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RESEARCH PAPER

Study of morphological behavior under water deficit of five productive categories of oil palm

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Abstract

Water supply is the main factor preventing the extension of oil palm in so-called marginal crop areas and limiting palm productivity in traditional crop areas. The morphological responses of palm categories subjected to a water deficit were evaluated for 45 days to identify categories that are tolerant of water deficit. Thus, these categories have been subjected to a gradual water deficit cycle to identify the tolerant at sensitive. The water satisfaction of the plants ranged from 100% to 10%. The morphological parameters studied are the weight, the length of the roots, the height of the plant and the collar circumference. The different levels of water deficits affected the studied parameters of the different categories at variable density. The values of certain parameters obtained at different levels of water deficit showed a good correlation of the effect of the water deficit on the studied categories, which made it possible to distinguish after the first weeks of experience, the tolerant material of the sensitive.

Key words: Elaeis guineensis, water deficit, tolerance, weight, root, growth, collar circumference.

Introduction

The main climatic factor limiting the expansion of the oil palm cultivation in some agricultural areas is lack of water or insufficient rainfall. Water is the environmental factor that further optimizes the vegetative potential and production potential of the oil palm.Water supply is the main yield-limiting factor of oil palm, Kallarackal et al.(2004). There are large cultivated areas worldwide, which lack optimal conditions in terms of water availability, and the direct result is the yield reduction in terms of production of fresh fruit bunches and oil (Cornaire et al., 1994). Authors such as Devuyst(1948) ; Surre(1968) ; Nguettia et al, (1995) ; Quencez(1996), showed the influence of the water deficit on the palm tree for its water satisfaction needs 1800 to 2400 mm of water per year, well distributed in the year, Dufour et al, (1988).

The lack of water due to low rainfall or long drought, has a negative effect on the growth of the plant, the sex ratio, Corley(1983). The lack of water causes a high abortion rate of female inflorescences, an increase in the number of male inflorescences, Caliman(1992),Corley and Tinker, (2003),and thus the significant drop in production. In very prolonged cases of water deficit, the tree dies, Nouy et al,(1999).

It is therefore important for the stability of Elaeis culture in the traditional zone and for its expansion in the marginal zone to detect at a young age, despite this sensitivity to the water deficit, categories of palms tolerant to drought.These categories must combine a normal vegetative growth level with a satisfactory level of tolerance to water shortage.

However, the study of oil palm behavior during drought remains difficult in the field due to the inability to control environmental climatic factors.The idea of experimenting in a greenhouse makes it possible to control the external climatic factors and thus to have a precision on the values to obtain. These results allow us to distinguish in the nursery phase the tolerant categories to the water deficit.The objective of this study is to evaluate the effect of the water deficit at the nursery stage on morphometric parameters of five categories of oil palm. This evaluation will be done through a comparative study of the values of the parameters of the control plants to those under stress, in order to rule on the tolerance of these categories.

This study is a preliminary step to detect categories of palm oil tolerant to popularize in marginal areas.

Materials and Methods

Site of the study

The trial was conducted in a greenhouse at the National Center for Agricultural Research (NCAR) located of La Me, at 30 km from Abidjan in Côte d'Ivoire. Normal cultivation conditions of the plant have been put in place so that the water deficit is only the stressing factor. A humidity sensor installed in the greenhouse recorded an average hourly temperature between 27 ° and 35 ° C and a humidity fluctuating between 80% at night and 50% at midday, adequate conditions for the cultivation of the plant, JC Jacquemard(1995), Quencez P(1996).

Plant material

The material consists of 150 seedlings of 4 months. These seedlings come from five categories of palms : C1001F, C2501, C7001, C2401 and C1001. These categories obtained by artificial fertilization on the Me station are characterized in the field by a high yield of production.These are the most popular categories in Côte d'Ivoire for growing palm trees. The C1001F category has the particularity of being tolerant to Fusarium wilt, Duarand-Gasselin et al, (2000).

The seedlings obtained after 3 months of pre-nursery were transplanted into nursery in black polythene bags of 25cm high and 20cm in diameter, perforated with 20 holes at the base and filled with 3500g of soil. After 1 month of nursery, 30 seedlings per category, thus 150 seedlings were selected according to the criteria of selection in nursery and their homogeneity to be subjected to different water treatment during a period of 45 days under a greenhouse.

Determination of water treatments

The experiment focused on five water regimes : one witness maintained at field capacity and four stressed treatments.

The value of the field retention capacity of 3500 g of soil was considered the value of the control water treatment. For the determination of this value which is 725ml, the 3500g of earth soil were conducted to saturation of water. The water having completely drained from this earth, it has been measured the wet weight of the earth (3980 g). This wet earth was then dried in a dryer at 105 ° C for 24 hours to determine the dry weight of this amount of soil (3255 g). The field capacity that represents the value of the control treatment was determined by the formula of the soil wetting and water holding capacity above, Feodoroff (1962).

In Table 1 below, the different values of the water treatments are mentioned. Stressed treatments are achieved by gradual reduction in the value of the control treatment (Table 1).

Table 1 : Value of different water treatments

Water treatment	**Value in (%) water treatments**	**Value in (ml) of water treatments**
control treatment	100%	725 ml
Stress treatment 1	75%	544 ml
Stress treatment 2	50%	363 ml
Stress treatment 3	25%	181 ml
Stress treatment 4	10%	73 ml

The water supply was done manually using graduated containers.

Experimental apparatus

The experimental set-up is a Fisher block allowing the study of two factors at five different levels : plant material (categories C1001F, C2501, C7001, C2401 and C1001) and water treatments (one control and four stressed treatments). The device is composed of 2 repetitions. Each repetition is composed of 15 experimental units which are the crossing of a plant material and a level of water treatment. Each experimental unit consists of 3 plants.

Morphological observations

All the morphological observations, after 45 days of application of water treatments, concerned plants aged 165 days. At this stage, each plant had at least 5 to 6 well-opened lanceolate leaves. The morphological parameters selected for our study are the weight, the length of the roots, the height of the plant and the circumference at the neck. These four parameters were selected for their fairly good correlation with the water deficit, Maillard G, et al, (1974), Adjahoussou DF(1983), Nouÿ B et al,(1999).

Parameter weight

Weight is a palpable and visible criterion for assessing the effect of the water deficit on palm categories, Jaleel et al., (2009), Indeed in times of water deficit, the young palm is characterized by intense dehydration due to evaporation of water, which leads to wilting of the vegetative organs, this causes a huge loss of weight in the plant Cornaire B. et al.(1994). To measure the weight of the plants, a PIONEER scale of the OHAUS CORP brand (www.bipm.org) was used.

Root length parameter

The root is directly affected by the deficit because of its contact with the soil and its role to draw from the soil all the elements necessary for the proper functioning of the plant, Sun et al., (2011). It is for this purpose, a good indicator of the effect of the water deficit on the plant. In case of severe water deficit, the roots stop their growth and development. There is atrophy of the roots due to the high temperature of the soil caused by lack of water. The most vulnerable die quickly compared to tolerants that have a fairly long life (Maillard G., et al. (1974), Nouÿ B. et al,(1999). For the measurement of the root length of the plant, a rule was used according to conventional measurement standards (www.metrologie-francaise.fr).

Parameter height of plants

The height of the plant is an observable indicator of the effect of water deficit on the growth of the plant, Cao et al.,(2011). In times of water deficit, the palm tends to reduce or stop growth in height. For the most tolerant, this period of lack of water is characterized by slow growth, while in the most sensitive, there is a stop growth accompanied by stunting of the plant and its death (Reis de Carvalho C. (1991), Cornaire B. et al,(1994). For the measurement of the height of the plant, it was used a rule according to the conventional standards of measurement, (www.metrologie-francaise.fr).

Circumferential collar parameter

The collar circumference is the index of vigor and development at the base of the palm. It is a non neglecting indicator of the effect of the water deficit on the palm tree in times of lack of waterSun et al.(, 2011). The neck at the base of the palm tends to increase in diameter and widen in periods of satisfaction with water, Adam J. (1910). But in periods of water deficit, the neck of the palm tree develops slowly and this leads to a weak growth of the palm tree, Nouÿ B. et al. (1999). For the determination of the circumference at the collar was used caliper, (www.metrologie-francaise.fr).

To measure the values of the parameters, the plants were removed from the nursery bags which were much wet with water. The plants were washed with water to remove all the cover soil. Then they were put in tissues to absorb the rinse water. After that, the plants have undergone measurements of the values of the different parameters.

Statistical treatment of data

The statistical analyzes were done with the IBM SPSS Statistics software version 20. The marginal means and the standard deviations of the analyzes were obtained by the method of the descriptive statistics. The post-hoc test, multiple comparison of the averages in treatments allowed us to build the profiles diagrams. Differences between treatments were considered statistically significant at the 5% level.

Results

Rate of survival of plants after 45 days of water treatment

After 45 days of water treatment, we observe in both repetitions a conservation of the number of plants in all categories at different levels of water deficit (6 plants, 100% survival), except in the C1001 category particularly in the strictest water deficit (73ml) where there was two mortalities, (66.67% survival, figure 1).

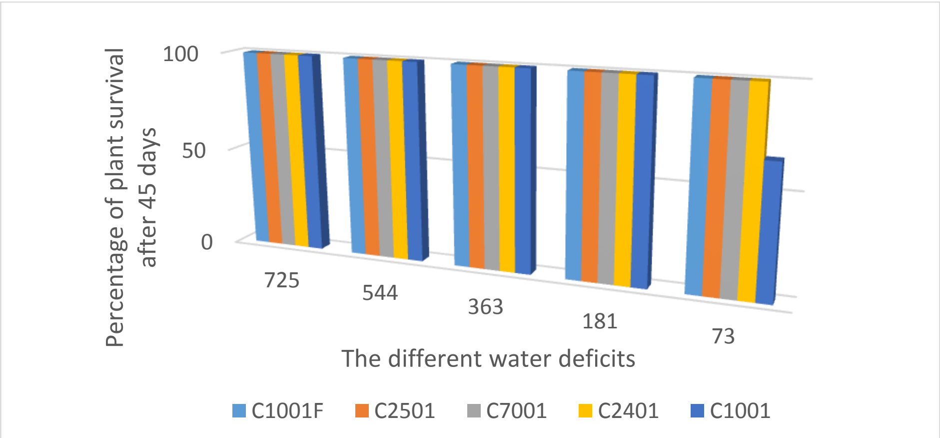

Figure 1 : Percentage of plant survival after 45 days of treatment

Effect of water deficit on categories weight

The weight of control plants in the categories studied is higher in C7001, C2401, and C1001 than in C1001F and C2501. This normal expression of weight values of categories without water deficit expressed as such, shows that some categories tend to be more vigorous than others with normal water satisfaction (Table 2, Figure 2). The change in weight according to the different stressed water regimes presented in Figure 2 shows that the weight tends to decrease as water intake is reduced. Thus this weight reduction is more intense at the strongh level of water deficit in categories C1001 and C2501, than in categories C2401, C7001 and C1001F.

All the studied categories do not have a linear decrease of the weight at the level of the different water deficits, so while at 544ml, there is a slight decrease of the weights of categories compared to the control, in the category C2401, the weight value exceeds that of the control (Table 2, Figure 2).

The analysis of the variations of the weight of the control at the last level of water deficit generally shows us a loss of weight. The weight loss is more intense at the last two levels of the water deficit (181 and 73 ml). At 73 ml of water deficit, the weight losses are high in the categories C1001 and C2501 (-55% , -50% compared to the control), they are below in the average for the categories C2401 and C7001 (-43%, -46%) and weak for the C1001F category (-25% compared to the control). Analysis of these differences values shows that the effect of the water deficit in the loss of weight was less intense on the C 1001F, average on the C 2401 and C 7001 and intense for the C 1001 and C 2501 categorie (Table 2).

Table 2: Average weight of plants (g) and deviation of variation in% of weight compared to the control

Average weight of plants (g) and difference in weight variation in%					
Categories / Water treatment and difference in weight variation in%	C 1001F	C 2501	C 7001	C 2401	C 1001
725ml	29,73±4,84	34,74±7,19	44±23,64	38,92±2,39	38,81±5,78
%	100	100	100	100	100
544ml	28,64±10,96	34,67±14,5	37±10,36	42,35±8,08	38±8,32
gap in%	-3	- 0.2	- 16	+ 8	- 2
363ml	26,71±6,59	26,39±4,52	29,33±6,48	33,3±3,58	33,19±7,27
gap in%	-10	-23	-33	-14	-14
181ml	22,51±3,31	22,36±7,6	27,76±6,9	32,32±4,58	23,71±7,8
gap in%	-24	-35	-37	-17	-38
73ml	22,23±3,31	17,41±1,5	23,51±3,19	22,16±2,89	17,40±6,15
gap in%	- 25	- 50	- 46	- 43	- 55

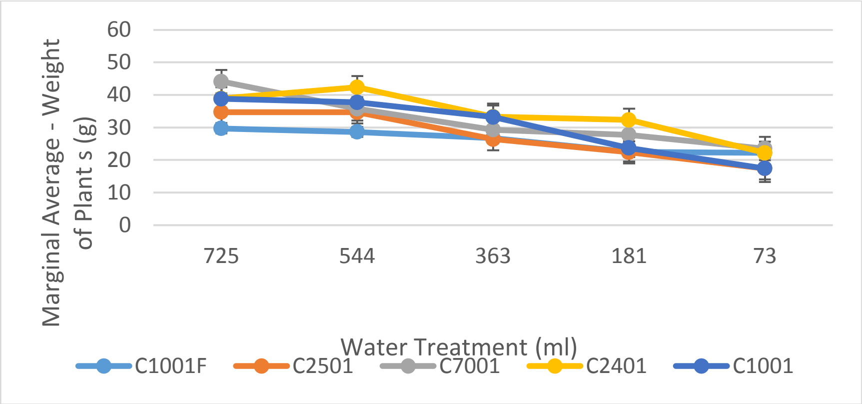

Figure 2: Evolution of weight according to different water treatment

Effect of water deficit on root length

In the state of normal water satisfaction, root elongation is more intense for categories C7001 and C1001F. It is less intense for categories C2401, and C1001 and C2501 (Table 3, Figure 3).

When water deficit was applied, there was an intense root elongation, greater than that of control, for the categories C1001F, C2501, C2401, C1001, for the water deficits 544ml and 363ml. For the category C7001 there is a gradual reduction in elongation at these levels of water deficits (Table 3, Figure 3).

At the most severe levels of water deficit (181 ml and 73 ml), there is a slight elongation of the roots of stressed plants, compared to those of control. The growth of the root in deep is low, but root activity remains more developed for the categories C7001 and C1001 and lower for C1001F (Table3, fig.3).

The analysis of variation in root length versus control for the different levels of water deficit in the studied categories shows an extension of plant roots in certain categories at the level of low water deficits 544 and 363 ml. These categories tend to extend their roots in search of water. This ability is especially developed in categories C2501, C2401, C1001, C1001F (Table 3). On the other hand, at the level of the very severe water deficits of 181 ml and in particular 73 ml there is a reduction in the length of the roots compared with the control. The reduction is high for the C1001F category (-37% of the control), average for the C2501, C2401 and C7001 categories (-29%, -31%, -31%), and low for the C1001 category (-19% by report to control) (Table 3).

Table 3: Mean root length (cm) and deviation variation in% of root length compared to the control

Mean root length (cm) and deviation of length versus control in%					
Categories / Water Treatments and difference in root variation in %	C 1001F	C 2501	C 7001	C 2401	C 1001
725ml	36,50±1,38	29±6,2	40,5±6,66	31,50±2,45	31,17±5,49
%	100	100	100	100	100
544ml	43,17±3,79	42,83±3,37	39,83±7,25	41±6,76	46,83±6,31
gap in%	+18	+ 47	-1	+30	+ 50
363ml	43±7,40	34,33±6,80	35,33±9,56	41,17±1,87	42,17±2,71
gap in%	+17	+ 18	-12	+30	+35
181ml	35,83±4,96	31±6,51	32,83±3,06	28,50±2,07	35±8,22
gap in%	-2	+ 6	-18	- 9	+12
73ml	22,67±2,50	20,33±1,86	27,83±2,93	21,67±1,51	25,17±4,74
gap in%	-37	- 29	- 31	-31	- 19

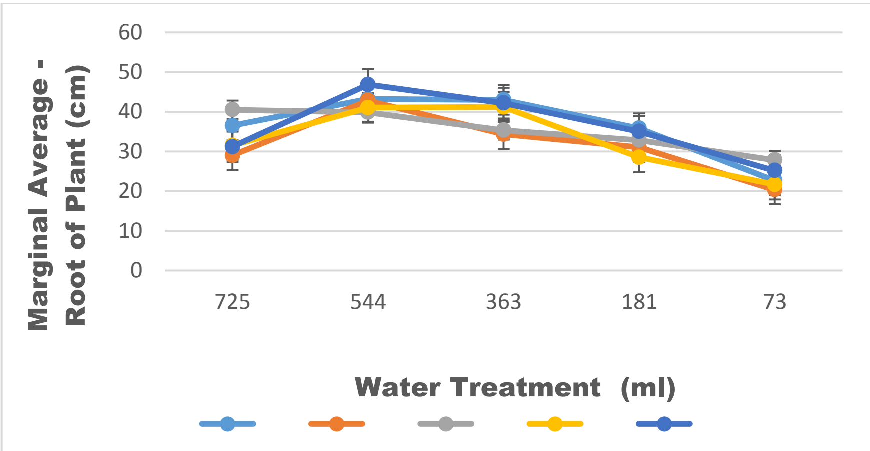

Figure 3: Evolution of root length (cm)of the plant according to different water treatment

Effect of water deficit on plant height of categories

The water deficit has an impact on the height of the plants, from control to the last level of water supply of each category, figure 4.

The plants of the various categories studied, in a state of normal satisfaction in water, tend to have almost the same heights (Table 4, Figure 4). With the application of the water deficiency regimes, there is a drop in the height of the plants compared to those of the controls. This drop is not linear in all the categories studied. Thus in the 544ml water deficit block, while there is a slight fall in the height of the plants of categories C7001, C1001F, C1001 and C2501 compared to the control, in the C2401 category the height of the plants exceeds that of the control (Table 4, Figure 4).At the highest level of water deficit (73ml), the fall in height is general in all categories studied. But in some categories such as

C1001F, C7001, and C2401, this decrease is not great compared to the controle, specially for C1001F, C7001 (Table 4, Figure 4).
The analysis of the variation of the height of the plants, from control to the last level of water deficit generally shows a decrease in the height of the seedlings of the categories. The decreases are more intense at the last two levels of the water deficit that are 181 and 73 ml. These discrepancies showing the decline in growth relative to controls are high in some categories than in others. Thus at the high level of water deficit 73ml, while this reduction in height is intense in categories C 2501 and C 1001 (-32% and -34% of control), it is low for categories C7001 and C2401 (-21 %; -28%). This drop in height is very low for the C1001F category (-16%) compared to the control, (Table 4).

Table 4 : Average plant height (cm) anddifference in height variation in% compared to the control

Average plant height (cm) and difference in height variation in %					
Categories / Water Treatments and difference in height variation in %	C 1001F	C 2501	C 7001	C 2401	C 1001
725ml	34,33±1,21	35±7,69	35,5±6,28	36,50±2,51	36±1
%	100	100	100	100	100
544ml	34±5,44	32,83±3,43	34,67±7,47	39,33±6,47	32,83±3,43
gap in%	-1	-6	-2	+7	-8
363ml	33,50±2,07	31,33±3,26	33,17±1,47	34,33±2,87	32,50±3,01
gap in%	-2	-10	- 6	- 6	-9
181ml	29,33±0,81	29,33±0,81	32,33±2,25	31±2,89	29,83±3,18
gap in%	-14	-16	- 9	- 15	-17
73ml	28,83±1,472	23,67±2,33	28±1,26	26,17±1,47	23,67±3,38
gap in%	-16	- 32	- 21	- 28	- 34

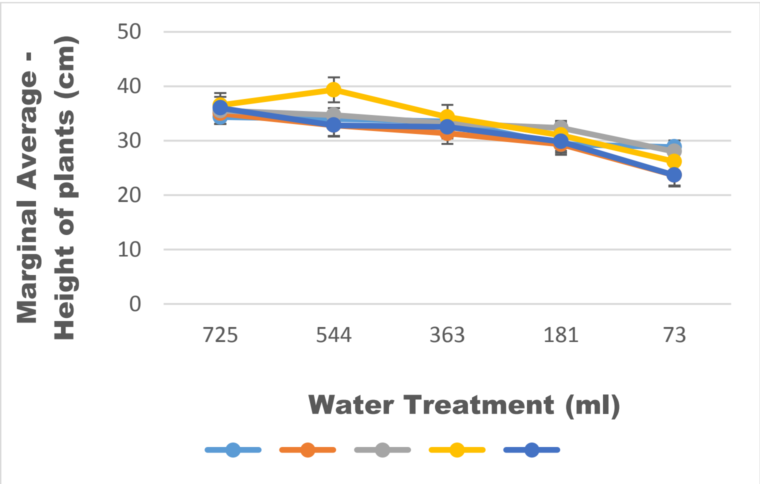

Figure 4: Evolution of the average heights of the plants according to the different water treatment

Effect of water deficit on the collar circumference of the plants of categories

The impact of the water deficit on the collar circumference of the plants studied, from control to the last level of water supply is shown in Table 5 and Figure 5. The collar circumference values at control of the plants of the categories, shown in Figure 4, show a net dominance of the value of the C1001 category over the others and almost equal values between the other four remaining categories (Table 5, Figure 5).

It is noted a gradual decrease compared to the data of their witness, the values of the collar circumference of the categories C1001F, C2501, C1001 and C7001,during the gradual reduction of water supply, except at the treatment 544ml or the category C7001 keeps an equality of value with his witness,(Table 5, Figure 5).

In the C2401 category, this decrease is not linear, it is found a values of the collar circumference greater than that of the control for the low and medium water deficit (544ml and 363ml), the decline is not great for the high water reduction of181ml (Table 5, Figure 5). At the most severe level of water deficit (73ml) the reduction of collar circumference is more intense in categories C1001, C2501, and C2401 (Table 5, Figure 5).

The analysis of the variations of the value of the circumference of the collar of the plants, of the control at the last level of water deficit, generally shows a gradual reduction of variable intensity of the values of the circumference to the neck. This reduction is linear for 4 of the categories studied : C1001F, C2401, C7001, C2501, C1001. In the C2401 category, neck circumference values are higher than control at water deficit levels of 544ml and 343ml. The reduction becomes general in all categories starting from the 181ml deficit level (Table 5). At the very severe level of the water deficit (73ml), this reduction in collar circumference becomes even more intense in category C 1001 (-42% of control), average in categories C2401 and C2501 (-30% of control), but remains low in the C7001 and C1001F categories (-21% and -18%) compared to the control (Table 5).

Table 5 : Circumference at the average collar of the plantsand difference in collar circumference variation in % compared to the control

Catégories / Water Treatments and difference in collar circumference variationin %	C 1001F	C 2501	C 7001	C 2401	C 1001
725ml	1,75±0,15	1,77±0,49	1,75±0,55	1,80±0,12	1,9±0,15
%	100	100	100	100	100
544ml	1,62±0,21	1,67±0,32	1,75±0,26	1,85±0,14	1,8±0,21
gap in%	-7	-5	0	+ 2	-5
363ml	1,58±0,32	1,55±0,27	1,65±0,27	1,82±0,13	1,63±0,26
gap in%	-9	-12	- 5	+ 1	-14
181ml	1,47±0,15	1,27±0,27	1,42±0,35	1,58±0,22	1,45±0,37
gap in%	- 16	-28	- 18	- 12	-23
73ml	1,42±0,30	1,23±0,14	1,38±0,21	1,25±0,14	1,1±0,13
gap in%	- 18	- 30	- 21	- 30	- 42

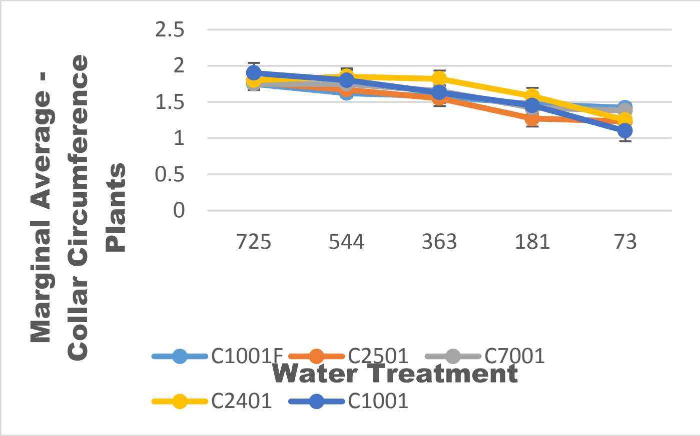

Figure 5 : Evolution of collar circumference of the plants according to different water regimes

Discussion

The tolerance of the five categories evaluated through the plant weight parameter

The weight parameter is one of the most significant indicators of the inhibitory effect of water stress on all categories studied, Cha et al. (2010)**.** This is verified by the very high values of the weight drops of the categories for the severes water deficit 181 ml and 73 ml.However, in this demonstration of the destructive effect of the deficit on the weight of the categories, certain categories showed a greater tolerance than others did when the statistical comparison of the data (Table 2). The C1001 category with a high weight to control, underwent a strong effect of the water deficit to the point that it recorded the greatest decrease in weight compared to the control (-55%), for the severe water deficit (73 ml). C1001 category was very sensitive to the inhibitory effect of lack of water. The C1001F category with a low control weight was characterized by a slight weight decrease in the various diets of the water deficit, especially at 73 ml or it has a drop of -25% compared to the control. The effect of the water deficit was less intense on the weight of this category which showed a tolerant character. The categories C 2401 and C7001 showed a normal tolerance to water deficit marked by a mean fall in their weight in the different treatments in comparison with the value of their control, observed in Table 2.

The tolerance of the five categories evaluated through the parameter of the length of the roots.

The effect of the water deficit was felt differently on the length of the roots of the categories studied, Ryser P (2006). The categories C1001F, C2401, C2501 and C1001, for the low and medium levels of water deficit, had an elongation of their roots that was significantly higher than the values of those of their control. This character of lengthening the roots for the low levels of water deficit shows the sensitivity of these categories to the reduction of water. The C7001 category was characterized by a adaptation to the lack of water, which was manifested by a gradual reduction of the elongation according to the different levels of deficit. At the first severe level of water deficit (181ml) elongation stops at C1001F and C2401, while it continues at C2501 and C1001. Categories C1001F, C2401 adapt to their condition, while C2501 and C1001, which are very sensitive to lack of water, continue to lengthen their roots. The last very severe level of the water deficit (73ml) is characterized by a fall of the elongation of the roots compared to the values of their control in all the categories studied. This drop in elongation compared to control is less intense in C2501 and C1001 because feeling a lack of satisfaction of water, due to the deficit, their roots at this level continued weakly to lengthen. This is not the case for the other categories whose plants have adapted to these severe levels of deficiency (181, 73ml), that *it why the elongation of their root have remained insignificant. The adaptation of roots to the severe level of water deficit by low growth of the roots is more significant for categories C1001F, C2401, and C7001.*

The tolerance of the five categories evaluated, through the seedling height parameter.

The levels of water deficit influenced plants height in all five categories differently, Cha et al. (2010),Cao et al., (2011).

At low level of water reduction (544, 363ml), the decline in the height of the seedlings of the categories remain apparently low compared to the values of their control. The category C2401 has even at the level of the water deficit 544ml a stimulation of growth, its value reached is greater than that of the control. The effect of the water deficit is less intense, although categories such as C2501 and C1001 have recorded large deviations from the others.

Has severe levels of water reduction; the inhibitory effect of the deficit is felt on the growths of certain categories studied, in particular for C2501 and C1001 especially at the 73 ml level or the height drop are very high compared to the controls (-34 and -32%). The decreases in the height of the plants in the categories C2401, and C7001 were less intense at this level water reduction, in particular for C1001F or the decrease was -16% compared to the control. The categories C1001F, C7001 and C2401, despite the inhibiting effect of lack of water, have maintained growth at the severe level of water deficit. This is due to a state of adaptation to the water deficit and therefore the development of a normal tolerance.

The tolerance of the five categories evaluated through the circumference parameter at the collar of the plants

The various levels of water deficit influenced the evolution of the values of the collar circumferences of the five categories studied,Cao et al.,(2011).

It is noted a reduction of the collar circumference for the low and medium levels water deficit (544ml and 344ml) in four of the categories studied. This reduction is weak for C1001F and C7001, but intensive in C2501 and C1001. In the C2401 category, at these levels of water deficits, the development of collar circumference is stimuled; the values obtained are greater than that of the control.

At level 181ml of water deficit; the collar circumference value decrease considerably because of the inhibitory effect of lack of water in the categories. However, the category C2401 characterized particularly by low decrease of values compared to the control. At the last level of the deficit (73ml), the fall deviations of the collar circumference are very elevated compared to controls for C2501, C2401 and C1001 (-30, -30 and -42%). For the categories C1001F and C7001, in particular for C1001F, The collar circumference decreases were small, despite this severe water deficit, the decrease was -18% compared to the control.

The categories C1001F, C7001 despite the inhibitory effect of the water deficit have a low drop the collar circumference ; because of the tolerance, they have developed at different levels of water deficit. They are followed by the category C2401 that suffers the negative effect of the deficit only at the last level of stress, 73ml. C1001F, C7001 and C2401 showed a character of adaptation and tolerance.

Conclusion

The study of vegetative behavior during the water deficit of the young palm tree is a very important step to evaluate their level of tolerance. Evaluation of vegetative parameters such as weight, plant height, root length, and collar circumference are essential for the study of the vegetative behavior of the palm tree under stress. The expression of the variations in the values of the control parameters to the last level of water deficit in our study allowed us to differentiate the level of tolerance of the five categories studied. The gradual decline in parameter values under the inhibitory effect of water stress relative to control was observed for three of the parameters of weight, plant height, and collar circumference. This was not the case for the root length parameter where the root values of four categories at low and medium levels of water deficit were above those of the control before declining.

All parameters, the weight, the length of the roots, the height of the plants, and the collar circumference by the variation of the deviations of their values allowed a very high level to differentiate the tolerant categories of the less tolerant. The determination and the analysis of the variations of the values of the parameters compared to the control under the action of the water stress showed us that certain categories studied (C1001F, C7001 and C2401) had a fairly developed a adaptation and normal tolerance to the water deficit compared to others.

These results are of interest because they make it possible at young age to morphologically distinguish categories that are tolerant to drought. They could serve as preliminary methods for breeders to set up early testing for the selection of drought tolerant oil palm. They can serve as a step that can be used to screen drought-tolerant oil palm categories at an early age.

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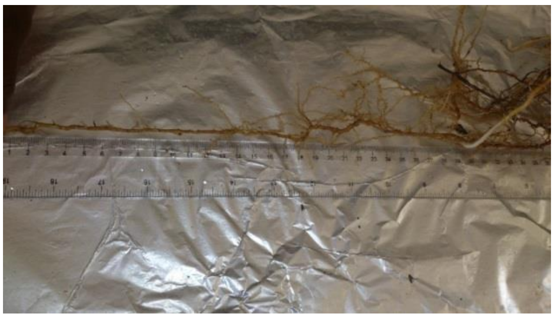
Illustration photography

1. Plants in the greenhouse

2. Measuring the weight of the plants



3. Measuring the length of the roots