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Physiological and Agronomic Response of Sesame [*Sesamum indicum* (L.)] to Temporary Water Deficit

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

Aims: In Burkina Faso, sesame has many economic, agronomic and food potential. However, insufficient rainfall and aridity of the soil negatively affect its yield. With this in mind that the present study was conducted to determine the influence of temporary water deficit on the productivity of two varieties of sesamum introduced in Burkina Faso.

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Study Design: The trial was conducted in a greenhouse in pots on a sandy-silty substrate.
Place and Duration of Study: It was set up from April 8th to July 20th, 2023 in the garden of the Life and Earth Sciences Training and Research Unit (UFR/SVT) of the Joseph KI-Zerbo University, Burkina Faso.
Methodology: A split plot with two factors and three replicates was used as an experimental set-up. The variety factor was at two levels (SN103 and HB168) and the water regime factor at three levels (control T0: watering every two days at the soil field capacity; T1: 10-day suspension of watering at the vegetative stage; T2: 10-day watering suspension at the flowering stage).
Results: The results of the study showed that the combination T1*HB168 leads to the lowest plant heights with 151.37±5.56 cm compared to the T1*SN103 (154.97±6.75 cm), T2*SN103 (165.34±3.35 cm) and T2*HB168 (165.14±3.70 cm) treatments. The mean number of capsules per plant was similar under the T1*SN103 and T2*SN103 combinations (161±1 and 155±3 capsules/foot, respectively) and lower compared to the T0*SN103 combination (168±3capsules/foot). In HB168, the same trend was observed because the number of capsules was reduced under T1 and T2 (193±4 and 190±6 capsules/stem, respectively) compared to those under T0 (207±6 capsules/stem). On the other hand, the water deficit had a negative and significant effect on the HB168 variety in which the T0*HB168, T1*HB168 and T2*HB168 treatments led to seed yields per plant (respectively (51.76±4.15 g/plant; 40.72±0.55 g/plant and 37.83±2.39 g/plant).
Conclusion: As a result, the SN103 variety is more tolerant to water deficit and is recommended in areas prone to temporary water deficits.

Keywords: Sesamum; variety; water deficits; temporary; yield.

Abbreviations

ANOVA : Analyze of Variance
APEX : Professional Association of Exporters
DGC : Directorate General of Cooperation
DGPV : Directorate General for Plant Production

1. Introduction

Sesame (*Sesamum indicum* L.) is the oldest annual oilseed cultivated in the world and widely grown in many tropical countries in Asia and sub-Saharan Africa (Siri *et al*., 2024) ; it is one of the most important cultivated oilseed plants for humans because of its tolerance to drought and unfavorable climatic conditions (Tassiou and Seyni, 2025). Global sesame production reached 6.64 million tons in 2020 (APEX, 2022). Cultivated in Burkina Faso since the 20th century (Siri *et al*., 2024), sesame has multiple agronomic and economic potentialities. It is one of the country's main cash crops (Zida, 2018). Sesame seeds, rich in oil and protein, are known for their nutritional properties, hence their use in the preparation of sauces, cakes and rolls (Ouedraogo, 2023). Oilcakes are also used in animal feed, especially poultry feed, as they ensure the resistance of chicks to diseases (Ouedraogo, 2023). With a view to diversifying export products, the Government of Burkina Faso has embarked on the promotion of promising agricultural sectors, including sesame. This has led to an increase in sesame areas from 400,255 ha in 2015 to 617,749 ha in 2019, with productions ranging from 237,094 tons to 374,703 tons, respectively (DGPV, 2021). Traditionally grown throughout Burkina Faso, sesame has become a major export product, accounting for 1.9% of global sesame exports in 2020, placing Burkina Faso in 12th place in the world (APEX, 2022). In 2021, the country exported about 61,201 tons of sesame seeds (DGC, 2022). This interest in sesame production is partly explained by its low input requirements.

However, despite its economic importance, sesame production in Burkina Faso faces major challenges, including climate change (Toure *et al*., 2015). Indeed, agriculture in Burkina Faso is highly dependent on climatic variations and is characterized by low productivity, due in particular to the deterioration of weather conditions and the reduction of soil fertility (INSD, 2023). According to the Regional Chamber of Agriculture (2017), drought poses a significant danger to sesame production. As a result, the search for varieties that maintain their productivity in the face of pockets of drought becomes a necessity. In this context that the present study was carried out with the objective to evaluate the agronomic performance of two sesame varieties in conditions of temporary water deficit. Specifically, the aim is to:

i) evaluate the effect of temporary water deficit on the growth of these varieties;
ii) determine the seed yield of these varieties under temporary water deficit condition.

2. Material and Methods

2.1 Selection of the Site

The trial was conducted in the garden of the Life and Earth Sciences Training and Research Unit (UFR/SVT) of the Joseph KI-Zerbo University, Burkina Faso. The experimental site is located at an altitude of 319 m, at 12° 22' 49'' north latitude and at 01°29' 58'' west longitude.

2.2 Plant Material

Seeds of two new sesame varieties (SN103 and HB168) of Nigerien and Senegalese origin constituted the plant material (Table 1). These varieties were selected for the study because of their interesting agronomic characteristics such as high productivity, short cycle time and seed color.

2.3 Experimental Design

The experimental setup used was a split plot with three (03) repetitions. Two factors were studied, namely: the variety with two (02) modalities (SN103 and HB168). The water regime has three (03) modalities which are: The control treatment (T0) consisting of watering at the capacity in the field every two days; the treatment (T1) which consists of a suspension of watering for 10 days at the vegetative stage and the treatment (T2) which consists of a suspension of watering for 10 days at the flowering stage.

Conduct of the test: The trial was set up on April 8, 2023. 15-litre plastic pots were used for this experiment. The bottoms of the pots have been made with holes to allow water to drain. Each pot was then filled with 15 kilograms of sandy-silty substrate and characterized.

To calculate these irrigation levels in relation to the field capacity of the soil per pot, we weighed pots containing 5 kg of dry substrate used in the experiment, P1 (P1 = weight of dry soil). Then we irrigated the pots until they were saturated, while covering the pots with black plastic to prevent the water from evaporating from the surface. After 24 hours of rest, the pots were weighed again at P2 (P2 = weight at saturation). The difference between P2 and P1 is the amount of water retained by the soil, which represents the capacity of the pots in the soil field. The field capacity (CAC) is estimated by the following equation: CAC = [(P2 - P1) / P1] x 100.

Sowing was done manually at a rate of 5 sesame seeds per pot to ensure that there were enough seedlings to then select the most vigorous individuals. Fifteen (15) days after sowing, a first demarriage was carried out at three (03) plants per pot: the most vigorous plants were then retained. A second demarriage was carried out at one (01) sesame foot per pot on the 19th DAS. Weeding work was carried out according to the requirements.

Table 1. Seed characteristics

Varieties	SN103	HB168
Origin	Niger	Senegal
Seed color	White	Creamy-white
Leaf color	Green	Dark green
Flower color	White + slight purplish tint	
Hairiness (stem, leaf and capsule)	Very hairy	
Emergence Time (DAS)	3	
Days to flowering (DAS)	36	36
Days to 50% flowering (DAS)	41	38
Cycle period (DAS)	90	

NB: DAS: Days After Sowing (Source: Seyni and Mahaman, 2020)

Table 2. Physical and chemical characteristics of the crop soil

Physical characteristics			**Chemical characteristics**										
Clay (%)	**Silt (%)**	**Sand (%)**	**pH KCl**	**pH Water**	**C %**	**MO %**	**N %**	**C/N**	**P ppm**	**K ppm**	**Fe ppm**	**Ca ppm**	**Mg ppm**
17.65	41.17	41.18	6.20	7.40	0.54	0.92	0.05	11.89	8.31	144.69	7.81	1.55	0.62

T1 treatment began on the 25th DAS until the 35th DAS. The T2 treatment took place between the 36th day and the 46th day of the day. For water stress in the reproductive phase, it was applied when more than 50% of the plants bore an open flower, so during flowering. Prior to the application of water stress, all plants were subjected to the same regimen, i.e. watering every two days at the field capacity of the soil which was 3.7 liters/15 kilograms of substrate. During the period of application of the water deficit, the plot was covered with a waterproof tarpaulin in case of possible rain.

The following Table 2 presents the physico-chemical characteristics of the experimental soil.

2.4 Measured Parameters

The agronomic performance of the two sesame varieties subjected to water deficit was evaluated based on phenological, morphological, physiological, and plant yield parameters. Phenological observations were made during flowering start time and cycle length. For morphology, measurements were made on the diameter at the collar (DC) using an electronic caliper, the height of the plants (HP) with a graduated ruler, the number of branches (NB) per plant by manual counting, and the dry weights of the aerial part (DWA) and roots (DWR) using an electronic balance with a precision of 0.001 g (Denver AC- 1200D). The physiological parameters estimated were leaf chlorophyll content and the harvest index per plant (HI). This last parameter was calculated according to the following formula: the ratio of total dry seed weight from a plant to the total dry weight of the plant. For the yield parameters, the number of capsules per plant (NCP) and number of seeds per capsule (NSC) were determined by manual counting. The 1000 seed weight (WTS) was determined using the same scale mentioned above. Seed yield per plant (SYP) was calculated according to the formula of Garfius : W = XYZ (X: number of capsules per plant; Y: average number of seeds per capsule; Z: average seed weight).

2.5 Statistical Data Analysis

The data collected was entered using the Excel 2016 spreadsheet that was also used to generate the graphs. The analysis of variance (ANOVA) was performed using the XLSTAT 2016 software. To assess the performance and differences between the varieties through the different treatments. The comparison of the means was carried out according to the SNK test at the probability level of 5%.

3. Results and Discussion

3.1 Results

3.1.1 Phenological Parameters

Table 3 presents the results of the statistical analysis of the means for the phenological parameters. For the beginning of flowering, no significant difference was observed between the means according to the variety (p=0.435). On the other hand, with regard to the combination of the factors of variety and water regime, the statistical analysis revealed a significant difference between the means for this same parameter (p=0.024). For both varieties, plants under T1 took longer to flower than those under T2.

Table 3. Phenology of plants following water treatment

		Settings	
		Days to flowering (DAS)	**Cycle Time (DAS)**
Varieties	SN103	37±0[a]	103±1[a]
	HB168	36±0[a]	101±2[a]
Probability		*0.435*	*0.311*
Variety * Water regime	T0*SN103	36±0[b]	101±5[a]
	T1*SN103	38±0[a]	105±5[a]
	T2*SN103	35±1[b]	103±2[a]
	T0*HB168	36±1[b]	95±2[a]
	T1*HB168	37±1[ab]	104±7[a]
	T2*HB168	36±0[b]	104±4[a]
Probability		*0.024*	*0.347*

Legend: T0: watering at the field capacity (control); T1= 10-day water suspension in the vegetative stage; T2: 10-day water suspension at the flowering stage; DAS: Days After Sowing.
NB: for each factor, the averages of the same column followed by the same letters are not significantly different at the 5% threshold

Table 4. Growth Parameters by Variety

		Settings		
		Plant Height (cm)	**Diameter at collar (mm)**	**Number of branches**
Varieties	SN103	163.84±2.60[a]	20.67±0.67[a]	6±0[a]
	HB168	162.41±2.98[a]	19.94±0.40[a]	6±0[a]
	Probability	*0.635*	*0.256*	*0.374*

NB: the averages of the same column followed by the same letters are not significantly different at the 5% threshold

As for cycle length, the analysis revealed no significant difference between the means, regardless of the factor considered, variety (*p*=0.311) or variety*water regime (*p*=0.347).

3.1.2 Growth Parameters

3.1.2.1 Height, Diameter at the Collar and Number of Branches Depending on the Variety

Analysis of variance by variety revealed no significant difference between the means of plant height (*p*=0.635), crown diameter (*p*=0.256) and number of plant branches (*p*=0.374); Table 4.

3.1.2.2 Height, Diameter at the Crown and Number of Branches of the Plants according to the Variety*Water Regime Association

Fig. 1 shows the growth parameters of sesame according to the variety/water regime association.

Regarding the diameter at the neck, the variety*water regime combination did not reveal a significant difference between the means (*p*=0.667; Fig. 1A).

For the number of branches, a highly significant difference was noted between the means (*p*=0.006; Fig. 1B). The combination of T1*SN103 and T2*SN103 recorded similar values and the T2*HB168 interaction reduced the number of branches more compared to the T0*HB168 control.

As for height, a highly significant difference was observed between plants (*p*=0.002; Fig. 1C). Indeed, the combinations T1*SN103, T2*SN103 and T2*HB168 and especially T1*HB168 led to a reduction in height compared to the controls.

3.1.2.3 Chlorophyll Content and Drought Tolerance Index by Variety

The results of the statistical analysis of the physiological parameters according to the varieties are presented in Table 5. There was no significant difference between the means of chlorophyll content of the 39th DAS (p = 0.630) and the 53rd DAS (p = 0.092). For the drought tolerance index, there was also no significant difference between the means (p = 0.184).

3.1.2.4 Chlorophyll Content and Drought Tolerance Index Following the Interaction Variety*Water Regime

Depending on the combination of variety and water regime, statistical analysis did not reveal a significant difference between the means of the drought tolerance index (*p*=0.440; Fig. 2A). Similarly, for the chlorophyll content of the 39th DAS (*p*=0.123; Fig. 2B) and the 53rd DAS (*p*=0.151; Fig. 2C), no significant differences were revealed.

3.1.3 Agronomic Parameters

The results of the statistical analysis of the agronomic parameters according to the variety are presented in Table 6. Statistical analysis showed a highly significant difference between the means for the number of capsules per plant (p<0.001) with a higher number in the HB168 variety. Similarly, a highly significant difference (p = 0.001) was found between varieties in the number of seeds per capsule with more seeds in SN103. For 1000 seed weight (p = 0.057), seed yield (p = 0.359), air dry weight (p = 0.19) and root dry weight (p = 0.95) no differences were found.

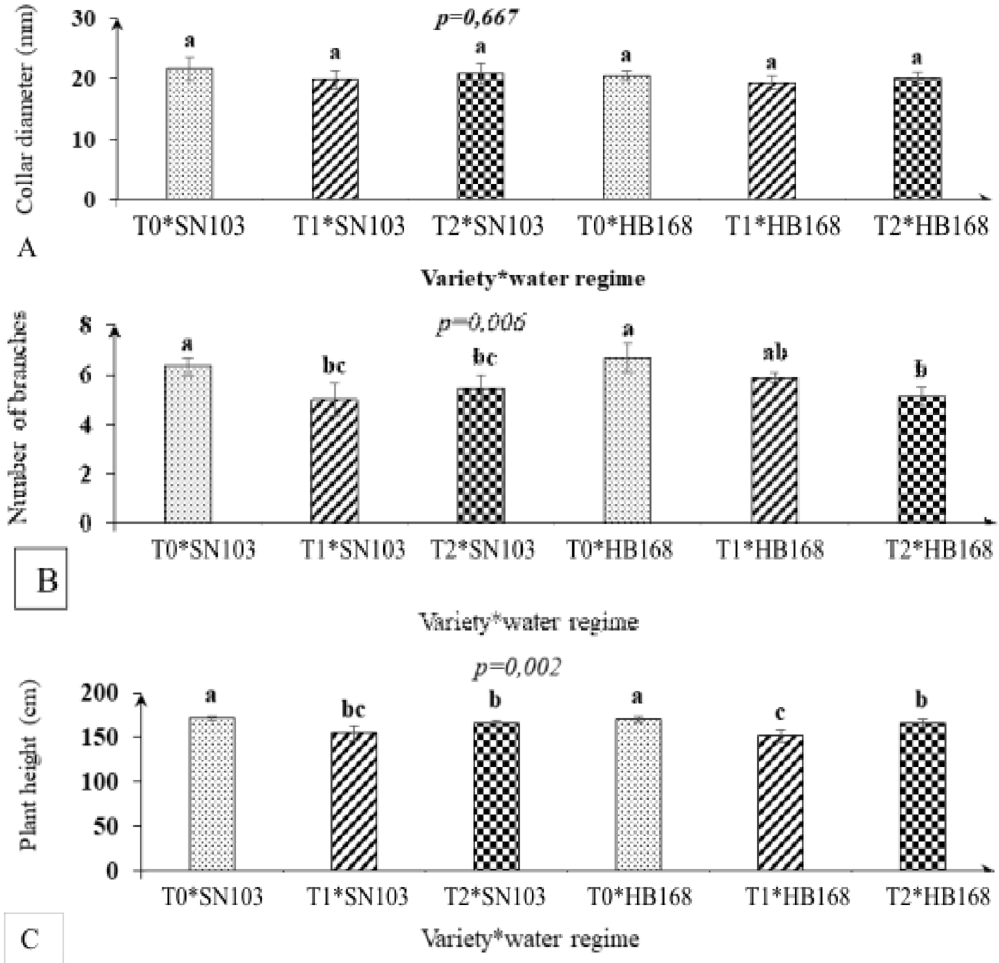

Fig. 1. Growth parameters according to the variety*Water regime interaction

Legend: A. Diameter at the collar; B. Number of branches; C. Height of the plants; T0: watering every two days to the capacity of the soil in the field; T1: 10-day suspension of watering at the vegetative stage; T2: 10-day watering suspension at the flowering stage)

Table 5. Drought tolerance index and leaf chlorophyll content

		Settings		
		Drought Tolerance Index	**Chlorophyll content 39 DAS (SPAD unit)**	**Chlorophyll content 53 DAS (SPAD unit)**
Varieties	SN103	0.88[a]	37.50[a]	46.04[a]
	HB168	0.77[a]	37.29[a]	48.12[a]
Probability		*0.184*	*0.630*	*0.092*

NB: the averages of the same column followed by the same letters are not significant at the 5% threshold. DAS: Days After Sowing

Table 6. Agronomic parameters according to variety

		Settings					
		NCP	**NSC**	**TSW(g)**	**SYPP(g)**	**DWS(g)**	**DWR(g)**
Varieties	SN103	16[b]	81[a]	3.12[a]	41.43[a]	12.96[a]	2.19[a]
	HB168	19[a]	64[b]	3.42[a]	43.44[a]	14.76[a]	2.17[a]
Probability		<0.001	0.001	0.057	0.359	0.19	0.95

Legend: NCP: number of capsules per plant; NSC: number of seeds per capsule; SYPP: seed yield per plant; TSW: Thousand seed weight; DWS: dry weight of the stems; DWR: dry weight of the roots; Significance code: p<0.001 is highly significant and p>0.05 is non-significant

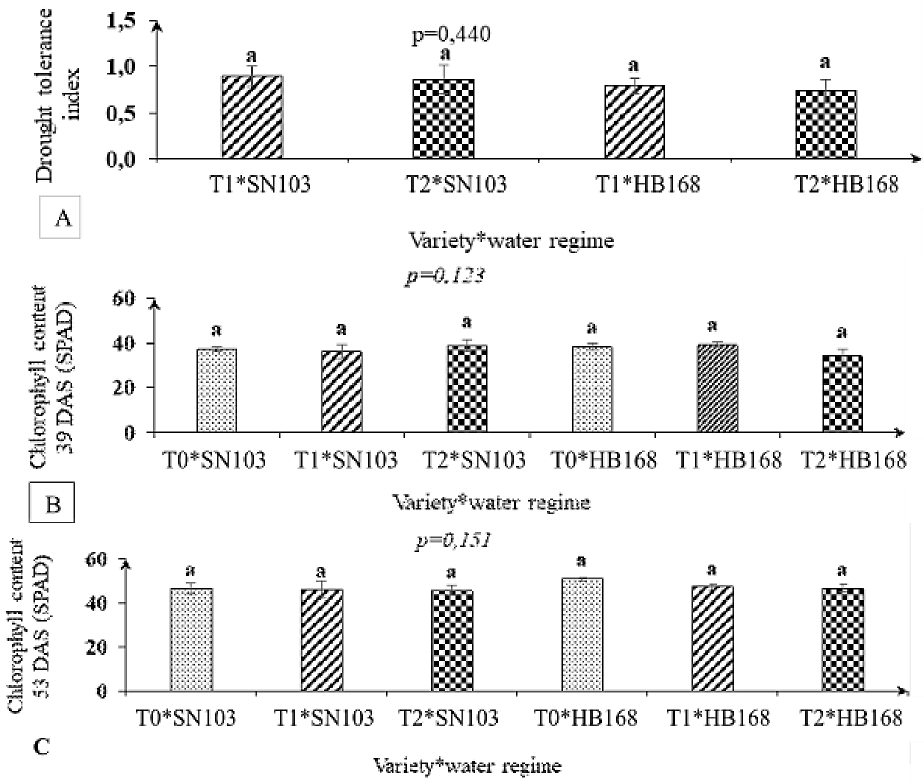

Fig. 2. Physiological parameters according to the combination of the two factors

Legend: A. Drought tolerance index; B. Chlorophyll content at the 39th DAS; C. Chlorophyll content at the 53rd DAS; T0: watering every two days to the capacity of the soil in the field; T1: 10-day suspension of watering at the vegetative stage; T2: 10-day watering suspension at the flowering stage), DAS: Days After Sowing

The results of the statistical analysis of the agronomic parameters following the variety*water regime interaction are presented in Table 7.

A highly significant difference was found between the means for the number of capsules per plant ($p<0.001$). The T2*SN103 and T2*HB168 interactions resulted in the greatest reductions in capsule number compared to the T0*SN103 and T0*HB168 interactions. Similarly, a highly significant difference ($p = 0.001$) was revealed between varieties in the number of seeds per capsule with greater reductions under the T2*SN103 and T2*HB168 interactions. For the weight of 1000 seeds ($p = 0.009$), the seed yield ($p = 0.024$), the analysis revealed significant differences between the means of the values obtained. Indeed, the T0*HB168 interaction resulted in the best seed weight and seed yield as opposed to the other interactions. For air dry weight ($p = 0.081$) and root dry weight ($p = 0.642$), no difference was found between the different treatments.

Table 7. Agronomic parameters according to the interaction Variety*Water regime

		Settings					
		NCP	**NSC**	**TSW(g)**	**SYPP(g)**	**DWS(g)**	**DWR(g)**
Variety*Water regime	T0*SN103	168^{c}	84^{a}	3.20^{b}	45.07^{ab}	14.04^{a}	1.92^{a}
	T1*SN103	161^{d}	82^{a}	3.03^{b}	40.17^{b}	11.03^{a}	2.23^{a}
	T2*SN103	155^{d}	78^{ab}	3.13^{b}	39.04^{b}	13.79^{a}	2.42^{a}
	T0*HB168	207^{a}	66^{b}	3.80^{a}	51.76^{a}	15.83^{a}	1.90^{a}
	T1*HB168	193^{b}	65^{b}	3.27^{b}	40.72^{b}	13.52^{a}	2.34^{a}
	T2*HB168	190^{b}	62^{b}	3.20^{b}	37.83^{b}	14.92^{b}	2.27^{a}
Probability		**<0.001**	**<0.001**	**0.009**	**0.024**	0.081	0.642

Legend: NCP: number of capsules per plant; NSC: number of seeds per capsule; SYPP: seed yield per plant; TSW: Thousand seed weight; DWS: dry weight of the stems; DWR: dry weight of the roots; Significance code: p<0.001 is highly significant and p>0.05 is non-significant

3.2 Discussion

During the test, the average daily temperatures ranged from 25.6 °C to 36°C and the average daily relative humidity ranged from 19% to 85%. These climatic factors would have favored the development of the sesame plant. Sanogo (2019) reported that temperatures above 25°C are favorable to the development of sesame.

The results of the ANOVA on the phenological parameters of the sesame plants studied showed a significant difference between the averages following the Variety*Water regime association. The T1*SN103 interaction lengthened the flowering start date, showing that water stress can modify the phenology of the SN103 variety.

Plants of both varieties subjected to water treatments at the vegetative stage (T1) and flowering stage (T2) showed a reduction in growth in terms of height. Indeed, growth is the first indicator of the nutritional status of plants (Nguinambaye *et al.,* 2020). The study showed that for the SN103 variety, the reduction in height was similar under T1 and T2. Indeed, Sesame is a plant that can tolerate water stress levels of up to 50% of field capacity (FC). But on the other hand, exposure to a water deficit of 20% FC can be translated into a decrease in plant length (Elhanafi *et al*, 2019). However, in the case of HB168, the reduction in plant height growth was greater under T1 compared to T2. Badiel *et al.* (2023), also observed that the water deficit causes a greater reduction in the height of sesame plants. Thus, the growth in length of plants of HB168 was more affected by the 10-day water deficit at the vegetative stage compared to SN103. The number of primary branches was also reduced in SN103 and HB168 when the plants were subjected to T1 and T2 water treatments. Lack of water disrupts development with the consequent reduction of tall growth and the number of primary branches. Thus, regardless of the stage of plant development (vegetative or reproductive), a 10-day watering suspension reduces the production of primary branching.

Physiological parameters were not affected by water suspension. This means that the ten-day water suspension (vegetative and reproductive stage) would not have been large enough to cause changes in chlorophyll content and drought tolerance index. Toudou *et al.* (2017), also reported that water stress induction did not significantly affect the chlorophyll content of cowpea plants stressed in the vegetative phase.

Regarding the yield components, the statistical analysis showed that the two varieties differ significantly in the number of capsules per plant and the number of seeds per capsule. Indeed, HB168 is more productive in terms of the number of capsules per plant. In addition, in terms of the number of seeds per capsule, SN103 was the most productive. This variety would therefore be tolerant to water stress. According to Baghery *et al.* (2023), a developed root system and an efficient photosynthetic apparatus, as well as a rapid and effective accumulation of protective compounds, allowed the sesame to tolerate water stress. Suspension of irrigation applied at the vegetative or reproductive stage reduced the number of capsules produced by SN103 and HB168.In cowpea, Elhanafi *et al*, (2019) showed that water deficit of 20% FC at sesame, has decrease the number of capsules per plant, the number of seeds per capsule, the length of the capsules and also the seed yield. Aziadekey *et al*. (2014), also found that 16 days of water stress at cowpea had greatly reduced all the agronomic and morphological traits, with a greater impact for the number of pods and total seed weight per plant. In stressed plants at the vegetative stage, the decrease in the number of capsules per okra plant is thought to be explained by the decrease in plant size and the number of primary branching (Nana, 2014). For the same author, this would result in a reduction in the number of organs bearing the flowers. In plants that are stressed at the reproductive stage, this reduction may be due to flower drop or wilt (Nana, 2014).

The variety/water regime combination shows that the number of seeds per capsule of varieties SN103 and HB168 was not affected regardless of the stage of intervention of the water deficit. For this parameter, the water deficit had no effect on the two varieties. According to Grieu *et al.* (2020), in sunflower, maintaining high photosynthetic activity is a major process for achieving high yield. Maintaining photosynthetic activity and therefore the quantity of organic substances produced would have made it possible to maintain the number of seeds per capsule produced.

As for the weight of a thousand seeds, the variety*water regime combination shows that the SN103 variety was not influenced regardless of the stage of watering suspension (vegetative or reproductive). On the other hand, for the same parameter, the water deficit applied to both stages of development had a negative influence on the HB168 variety. According to Kahali *et al.* (2016), in wheat, grain yield is the result of assimilates produced during the life of the plant. At anthesis, the leaf biomass produced must be sufficient to ensure the filling of the grain. This would explain the depressive effect of the water deficit applied in the vegetative stage on the mass of a thousand seeds of HB168. The weight of a thousand seeds was also reduced in plants under T2 (reproductive) for HB168. Tassiou and Seyni (2025) showed that HB168 is the genotype with larger kernels (4 g per thousand kernels) while UMS1804 is the one with smaller kernels (3.2 g). According to Aziadekey *et al.* (2014), a severe water stress has a negative impact on seed formation, more specifically photosynthesis and assimilate translocation The combination of variety and water regime shows that variety SN103 was not affected by water deficits for the seed yield per plant parameter. In contrast, the combination showed similar negative effects in HB168 under water deficit at the vegetative and reproductive stages. For Mahdavi Khorami *et al.* (2020), water deficit has a depressive effect on crop yield and its components; According to these authors, severe water stress (applied during the flowering phase) resulted in a decrease in chlorophyll content and grain yield. Therefore, a reduction in yield components such as the number of capsules per plant and the weight of a thousand seeds would reduce the seed yield per plant of HB168.

4. Conclusion

In this study to identify the most productive sesame variety under temporary water deficit conditions, varieties SN103 and HB168 were evaluated for their growth, physiology and seed yield. It appears that the effect of the temporary water deficit on the varieties varies according to the parameters studied. Regarding the beginning of flowering, the Niger variety (SN103) was affected by the 10-day suspension of water in the vegetative stage. As for the number of capsules per plant, both varieties (SN103 and HB168) were found to be sensitive to the ten-day water suspension in the vegetative stage in the same way as that in the reproductive stage. However, for both varieties, the water deficit had no effect on the number of seeds per capsule. In terms of the weight of one thousand seeds and the seed yield per plant, it appears that the ten-day water suspension at any stage of development had no impact on SN103. On the other hand, for the same parameters, the Senegalese variety (HB168) was sensitive to the ten-day water suspension at the vegetative and reproductive stage with similar effects.

5. Future Prospect

Since the main objective of sesame production is seed yield, SN103 could be used in agriculture in areas where water resources are limited. The grower may suspend watering the plants during the vegetative or reproductive phase. This would not only allow for more efficient water management, but also for a satisfactory yield to be achieved despite the induction of water deficit.

Disclaimer (Artificial Intelligence)

All authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Competing Interests

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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