3 (2) : 116 - 118.

Reis de Carvalho C. (1991). Mécanismes de résistance à la sécheresse chez les plantes jeunes et adultes de palmier à huile. Thèse, université Paris-Sud, Orsay, France 134. P

Rivera-Mendes Y. D., Cuenca J. C., Romero H. M. (2016). Physiological responses of oil palm (Elaeis guineensisJacq.) seedlings under different water soil conditions. *Agronomía Colombiana*, 34(2): 163-171. DOI: <https://doi.org/10.15446/agron.colomb.v34n2.55568>

Suharyanti N. A., Mizuno K., Sodri A. (2020). The effect of water deficit on inflorescence period at palm oil productivity on peatland. E3S Web of Conferences 211, 05005, The 1st JESSD Symposium 2020. <https://doi.org/10.1051/e3sconf/202021105005>

Tano E. K., Konan J.-N., N’nan O. A., Akanvou R., Nguetta A. S.-P., Konan K. E. (2019). Etude des performances génétiques des descendances parentales issues de deux systèmes de reproduction de géniteurs utilisés en production de semences sélectionnées de palmier à huile (Elaeis Guineensis Jacq.). *International Journal of Biological and Chemical Sciences*, 13(3): 1800‑1816. <https://doi.org/10.4314/ijbcs.v13i3>

USDA (United States Department of Agriculture) (2024). *Oilseeds: World market and trade* (Circular Series October 2024, pp. 1-41). Foreign Agricultural Service, United States department of Agriculture. Retrieved from http//apps.fas.usda.gov/psdonline/circulars/production.pdf.

Wang L., Lee M., Ye B., Yue G. H. (2020). Genes, pathways and networks responding to drought stress in oil palm roots. *Scientific Reports*, 10 :21303. <https://doi.org/10.1038/s41598-020-78297-z>.

Yehouessi L. W., Nodichao L Adoukonou-Sagbadja H., Ahanhanzo C. (2020). Analyse différentielle du rendement chez neuf génotypes de palmier à huile (*Elaeis guineensis* Jacq.) sous conditions de stress hydriques. Journal of Applied Biosciences 153 : 15780 – 15787. https://doi.org/10.35759/JABs.153.5