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Effects of Water Stress on the Physiological Behavior, the Flowering and the Fruiting of *Jatropha curcas* L. Under Semi-controlled Conditions

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Authors' contributions

This work was carried out in collaboration between all authors. Author ID designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors RB and BO reviewed the experimental design and all drafts of the manuscript. Author DO managed the analyses of the study and performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Jatropha curcas L (J. curcas) sectors are increasingly promoted in the Sahel for biofuel production. Though, our understandings on the species responses to water deficit particularly of mature trees are still sketchy. So, this study aims at investigating the effects of water deficit on the physiological behavior, the flowering and the fruiting of *J. curcas*.
The experimental design was a randomized complete block design with 6 replications and 4 treatments.
The study was conducted at the research station of the National High School of Agriculture (ENSA) located at 4 km from Thiès, Senegal. The study lasted 113 days from April 1st to July 22nd 2013.
J. curcas trees at 21 months old, grown from seeds collected at ENSA were used for the study. The

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experimentation was conducted in semi-controlled conditions and the 4 treatments considered are: T0 (maximal evapotranspiration); T1 (75% of maximal evapotranspiration); T2 (20% of maximal evapotranspiration) and T3 (without watering). The crop evapotranspiration, the stomatal conductance, the leaf area index (LAI) as well as the flowering and the fruiting were monitored.
The results show that only severe water deficit (watering at 20% of maximal evapotranspiration) negatively affect the physiological traits (stomatal conductance and LAI) and the yields (fruits weight per tree and seed weight per tree) of *J. curcas*. However, only very harsh water deficit (watering at about 1% of maximal evapotranspiration) reduce flowering parameters (inflorescence size, number of male and female flowers). The flowering and the fruiting of *J. curcas* are less affected by water stress.
The experimentation concluded to a negative effect of only severe water stress on *J. curcas* physiological traits but fruits and seeds production are solely affected when water uptake of *J. curcas* declines under 20% of maximal evapotranspiration. This question must be deeply investigated trough long-term experimentation with more treatments in order to determine the threshold of water deficit at which *J. curcas* yield significantly declines.

Keywords: Jatropha curcas L.; water deficit; stomatal conductance; flowering; yield; Senegal.

1. INTRODUCTION

Water scarcity is one of the most important constraints affecting plant production particularly in semi-arid zones that cover more than 35% of earth surface [1]. In these zones, annual rainfall is insufficient and is characterized by a high spatio-temporal variation. As a result, droughts and agricultural yield losses are frequent in this zone. Fortunately, many plants have developed adaptation strategies to cope with water deficit allowing them to survive and to produce biomass under water deficit conditions. From these strategies, the main ones are: drought escape, drought avoidance and drought tolerance [2,3]. A better understanding of these strategies for a given crop allows formulating an efficient watering strategy in order to reduce water losses without affecting negatively crop development and yield. *J. curcas* is a shrub species belonging to Euphorbiaceae family. It is native to Central and South America but its current geographic distribution area covers all tropical and sub-tropical zones [4]. Nowadays, the plant is considered as one of the most promising species for biofuel because of its seed oil whose characteristics are close to diesel besides its relative tolerance to water stress [5,6]. This last trait made *J. curcas* to be considered as a priority for biofuel production in the arid and semi-arid zones with minimal water consumption. It is one of the reasons why it was introduced in Sahelian countries to reduce the dependency on fossil oils and also to generate incomes for farmers. In fact, Sahelian zone is known to be one of the areas mostly subjected to drought in the world and this situation will become more and more complex under future climate scenarios that predict an increase in drought occurrence with harmful impacts on agricultural production [7]. In this context, it is imperative that diversification crops introduced in Sahelian zone such as *J. curcas* require a deeply investigation of their vulnerability and adaptation strategies to cope with water deficit. Then, this information will allow identifying efficient management strategies of these crops that could guarantee their sustainable production.

In contrary, little knowledge is available on the responses of *J. curcas* to water stress. Except [8] works conducted in Egypt on mature trees, the few researches on *J. curcas* responses to drought stress is limited to *J. curcas* seedlings obtained from seeds originated to regions those ecological conditions are different to those of Sahel zone [9,10,11,12]. Whereas, it is assumed that plant responses to water deficit change according to the species, accessions or varieties as well as their development stage [13,14].

In this context, the objective of this study is to determine the effects of water deficit, flowering and fruiting of *J. curcas*.

2. MATERIALS AND METHODS

2.1 Physical Characterization of Experimental Site

This study was conducted at the research station of National High School of Agriculture (ENSA), University of Thiès (latitude 14°42'52'' N and

longitude 16°28'64'' W) in Senegal. The study lasted 113 days from April 1st to July 22nd 2013. The climate of the study site is semi-arid tropical type characterized by two seasons: rainy season which occurs from June to October and dry season from November to May [15]. The mean annual rainfall is 429.2 mm [16] and means monthly temperatures vary from 20 to 36°C. Mean relative humidity is about 62%. Sun exposure is about 9 h from January to April, 7 h from May to September and 8 h from October to December [17].

2.2 Plant Material

J. curcas trees were grown from seeds collected at the research station of ENSA. The water deficit experimentation started 21 months after sowing and coincided to the outset of flowering. Trees heights ranged from 100 to 146 cm with mean height of 126.3 cm whereas mean number of primary branches was 7.8 ± 1.8. The collar diameter varied from 70.3 to 84.4 cm with a mean of 76.4 cm whereas the mean diameter of crown was 97.3 cm with a minimum diameter of 90 cm and a maximum of 113.5 cm.

2.3 Experimental Design

The experimental layout is a randomized complete block design and one factor (water regime) was investigated including 4 treatments:

- T0 : trees watered with 9.4 litres of water each week ;
- T1 : trees watered with 7 litres of water each week;
- T2 : trees watered with 1.8 litres of water each week;
- T3: non-watered trees.

Each treatment was replicated 6 times; this corresponds to a total of 24 trees for the experimentation. The treatments have been determined based on the normal rainfall of the department of Thiès [16]. So, T0 corresponds to the cumulative weekly mean rainfall of a normal rainfall per year. Treatments T1 and T2 correspond to 75% and 20% of rain quantities, respectively, received weekly in study site during normal rainfall year. Treatment T3 correspond to stressed trees that haven't been watered during the experimentation. Watering has been performed with a 2 L burette that allows quantifying water to bring into the pots in order to equalize water losses in each pot.

2.4 Pots and Plantation Substrates

J. curcas trees have been grown in 80 litres plastic pots filled with a substratum which was a mixing of sand and mould (3:1). The bottom of each pot has uniformly been drilled and covered with grits in order to allow percolation of excess water from watering.

2.5 Climatic Conditions

The experimentation has been conducted in dry season. Climatic variables such as air relative humidity and air temperature have been recorded along the experimentation with a micro-meteorological station "microclimate monitoring system" (Decagon Devices, Inc., Pullman, WA, USA) installed in the experimentation site.

2.6 Soil Water Measurements

The monitoring of soil water content has been achieved using gravimetric method. Then, wet soils were sampled using a hand auger. Samples wet weight and dry weight were determined before and after drying in an oven at 105°C for 24 hours, respectively. For each sample, the moist weight (Hp) was determined by the following formula:

$$Hp = \left(\frac{WW-DW}{DW}\right) * 100 \quad (1)$$

Hp = Moist weight; WW= wet sample weight; DW= dry sample weight

For each treatment, three trees were chosen for soil water content monitoring weekly. Total of 12 (3 x 4 repetitions) trees were considered. Soil was sampled into horizons of 10 cm from the surface to 45 cm depth. Volumetric soil water-content was calculated by multiplying moist weight of each soil horizon with the bulk density. For bulk density, a cylinder (135.1 cm^3) was used. Then soil was sampled at the 0-10 cm horizons of three pots chosen randomly. Samples were oven dried at 105°C for 24 hours and weighted. Dry soil weight allowed determining soil bulk density using the formula:

$$BD = \mathrm{DW/V} \quad (2)$$

Where, BD: bulk density; DW: soil dry weight; V: cylinder volume

The crop evapotranspiration at each measurement date was calculated by using the water balance equation into crop roots zone:

$$P + I = ETC \pm \Delta SW + R + D \quad (3)$$

With:

- ΔSW = Soil water variation between two periods t1 and t2;
- P = cumulative precipitation between measurement dates;
- I = irrigation between measurement dates
- R = runoff
- D = water lost by drainage
- ETC: crop evapotranspiration

The experimentation was carried out during the dry season and in pots covered with plastic sheet to avoid soil evaporation and to prevent rain water. So, precipitation (P), runoff (R) and drainage (D) components were negligible in water balance equation. Then, the equation becomes:

$$ETC = I \pm \Delta SW \quad (4)$$

2.7 Stomatal Conductance

Measurements were recorded using porometer « SC-1 leaf Porometer » (Decagon Devices, Inc., WA, USA) between 13 h and 14 h, at which moment, plant in normal water regime presents a maximal stomatal conductance. Stomatal conductance was recorded at 70 days after water deficit application and was measured on 6 trees per treatment. On each tree, measurements were done on three random leaves chosen from the most bloomed leaves exposed to the sun.

2.8 Leaf Area Index (LAI)

Leaf Area Index was recorded using LAI ceptometer LP80 (Decagon Devices, Inc., Pullman, WA, USA) at 70 days after water deficit application. Measurements were performed between 13 h and 14 h at all the 4 sides of each plant.

2.9 Flowering

Flowering of all *J. curcas* trees used in this experimentation has been monitored. Measured traits were: number of inflorescence per plant, inflorescence size, number of male flowers per inflorescence and the number of female flowers per inflorescence. Monitoring of the number of inflorescence consisted to count the number of new inflorescences of each tree every 15 days during the experimentation. Then, at each measurement day, new inflorescences recorded were marked with a strap.

Counting of female and male flowers of trees was performed once each 30 days along the experimentation. The observations and measurements were made on 6 trees per treatment. For each tree, the size of 5 inflorescences was measured resulting to a total of 30 inflorescences per treatment.

Measurements were performed using an electronic caliper at 70 days after water stress implementation. Measured variables were: height, length and breadth of inflorescences.

2.10 Fruiting

Yield parameters were computed based on the monitoring of fruit production during the 30 last days of the experimentation. Fruiting monitoring consisted to harvest each 15 days all the ripe fruits (yellow and brown color) of each tree and to weigh the harvested fruits after an oven drying of the fruits at 64℃ during 24 h. The observations started when flowers identified at the beginning of water deficit implementation started producing fruits. These fruits were shelled and their seeds weighed using an accurate scale (Kern 440-55N, precision 0.2 g, Germany). All operating processes allow to determine:

- total number of fruits produced per tree corresponding to the total number of fruits harvested on the tree at each harvesting day;
- total dry weight of fruits produced per tree corresponding to the total dry weight of all the fruits harvested on the tree at each harvesting day;
- total number of seeds produced per tree corresponding to the sum of seeds from fruits harvested on the tree at each harvesting day;
- total dry weight of seeds produced per tree corresponding to the total weight of the dry weight of seeds from the fruits harvested on the tree at each harvesting day;
- 20-seeds weight corresponding to the weight of 20 seeds replicated three times of each treatment; this allows determining 100-seeds weight based on the rule of three.

2.11 Statistical Analysis

The data of the measured parameters (daily water use, stomatal conductance, leaf area index, number of inflorescence, inflorescence size, female and male flowers and yield parameters) were arranged in Excel sheet and analyzed using the XLSTAT Software. One-way Analyses of Variance (ANOVAs) were run to test the treatments (T0, T1, T2, T3) effects on the measured parameters. When ANOVA tests were significant, differences among the mean values were performed by Tukey's test. All the tests were considered significant at $p<.05$ and highly significant at $p<.01$.

3. RESULTS

3.1 Climatic Conditions of the Experimentation

The analysis of Fig. 1 shows two phases of temperatures evolution along the experimentation. The first phase is characterized by a discontinuous increase in temperatures that rose from 25.7℃ at the first 10 days of April to a peak of 30.1℃ at the first 10 days of May 2013. Afterwards, the second phase begins at the second 10 days of May and ends at the end of the experimentation at the second 10 days of July. This phase is marked by a low variation in the temperatures (27.5 to 28.2℃) and that are lower compared to the peak.

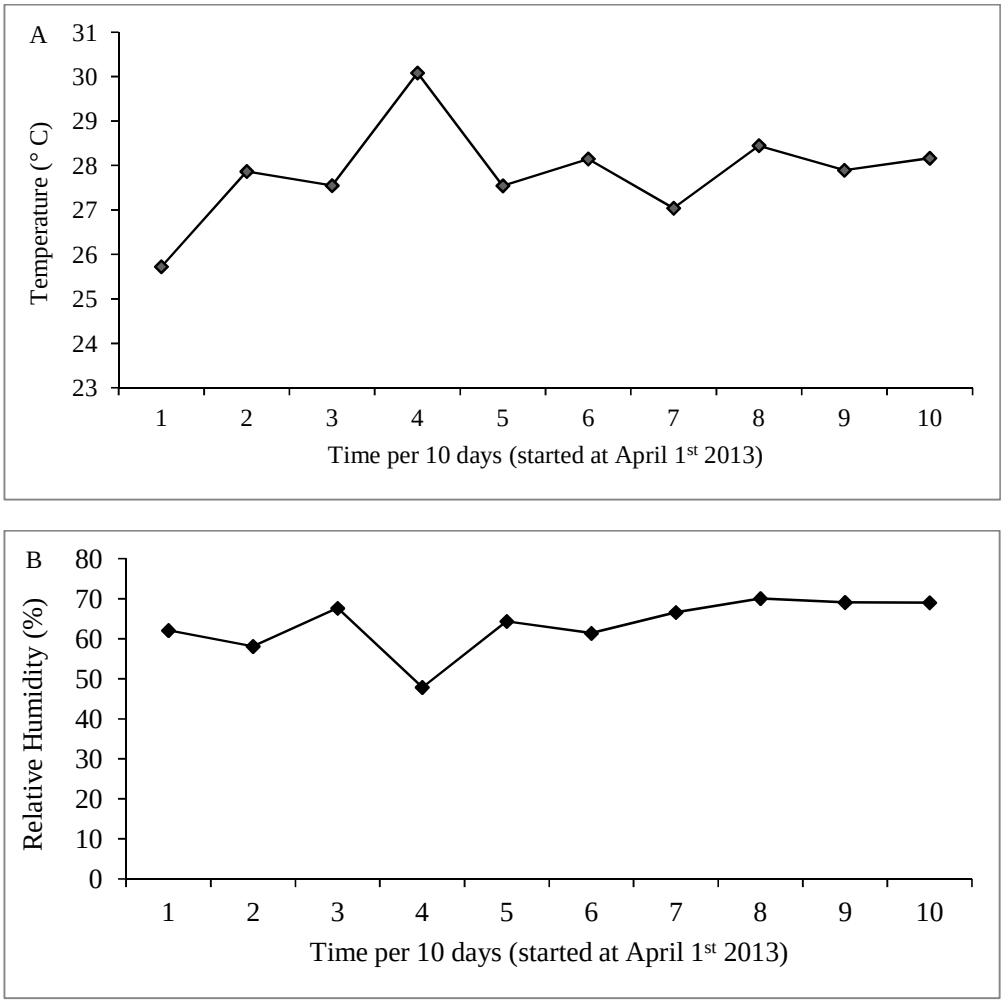

Fig. 1. Variation of mean temperature (A) and relative humidity (B) recorded at the experimentation site according to time per 10 days (From April 1st to July 2013)

Relative humidity varied from 62.12 (first 10 days of April) to 70.1% (second 10 days of June) along the experimentation. However, the variation of relative humidity in the last two months (April and May) was higher.

3.2 Tree Water Use in the Different Treatments

Daily water use of trees was higher from May 21st to May 28th and from May 28th to June 11th independently to the treatment (Table 1). In this period, ANOVA analysis showed high significant differences ($p < .001$) between the treatments and allowed distinguishing two groups of treatments: T0 and T1 constituted the first group representing a high water use. The second group composed by T2 and T3 had a low water use.

During June 11st to 25th and from June 25th to July 9th, daily water use recorded lower values than those of the first three weeks regardless to the treatments. Differences between treatments were highly significant ($p < .001$) and analysis distinguished 4 groups corresponding to the four treatments.

We highlight that during the experimentation, for the same treatment, daily water use remains almost stable. Then, for T0, daily water use varied from 6.21 to 7.24 mm j^{-1} with a mean value of 6.65 mm j^{-1}. In treatment T1, the recorded values changed from 4.79 to 5.23 mm j^{-1} with a mean value of 5.04 mm j^{-1}. In treatment T2, daily water use of the tree varied from 1.06 to 1.81 mm j^{-1} with a mean value of 1.32 mm j^{-1}. At last, in treatment T3, mean daily water use was 0.06 mm j^{-1} with minimum and maximum values of 0 and 0.16 mm j^{-1} respectively.

3.3 Stomatal Conductance

Fig. 2 shows variation of stomatal conductance according to the treatments at 70 days after water deficit application. It appears that water stress impacts negatively the stomatal conductance ($p < .001$) and the result of ANOVA analysis allows distinguishing two groups of treatments.

The first group gathers T0 and T1, the most watered treatments and that present the higher values of stomata conductance, 188.67 and 188.11 $mmol.m^{-2}.s^{-1}$ respectively. The second group, which stomatal conductance values are significantly lower, includes treatments T2 (severe water stress) and T3 (very severe water stress) that recorded 51.82 and 32.24 $mmol.m^{-2}.s^{-1}$ respectively. From T0 (watering with 9.4 L each week) to T3 (treatment without watering), stomatal conductance has fallen to about 82.9%.

3.4 Leaf Area Index

Fig. 3 shows that water stress significantly ($p < .001$) reduces leaf area index, 70 days after water deficit implementation.

In fact, results of ANOVA analysis highlighted 3 groups of treatments. The first group includes T0 and T1 which LAI values are higher, 1.86 and 1.74 respectively. The second groups correspond to T2 which LAI value is 1.09 and the last group represented by treatment T3 which has the lowest LAI value, 0.47. The decline of LAI values from T0 to T3 was estimated to 74.73%.

3.5 Effect of Water Deficit on the Number of Inflorescence Produced Per Tree

Water deficit didn't significantly affect the mean number of inflorescences produced per tree (Fig. 4). The mean number of inflorescences varied from 22.5 (T2) to 27.5 (T0). So, water deficit doesn't significantly affect the inflorescences production.

Table 1. Daily water use per tree (mm j^{-1}) according to the treatments

Treatments	Periods				Mean
	May 21-28	May 28- June11	June 11-25	June 25 – July 9	
T0	7.24^{a}	6.86^{a}	6.21^{a}	6.30^{a}	6.65^{a}
T1	5.23^{ab}	5.23^{a}	4.79^{b}	4.89^{b}	5.04^{b}
T2	1.14^{b}	1.81^{b}	1.06^{c}	1.25^{c}	1.32^{c}
T3	0.00^{b}	0.07^{b}	0.0^{d}	0.16^{d}	0.06^{d}

T0 (trees watering with 9.4 L each week) ; T1 (trees watering with 7 L of water each week) ; T2 (trees watering with 1.8 L of water each week) ; T3 (non watering trees). Different letters indicate for each date, the significant differences in daily water use per tree among the treatments according to Tukey's tests at 5% level of probability

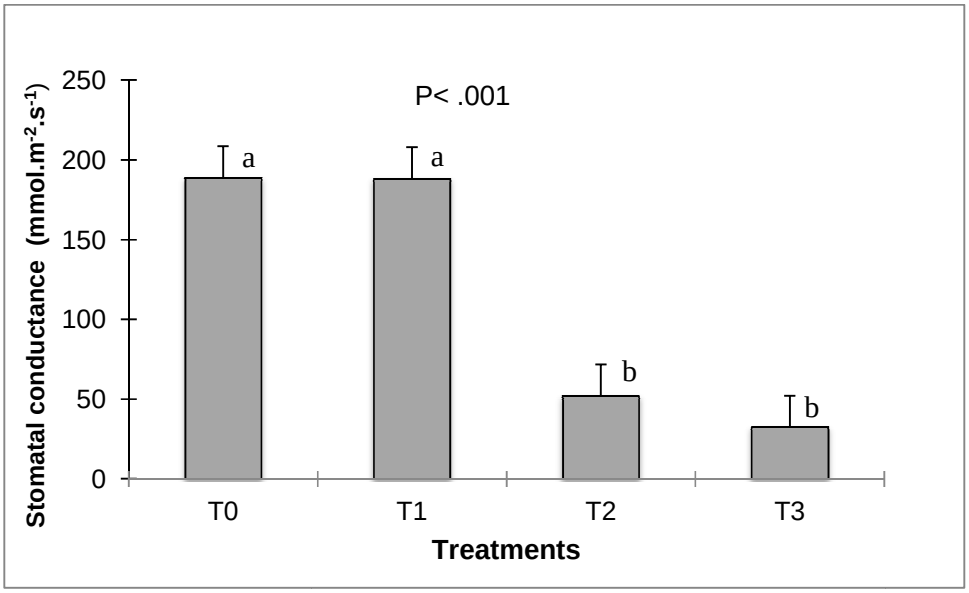

Fig. 2. Effect of water stress on the stomata conductance at 70 days after water stress implementation

T0 (trees watered with 9.4 L each week); T1 (trees watered with 7 L of water each week); T2 (trees watered with 1.8 L of water each week); T3 (non-watered trees). Bars with the same letter are not significantly different at P < 0.05 according to Tukey's test

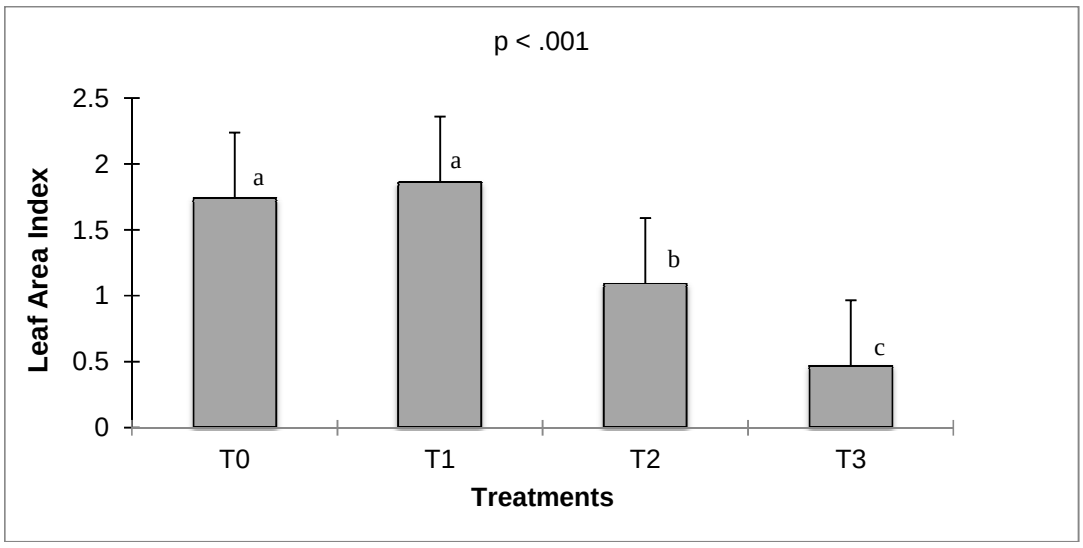

Fig. 3. Effect of water stress on leaf area index 70 days after stress implementation

T0 (trees watered with 9.4 L each week); T1 (trees watered with 7 L of water each week); T2 (trees watered with 1.8 L of water each week); T3 (non-watered trees). Bars with the same letter are not significantly different at P < 0.05 according to Tukey's test

3.6 Effect of Water Deficit on Inflorescence Size

Analysis of Fig. 5 illustrates that water stress had a very significant effect ($p < .001$) on the different variables (length, breadth, height) of the inflorescence.

ANOVA analysis allows gathering treatments into two groups independently to the variables:

- the first group, which has significantly large inflorescence, includes T0 (height = 4.9 cm; length = 5.7 cm and breadth = 3.6 cm), T1 (height = 4.9 cm; length = 5.6 cm and

breadth = 3.6 cm) and T2 (height = 4.8 cm; length = 5.6 cm and breadth = 3.5);

- the second group which has small inflorescence is represented by T3 (height = 3.7 cm; length = 4.2 cm and breadth = 2.7 cm).

3.7 Effect of Water Deficit on Female and Male Flowers Production

Table 2 shows that water deficit significantly affects the number of male flowers per inflorescence ($p < .001$) and the number of female flowers per inflorescence ($p < .001$). Analysis of the number of male flower showed two groups. The first group presents significant ($p<.001$) higher values. This group includes T0 (83.17 flowers), T1 (74.97 flowers) and T2 (89.34 flowers). The second group is represented by treatment T3 which recorded the lowest value (15.07 flowers).

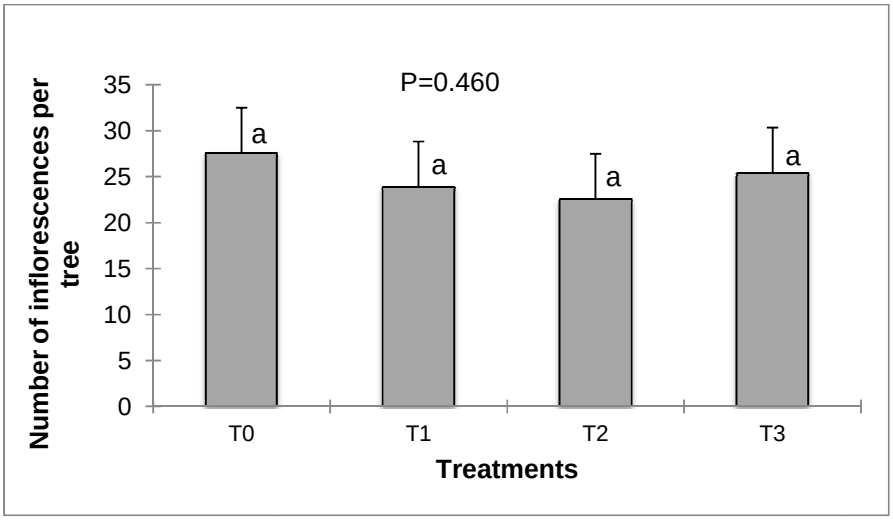

Fig. 4. Effect of water stress on the mean number of inflorescences per tree according to the treatment

T0 (trees watered with 9.4 L each week); T1 (trees watered with 7 L of water each week); T2 (trees watered with 1.8 L of water each week); T3 (non-watered trees). Bars with the same letter are not significantly different at P < 0.05 according to Tukey's test

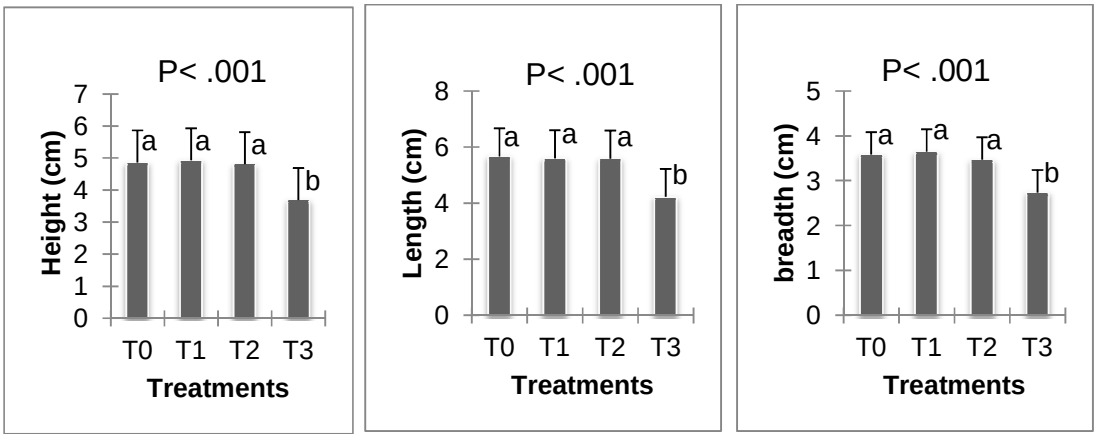

Fig. 5. Effect of water stress on inflorescence breadth, length and height 70 days after water deficit implementation

T0 (trees watered with 9.4 L each week); T1 (trees watered with 7 L of water each week); T2 (trees watered with 1.8 L of water each week); T3 (non-watered trees). Bars with the same letter are not significantly different at P < 0.05 according to Tukey's test

The number of female flowers per inflorescence presents the same trend with the number of male flowers in the different treatments. It is statistically lower in the treatments T3 (0.57 flowers) compared to the other treatments (T0, T1 and T2) that constitute a homogenous group with a number of female flower per inflorescence range from 3.37 to 4.1.

Table 2. Variations of the mean number of female flowers per inflorescence and the mean number of male flowers per inflorescence according to the treatments

Treatments	Number of male flowers	Number of female flowers
T0	83.17[a]	4.1[a]
T1	74.97[a]	3.47[a]
T2	89.34[a]	3.37[a]
T3	15.07[b]	0.57[b]

T0 (trees watered with 9.4 L each week); T1 (trees watered with 7 L of water each week); T2 (trees watered with 1.8 L of water each week); T3 (non-watered trees). Different letters within the same column indicate significant differences between factor levels according to the Tukey's post-hoc testing (p<.05)

3.8 Effect of Water Deficit on Yield Parameters

Results depicted in Table 3 reveal that the treatments have a significant effect on the yield parameters of *J. curcas*. It appears that water deficit reduces fruit production and consequently seed production.

The number of fruits produced per tree and the number of seeds produced per tree are significantly higher in treatment T0 (that received the higher quantity of water by watering) with values of 7.67 fruits/tree and 18.67 seeds/tree respectively. The treatment T1 (moderate water deficit) has produced 2.83 fruits/tree and 7.17 seeds/tree. However, treatment T2 (severe water deficit) and treatment T3 (very severe water deficit) didn't produce fruits.

100-seed weight treatment, T0 (56.25 g), is significantly higher than treatment T1 (46.70 g). This result suggests that water deficit affects fruits by reducing its weight.

4. DISCUSSION

This study aimed at determining the effect of water stress on the physiological behavior, the flowering and the fruiting of *J. curcas*. The experimentation was conducted in a randomized complete block design with 4 treatments replicated 6 times. The treatments corresponded to different water regimes. Eco-physiological variables and agro-morphological variables of the tree as well as environmental variables (soil humidity and micro-climatic variables) have been monitored.

The results show that, except the control (T0) where trees received optimal watering, the treatments T1 corresponds to a moderate water stress (75% of mean daily water use per tree compared to T0). The treatment T2 corresponds to a severe water deficit (20% of mean daily water use per tree compared to T0) and T3 corresponds to a very severe water deficit (≤ 1 % of mean daily water use per tree compared to T0).

The different treatments corresponding to the different levels of mean daily water use per tree have been maintained along the experimentation that demonstrates a good application of the treatments.

The experimentation also highlights that water stress has a significant negative effect on trees eco-physiological parameters. Consequently, treatments T2 (severe water deficit) and T3 (very severe water deficit) caused a decrease of

Table 3. Variation in fruit and seed yield parameters according to the treatments

Treatments	Number		Weight (g)		100 Seeds
	Fruits/Tree	Seeds/Tree	Fruits/Tree	Seeds/Tree	
T0	7.67[a]	18.67[a]	15.07[a]	9.96[a]	56.25[a]
T1	2.83[ab]	7.17[ab]	5.21[b]	3.36[b]	46.70[b]
T2	0.00[b]	0.00[b]	0.00[b]	0.00[b]	-
T3	0.00[b]	0.00[b]	0.00[b]	0.00[b]	-
P	< .002	< .004	< .002	< .002	< .0001

T0 (trees watered with 9.4 L each week); T1 (trees watered with 7 L of water each week); T2 (trees watered with 1.8 L of water each week); T3 (non-watered trees). Different letters within the same column indicate significant differences between factor levels according to the Tukey's post-hoc testing (p<.05)

72.5% and 82.9% in stomatal conductance of trees respectively. In return, moderate water deficit (T1) didn't affect significantly the stomatal conductance. This result conforms to those of Diaz-Lopes et al. [1] who highlighted a decrease in stomatal conductance of *J. curcas* seedling in water stress conditions. The result is also consistent with those of Moura et al. [11] who have compared water relations of different accessions of *J. curcas* on two sites, one in the semi-arid condition and the other in humid condition. The authors [11] recorded low value of stomatal conductance in the semi-arid site compared to the values recorded in humid site. This result could be explained by the fact that in water stress condition, plant reversibly adjusts the flow of water through the stomata closure. Stomata closure results in a decrease of turgor guard cells of the stomatal chamber. Decrease of turgor guard cells is initiated chemically by a phytohormone, abscisic acid (ABA) synthesized by the roots subjected to water stress and conveyed to the leaves by xylem sap. The closure of stomata allows plant to reduce water loss and to keep a favorable water status.

Water deficit also significantly reduced trees leaf area index (LAI). The decrease in LAI from the control (T0) to the treatment T3 (very harsh water stress) was about 74.7%. This result is similar to those of several authors [5,18,1,10,19] that have also showed a decrease of the LAI of *J. curcas* under water deficit. The decrease of LAI results from the decrease in leaf size and leaf number caused by early senescence of leaves in limiting water supply condition. Overall, when subjected to water deficit, plant senescence increases.

In addition, the results showed that water deficit didn't affect the inflorescence production. The number of inflorescence produced by *J. curcas* trees subjected to water deficit isn't significantly different to the ones produced by the trees in the control (T0). In return, water stress has negatively affected the development of inflorescences and the production of female and male flowers. In the treatments subjected to water stress, trees produced small inflorescences on which it was difficult to distinguish female and male flowers by naked eye. These observations are consistent with the results of Aspinall and Husain [20] who highlighted in *Lolium temulentum* L. an inhibitor effect of water deficit on flowering. However, this behavior noted in *J. curcas* is different to the one recorded with many woody fruit species those flowering are stimulated by water deficit [21].

The results showed that water deficit induces a decrease of fruits production and consequently seed production. Seed production decreases to 65% when daily water use decreases to 25% of daily water use of the control. When daily water use decreases to 80% of the control, fruit production becomes null. On one hand, the decrease of yield parameters of *J. curcas* subjected to water deficit could be explained by the decrease of photosynthesis due to the decrease of stomatal conductance and LAI [22, 23]. It results in a decrease in CO_2 flow through stomata and a decrease of the quantity of radiation intercepted by plants and converted to chemical used in Calvin cycle. The bad quality of inflorescences promotes abortions during fecundations. This combined with low production of female flowers also limit fruit production and consequently seed production. These results are consistent to those of Diouf et al [24] who highlighted in maize that water deficit negatively affects flowering and reduces very significantly seeds yield and seed yield parameters. Likewise, Chebouti et al. [25] showed, in three species of alfalfa, that seed yield was greater in non-watered deficit treatment compared to the treatment subjected to water stress.

5. CONCLUSION

This study is a contribution to a better understanding of physiological mechanisms that allow adaptation of *J. curcas* to drought and their effects on flowering and fruiting. It allows confirming that *J. curcas* fit to water deficit using an avoidance strategy. This consists to reduce, when subjected to water deficit, stomatal conductance and total evapotranspiration area by the abscission and the reduction of leaf expansion. Likewise, the study highlighted that water deficit negatively affects the flowering by a reduction of inflorescence size and a decrease in flowers productions. This experimentation revealed that when water uptake of *J. curcas* declines to 20% of maximal evapotranspiration, the negative effects of water deficit on physiological parameters induce a significant decrease in fruits and seed production. Based on these results and considering the limits of this experimentation, we recommend a long-term experimentation including dry and rainy seasons that could allow discriminating the effect of soil water availability to those of climatic factors (relative humidity, photoperiod, temperature, saturated water vapor pressure) on the flowering and the fruiting of *J. curcas*.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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