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STUDY OF SEEDLING EMERGENCE IN A PRE-NURSERY ENVIRONMENT OF 14 GENOTYPES OF OIL PALM (ELAEIS GUINEENSIS J.) WITH VARYING SENSITIVITY TO WATER DEFICIT

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ABSTRACT

Objectives: The germination of oil palm seeds into seedlings in a pre-nursery setting is of crucial importance, as it allows us to assess the quality, growth vigor, and success of future nursery plants, whether for a single genotype or several genotypes studied. Our work will consist of studying, in a pre-nursery setting under natural conditions, the germination of seeds into seedlings of 14 high-producing genotypes of oil palm (Elaeis guineensis J.), exhibiting varying sensitivities to water deficit.

Methodology and Results: The trial was conducted in a pre-nursery setting at the CNRA (National Center for Agricultural Research) in La Mer (La Mer), under natural conditions. A completely randomized Fisher block design with three replicates of seeds from the 14 genotypes was set up. The plant material consisted of seedlings grown from germinated seeds of the genotypes that had been transplanted (67 germinated seeds per genotype per replicate, therefore 201 seeds for one genotype across the three replicates or blocks). Measurements of growth morphological parameters were taken during the 3 months following seedling emergence. The data were subjected to analysis of variance (ANOVA). Genotypes G26(T) and G19(S) had the highest number of seedling emergences, closely followed by genotypes G9(T) and G22(S). Genotype G26(T) had the highest number of first-leaf emergences, closely followed by genotypes G9(T), G19(S), and G22(S). All genotypes had low seedling mortality on day 90 after sowing, but the number of live seedlings was highest in genotypes G26(T) and G19(S), followed by G24(T) and G22(S). Conversely, genotypes G5(T), G14(S), and G21(S) exhibited the highest seedling mortality.

Conclusions and outlook: Multivariate analyses (PCA) revealed that genotypes identified as tolerant or sensitive to water deficit share common morphological characteristics. Genotypes G26(T) and G19(S) demonstrated the best morphological performance, followed by genotypes G22(S), G24(T), G9(T), G10(T), G25(T), and G7(T). However, it was observed that the best morphological performance was more pronounced in genotypes identified as tolerant, than sensitive to water.

Keywords: Oil palm, genotype, Variable Sensitivity, Water Deficit, Morphological Parameters, Pre-Nursery, Cote d'Ivoire

1 INTRODUCTION

The oil palm originates from the humid intertropical zone of West Africa (Ergo, 1997; Aghalino S.O., 2000). The species (Elaeis guineensis J.) is a plant of very important economic and social significance, as it has become the world's leading source of vegetable oil (Mensah, G. A., 1999; Auffray, 2017). In Côte d'Ivoire, this crop plays a major role in the economy. The oil palm sector is currently experiencing spectacular growth, with a national production of 600,000 tons of crude palm oil per year (USDA, 2024), generating more than 200,000 direct and indirect jobs, thus contributing to the fight against poverty in rural areas (AIPH, 2023). In order to maintain its label, Côte d'Ivoire aims to increase its production to 933,000 tonnes by 2030 (Cumunel, 2020) and to expand the oil palm cultivation area to so-called marginal zones (subject to water deficit) (Gogoue et al., 2024). Therefore, it is essential to identify oil palm genotypes with high seed germination rates in pre-nurseries and nurseries, good tolerance to diseases and water deficit (N'diaye et al., 2007; Gogoue et al., 2025), and good field production potential (Jacquemard, 2012). The use of selected oil palm varieties with good production potential is recommended to improve oil palm productivity (Gascon J.P., et al., 1981; Durand-Gasselin T., et al., 2000). This primarily involves identifying high-yielding genotypes characterized by high field yields (Jaquemart, 1995; Cochard B. et al., 1993; Meunier J., Gascon JP., 1972). Authors such as Durand-Gasselin T., et al. (2000), Gascon J.P., et al. (1988), and Cochard B. et al. (2005) have highlighted the high field yields of selected and improved genotypes. The desire to expand oil palm cultivation will lead to planting in areas with average rainfall, where water has an impact on the vegetative growth of the different genotypes. Indeed, the date palm remains a plant dependent on water to reach its full potential (N'guetta R.Y et al, 1995, Omoro et al, 2019, etc.). Therefore, it is crucial to research genotypes capable of adapting to marginal areas with water scarcity, or traditional areas subject to climate change (Rival et al, 2018; Gogoue D.O. et al., 2024; Gogoue D.O. et al., 2025). However, successful cultivation of any genotype hinges on a well-executed pre-nursery process (transformation of germinated seeds into seedlings, resulting in plants and trees for the field). Indeed, the germination of oil palm seeds in the pre-nursery is a fundamental step in production, as it determines the quality, uniformity, and vigor of the future plants (Gascon J. P. et al., 1981; Jacquemard et al., 1981). This phase, which lasts approximately four months, transforms a selected seed into a young seedling ready to be transferred to the main nursery (Jacquemard, 2012). Germination primarily consists of the emergence of germinated oil palm seeds into seedlings and their subsequent growth in the pre-nursery. This crucial step determines 50% of the success and future yield of the plantation. During germination in the pre-nursery, the most vigorous seeds are identified and selected. The pre-nursery allows for the identification and elimination of seeds with abnormal germination (deformed stem or radicle) or undifferentiated germination, ensuring that only vigorous plants are retained. It allows for verification of the homogeneity of the plant material in order to obtain a batch of plants uniform in age and development, which facilitates plantation management and ensures synchronous growth of the palms in the field. It allows for monitoring root and leaf development, as during this period the young seedling develops its first two leaves and adventitious roots (first month), then lanceolate leaves and primary roots (up to 4 months). It reduces mortality by controlling germination conditions (humidity, temperature of 28-32°C), and the care taken in transplanting pre-germinated seeds minimizes losses. This is a crucial issue because seeds are expensive and the germination process is delicate (Jacquemard J.C. 1995). The emergence of germinated seeds into seedlings in pre-nurseries is the very essence of the success of a nursery and of palm plantations in the field (Fabre D., 2008). It is within this context that this work is situated, with the objective of evaluating, under natural conditions in pre-nurseries, the morphological differences in seedling emergence of 14 high-producing genotypes with varying sensitivities to water deficit, in order to determine those with the best pre-nursery performance. These results will serve as a database for the future agro-physiological evaluation of these genotypes in nurseries and in the field under real-world conditions, in both water-deficit and normal growing areas.

2 MATERIAL AND METHODS

2.1 Study Site

The trial site was the CNRA research station in La Me. It is located in southeastern Côte d'Ivoire, in the Abidjan district, specifically in the Alépé department. It is approximately 24 kilometers from Abidjan and approximately 20 kilometers from Alépé. Geographically, it is located between 5°26’ North latitude and 3°50’ West longitude (Traoré and Mangara, 2009). The trial was conducted in a pre-nursery under natural conditions. Normal growing conditions (abundant watering, phytosanitary monitoring of the plant in the pre-nursery) were implemented to ensure that there were no stressors on plant growth (Jacquemard J.C., 1995, Zoueu J., 2013).

2.2 Plant material

The plant material consisted of germinated seeds of 14 oil palm genotypes (67 seeds per genotype per replicate, therefore 201 seeds for one genotype across all three replicates or blocks), and seedlings grown from these germinated seeds (Figure 1). These 14 genotypes comprise seven sensitive and seven tolerant genotypes to water deficit (Table 1). These genotypes were determined after screening in a greenhouse (Obed G., et al., 2025). These genotypes originate from the C1001F category, which is obtained through artificial fertilization at the ME station. In the field, they are characterized by high yields (Cochard B., et al, 2005). They are widely used for establishing oil palm plantations because they are tolerant to Fusarium wilt (Diabaté, 2009).

Table 1: Classification of the 14 genotypes studied (Gogoue et al., 2025)

Genotype states	Genotypes	Order number
Water deficit tolerant	LM 18443	G5
	LM 18783	G7
	LM 19121	G9
	LM 18801	G10
	LM 7465	G24
	LM 7899	G25
	DA10D	G26
Sensitive to water deficit	LM 19175	G11
	LM 18805	G14
	PO 6637	G16
	LM 11076	G19
	LM 20258	G21
	LM 21187	G22
	LM404D	G23

Figure 1: Germinated seeds of the genotypes (A) and the seedlings resulting from their growth in the pre-nursery (B).

2.3 Study Methods

Germinated seeds of the 14 genotypes, with 67 seeds per genotype per replicate (201 seeds per genotype for the three blocks or replicates), were transplanted into black polyethylene bags filled with identical potting mix (Figure 1). This pre-nursery was maintained in this potting mix for three months to produce seedlings at the end of the third month. The following morphological parameters were measured during the growth of the germinated seeds into seedlings over the three-month trial: seedling emergence rate on days 21 and 42, first leaf emergence on days 42 and 90, and the percentage of live seedlings on day 90.

2.4 Experimental Design

The trial was conducted in a completely randomized, one-factor Fisher block design. The genotype factor, with 14 categories (Figures 2, 3), was subjected to identical watering in all three replicates (blocks). Watering was manual and abundant, with the bags thoroughly soaked, twice daily, morning and evening, depending on sunlight. In each of the three blocks (replicates), each genotype was represented by a subblock of 67 germinated seeds in bags. The subblocks were spaced 20 cm apart within the row and 60 cm apart between rows. The experiment lasted three months. Morphological parameters were measured throughout the trial

Figure 2: Schéma du dispositif expérimental de l'essai

Figure 3: Vue partielle du dispositif expérimentale de l'essai en pré pépinière

2.5 Observations and Measurement of Morphological Parameters Studied

The germination rate per genotype (number of germinated seeds out of 60 pre-germinated seeds sown per genotype) was determined by manual counting. Germination was defined as the appearance of the first leaf. Germination rates were determined on days 21 and 42 after transplanting. The appearance of the first leaves was identified by manual counting, characterized by two or three leaves on days 42 and 90, (Breure C.J. 2010). The number of live seedlings per genotype was determined by manual counting of live seedlings on day 90 of the trial.

2.6 Data Analysis

Analysis of variance (ANOVA, $p < 0.05$) was used to compare the means of the different genotypes in order to determine statistically significant differences in means. The means and standard deviations obtained using descriptive statistics were used to evaluate the average performance of the genotypes. The Newman-Keuls post-hoc test was used to identify differences between genotypes. A hierarchical cluster analysis (HCA) was performed to group statistically similar genotypes. These tests were applied at an alpha level of 5%. These analyses were carried out using R software (version 4.5.0).

3 RESULTS

3.1 Seedling emergence rate of germinated seeds of the genotypes

Significant differences, respectively F=10.53, p=1.108e-07; F=12.32, p=1.261e-11 (Table I), were observed in seed emergence rates on both days 21 and 42 after sowing (transplanting) of germinated seeds of all genotypes. Specifically, on day 21, genotype G19 showed the highest number of emergences (171±0.42), representing a rate of 85.5%, while genotypes G11, G21, and G23 exhibited the lowest numbers of emergences (88±0.65; 44%). Conversely, on day 42, genotype G26 achieved the highest number of germinations (198 ± 0.72; 99%), closely followed by G19 (189 ± 0.64; 94.5%), G9 (188 ± 0.94; 94%), and G22 (179 ± 0.84; 89.5%). Genotypes G5, G16, G21, and G23 continued to show the lowest germination rates, at 65%, 63.5%, 69%, and 71%, respectively.

Table 2: Germination Rate (%) of Seeds on Days 21 and 42 After Transplanting by Genotype

Genotypes	Number of seeds that have sprouted after 21 days	Germination Rate of Seeds on Days 21, in (%)	Number of seeds that have sprouted after 42 days	Germination Rate of Seeds on Days 42, in (%)
G5	109 ± 0.61 bc	54	130 ± 0.67 c	65
G7	115 ± 0.91 bc	57	160 ± 0.81 b	80
G9	150 ± 0.61 ab	75	188 ± 0.94 ab	94
G10	129 ± 0.72 b	64	162 ± 0.94 b	81
G24	153 ± 0.65 ab	76	169 ± 0.33 b	84
G25	168 ± 0.64 a	84	166 ± 0.47 b	80
G26	151 ± 0.61 ab	75	198 ± 0.72 a	99
G11	88 ± 0.43 c	44	168 ± 0.64 b	84
G14	115 ± 0.87 bc	57	145 ± 0.42 bc	72
G16	122 ± 0.54 b	61	132 ± 0.24 c	63
G19	171 ± 0.42 a	85	189 ± 0.64 ab	94
G21	88 ± 0.65 c	44	138 ± 0.67 c	69
G22	167 ± 0.43 a	83	179 ± 0.84 ab	89
G23	88 ± 0,64 c	44	142 ± 0.62 bc	71
F	10.53		12.32	
p-value	1.108e-07		1.261e-11	

Within a column, means followed by the same letters are not significantly different (Newman-Keuls test, $p < 0.05$); P: Approximate probability of tests; F: Fisher's constant; NGL: Number of seeds that emerged.

3.2 First Leaf Emergence of Germinated Seedlings

For first leaf emergence, statistically significant differences were observed among the genotypes on both day 42 (F=11.23, p=0.0081**) and day 90 (F=9.76, p=0.0024*) after sowing (Table III). All genotypes exhibited first leaf emergence on both day 42 and day 90. However, genotype G26 had the highest number of first leaf emergences on day 42 (192 ± 1.14; 96%), followed by genotypes G9 (179 ± 0.64; 89%), G19 (176 ± 0.91; 88%), and G22 (173 ± 0.64; 86%). On day 90, genotypes G26, G9, G19, and G22 maintained a high number of first leaves, forming statistically similar groups. Conversely, G5 consistently exhibited the lowest number of first leaves on both day 42 (94 ± 0.7; 47%) and day 90 (116 ± 0.32; 58%).

Table 3: Percentage of plants with first leaves appearing on day 42 and day 90 after transplanting, by genotype

Genotypes	Number of seedlings with first leaves appearing on day 42	Percentage of seedlings with first leaves appearing on day 42	Number of seedlings with first leaves appearing on day 90	Percentage of plants with first leaves appearing on day 90
G5	94 ± 0.7 ^{a}	47	116 ± 0.32 ^{a}	58
G7	126 ± 0.25 ^{ab}	63	158 ± 0.64 ^{b}	79
G9	179 ± 0.64 ^{bc}	89	177 ± 0.67 ^{bc}	88
G10	146 ± 0.81 ^{b}	73	149 ± 0.84 ^{b}	74
G24	157 ± 0.24 ^{b}	78	169 ± 0.37 ^{b}	84
G25	149 ± 1.47 ^{d}	74	157 ± 0.64 ^{b}	78
G26	192 ± 1.14 ^{c}	96	191 ± 1.05 ^{c}	95
G11	145 ± 0.94 ^{b}	72	127 ± 0.54 ^{ab}	63
G14	127 ± 0.42 ^{ab}	63	126 ± 0.61 ^{ab}	63
G16	116 ± 0.64 ^{ab}	57	146 ± 0.72 ^{b}	73
G19	176 ± 0.91^{bc}	88	178 ± 0.71 ^{bc}	88
G21	107 ± 0.43 ^{ab}	53	121 ± 0.62 ^{ab}	60
G22	173 ± 0.64 ^{bc}	86	176 ± 0.81 ^{bc}	88
G23	111 ± 0.82 ^{ab}	55	126 ± 0.94 ^{ab}	63
F	11.23		9.76	
p-value	0.0081**		0.0024*	

In one column, means followed by the same letters are not significantly different (Newman-Keuls test, p < 0.05) P: Approximate probability of tests; F: Fisher's constant; PPPFA: Percentage of plants whose first leaves have appeared; NPPFA: Number of plants whose first leaves have appeared.

3.3 Number of live oil palm seedlings

The number of live plants was assessed on day 90 of the trial. Significant differences in the number of live plants were observed among the genotypes (F=9.57, p=0.0082; Figure 18). All genotypes had a considerable number of live plants at the end of the trial on day 90 after sowing the germinated seeds (Figure 17). However, the number of live plants was highest in genotypes such as G26, (T), G19 (S), G24 (T), and G22 (T). Genotype G26 recorded the highest number of live plants (195 ± 0.61). Conversely, genotype G5 consistently showed the lowest number of live plants (137±0.51a) as did genotypes G14 (144 ± 0.61) and G21 (145 ± 0.72) (Table IV).

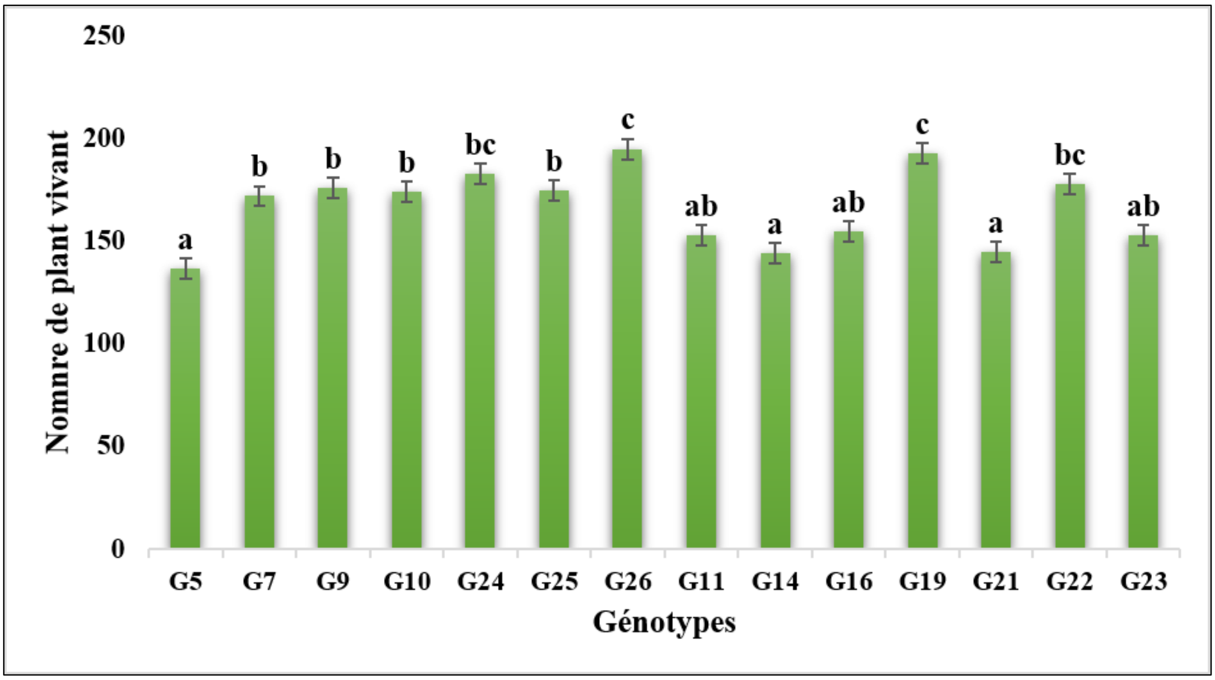

Figure 4: Number of live oil palm seedlings in the nursery according to genotype

3.4 Comparison and classification of the studied genotypes according to the different parameters studied

Based on the table of aligned values for the different parameters studied, the comparison of the genotypes according to the values of the last parameter, which is the number of seedlings alive at the end of the trial, shows that two genotypes, G19 and G26, have the highest rate of live seedlings, exceeding 190 seedlings. They are followed by genotypes G22 and G24, which have 178 and 183 seedlings, respectively. Genotypes G7, G9, G10, and G25 have a high intermediate number of live seedlings, between 170 and 177. Three genotypes, G11, G16, and G23, have an average number of live seedlings, between 150 and 153. The low number of living seedlings is evident in genotypes G5 (135 seedlings) and G14 (144 seedlings).

Table 4: Grouped values of the four parameters evaluated in the pre-nursery phase

Génotypes	NSS 21ième days	NSS 49ième days	NSFLA 42ième days	NSFLA 90ième days	NSL 90ième days
G5	109 ± 0.61 ab	130 ± 0.67 a	94 ± 0.7 a	116 ± 0.32 a	137 ± 0.51 a
G7	115 ± 0.91 ab	160 ± 0.81 b	126 ± 0.25 ab	158 ± 0.64 b	172 ± 0.91 b
G9	150 ± 0.61 b	188 ± 0.94 bc	179 ± 0.64 bc	163 ± 0.67 b	176 ± 0.64 b
G10	129 ± 0.72 ab	162 ± 0.94 b	146 ± 0.81 b	149 ± 0.84 b	174 ± 0.94 b
G11	88 ± 0.43 a	168 ± 0.64 b	145 ± 0.94 b	127 ± 0.54 ab	153 ± 0.81 ab
G14	115 ± 0.87 ab	145 ± 0.42 ab	127 ± 0.42 ab	126 ± 0.61 ab	144 ± 0.61 a
G16	122 ± 0.54 ab	126 ± 0.48 a	116 ± 0.64 ab	146 ± 0.72 b	155 ± 0.54 ab
G19	174 ± 0.42 c	189 ± 0.64 bc	176 ± 0.91bc	178 ± 0.71 bc	193 ± 0.67 c
G21	88 ± 0.65 a	138 ± 0.67 ab	107 ± 0.43 ab	121 ± 0.62 ab	145 ± 0.72 a
G22	167 ± 0.43 bc	179 ± 0.84 bc	173 ± 0.64 bc	176 ± 0.81 bc	178 ± 0.68 bc
G24	153 ± 0.65 b	169 ± 0.33 b	157 ± 0.24 b	169 ± 0.37 b	183 ± 0.66 bc
G25	168 ± 0.64 bc	166 ± 0.83 b	149 ± 1.47 d	157 ± 0.64 b	175 ± 0.67 b

G26	151 ± 0.61 b	198 ± 0.72 c	192 ± 1,14 c	191 ± 1,05 c	195 ± 0,61 c
G23	88 ± 0.64 a	142 ± 0.62 ab	111 ± 0,82 ab	126 ± 0.94 ab	153 ± 0.48 ab
F	**10.51**	**12.08**	**11.23**	**9.76**	**9.57**
p-value	**0.0043****	**0.0072*****	**0.0081****	**0.0024***	**0.0082**

The hierarchical ascending classification, based on the values of all the studied morphological parameters, allowed the genotypes to be classified into three distinct classes. The first class, comprising genotypes G9(T), G19(S), G22(S), G24(T), G25(T), and G26(T), contains genotypes with high values for the studied vegetative parameters. This class is divided into two distinct groups: Group 1 (G19(S), G26(T)), characterized by the highest number of live seedlings and very high and increasing values for the other two parameters, seed germination rate and number of leaves; and Group 2 (G9, G22, G24, G25), characterized by a high number of live seedlings and low variation in the values for seed germination rate and number of leaves per seedling. The second class consists of genotypes G5, G14, G16, G21, and G23, forming group 3. This group is characterized by an average number of live seedlings and strong, increasing values for the parameters of seedling emergence and number of leaves per seedling. The third class consists of genotypes G7, G10, and G11. This class comprises two distinct groups: group 4 (G11), characterized by an average number of live seedlings and a decrease in the number of leaves per seedling, and group 5 (G7 and G10), characterized by a high number of live seedlings and a strong, variable, and evolving growth in the parameters of seed emergence and number of leaves per seedling. Through hierarchical clustering, we observe that genotypes that are both sensitive and tolerant to water deficit share, for some, similar characteristics of the vegetative growth parameters studied through group formation. From this hierarchical classification of the 14 studied genotypes into three groups, it is noted that these groups include both sensitive and tolerant genotypes to water deficit, which have the same similarities and common statistical resemblances.

Table 5: Overall classification of the 14 genotypes according to the different parameters studied

Groupe	Genotypes
Cluster 1	G9, G19, G22, G24, G25, G26
Cluster 2	G5, G14, G16, G21, G23
Cluster 3	G7, G10, G11

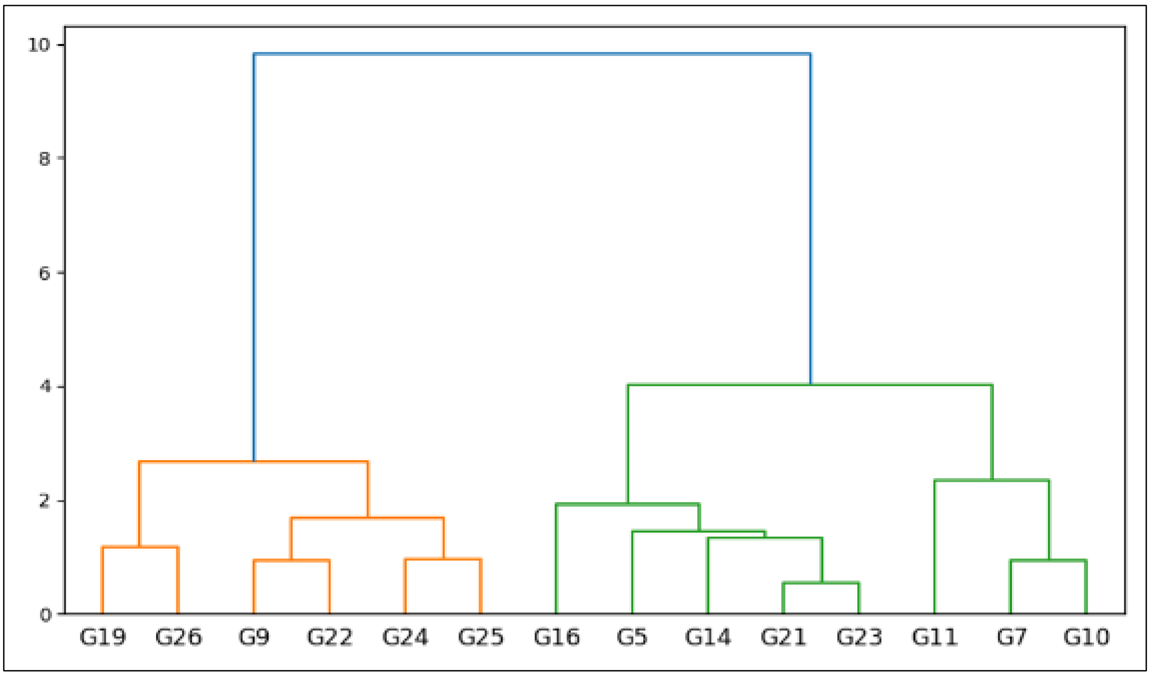

Figure 5: Dendrogram of Genotype Similarity Based on Statistical Resemblance

4 DISCUSSION

The study comparing 14 oil palm genotypes under natural conditions in the pre-nursery stages focused on their morphological characteristics. The results of this study revealed the specific performance of each genotype. At this pre-nursery stage, some oil palm genotypes stood out due to their promising performance. The high emergence rate observed in these genotypes indicates good adaptation to pre-nursery conditions. This could be attributed to a better water absorption capacity and efficient mobilization of endosperm nutrient reserves. Genotypes G26 and G19, for example, may possess genetic characteristics that promote rapid and uniform germination. Conversely, the low emergence rates in G11, G21, and G23 could be linked to more pronounced dormancy, increased sensitivity to initial environmental conditions (such as temperature or substrate moisture), or lower physiological seed quality. These observations are consistent with the work of Bradford (1995) and Ellis & Roberts (1981), who emphasized that genetic differences between cultivars can significantly influence the metabolic processes of emergence, leading to variations in a seed's ability to germinate rapidly and uniformly. Rapid emergence and a high number of first leaves are also crucial indicators of seedling vigor. These characteristics demonstrate the ability of the genotypes to rapidly establish a photosynthetically active leaf area. This suggested that high-performing genotypes achieve an efficient transition from dependence on seed reserves to autotrophy. Conversely, genotypes with low first-leaf emergence, such as G5, may have a slower metabolism or be more sensitive to environmental stresses, thus delaying leaf development. These data are consistent with the work of Taiz & Zeiger (2010), who explain that rapid leaf development is essential to maximize photosynthesis and biomass accumulation, fundamental elements for plant survival and subsequent growth. The study also showed that the number of live plants is a direct indicator of seedling survival and robustness in the face of pre-nursery conditions. Indeed, genotypes that maintain a high number of live plants demonstrate better tolerance to stresses (water, pathogens, etc.) and a greater capacity to adapt to the environment. This may be linked to better overall vigor, increased disease resistance, or more effective defense mechanisms. Conversely, genotypes with low survival rates may be more sensitive to environmental factors, leading to higher mortality. This trend was also noted in the work of Evans (1992), who emphasized that a plant's ability to survive in its early developmental stages is often correlated with its genetic vigor and its capacity to efficiently mobilize its resources.

5 CONCLUSION

The morphological growth performance of 14 identified genotypes, both tolerant and sensitive to water deficit in greenhouses, was determined in a real-world, pre-nursery environment. A comparative study of their growth under natural conditions revealed significant variability in their morphological performance. Statistical analyses (ANOVA, multivariate analyses) identified genotypes exhibiting early vigor and promising development (G19, G26, G22, G24, G7, G10) and revealed groupings of genotypes sharing similar performance profiles (G19, G26, G7, G10, G9, G22, G24, G25, G5, G14, G16, G21, G23). The results highlight that the best agronomic performance is observed in both water deficit-sensitive and tolerant genotypes. However, it has been observed that the best morphological performance is more pronounced in the identified genotypes that are tolerant than sensitive to water deficit. This indicates the high probability of success for these genotypes in nurseries and in fields under natural conditions. Therefore, this pre-nursery study should be continued in nurseries and fields in both water-deficit and non-water-deficit areas.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare that they have no conflicts of interest related to the publication of this article.

Author Contributions

The five authors collected the data. The first author processed and drafted this article. The other authors read and revised the manuscript. All authors read and approved the final version of the manuscript.

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