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Full Length Research Paper

Temporary water stress effect on vegetative and flowering stages of sesame (*Sesamun Indicum* L.) plants

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Abstract

The aim of this study was to evaluate the impact of water deficit during the vegetative stage and to flowering on the morpho-physiological and agronomic responses of four varieties and six sesame descendants (*Sesamum indicum* L.). The plants were grown in a greenhouse under three water treatments: a continuous water supply (S0), a water supply with a 14-day suspension at the vegetative stage (S1) and a water supply with a 14-day interruption at flowering (S2). Plant height, relative water content, total chlorophyll content, leaf content of mineral elements (Na, K and Mg), number of capsules, number of seeds per capsule, thousand seeds weight and Total dry biomass were determined. Water stress caused total height and total dry biomass reduction in all plant varieties and stressed descendants at the vegetative stage and bloom. In addition, all varieties and descendants expressed their response to water deficit by a reduction in foliar content in water and an increase in the total chlorophyll content of the mineral matter, in particular Na, K and Mg. Water stress caused total height and total dry biomass reduction in all plant varieties and stressed lines at the vegetative stage and bloom. Under the effect of water stress, both at the vegetative and flowering stages, the S-42 variety and the descendants produced well filled capsules. As for variety 32-15, the filling of its capsules was not complete but the weight of its thousand seeds was higher. This shows that varieties and lines have shown different responses to water deficit in terms of yields in capsules and seeds. Thus, variety S-42 and all descendants were more tolerant of water shortage compared to varieties 32-15, Humera and Wollega.

Keywords: Sesame, Varieties, Descendants, Tolerance, Water stress.

Introduction

Sesame (*Sesamum indicum* L.), one of the oldest cultivated plants in the world, is a unique form of fertilizer whose seed contains high oil contents (45 to 57%), about 19 to 25% Proteins, Vitamins B, E, etc. and mineral salts (Ca, P, Mg, etc.) (Whfoods, 2011). Burkina Faso's second most important export commodity after cotton, sesame production in Burkina Faso has not increased steadily over the past decade (2006-2016); It evolved into saw tooth. From 22 887 tons in 2006, domestic production jumped considerably to reach 100 488 tons in 2013. It then declined significantly in 2014 and 2015, with 21 773 tons and 15 055 tons, respectively. In 2016, its production again made a spectacular link to reach 235079 tons, an increase of 1561% in one year (DGPER, 2016). This growing interest in the cultivation of sesame by farmers is explained by the favourable trends in world markets and also by the fact that sesame remains one of the crops accessible by the poorest, especially women. However, sesame production is unevenly distributed throughout Burkina Faso, with some regions producing more than others (DGPER, 2013). Also, the yield of sesame per hectare remains low, about 1000 kg/ha in the plant and 450 kg / ha in the peasant environment (Rongead, 2013). This decline in production is linked to a number of constraints, including lack of rainfall, poor spatial and temporal distribution and lack of innovation in cultural techniques (Kaboré, 2007). Thus, a water deficit in sesame plants has been reported to significantly reduce yield (Compaore, 2011, Hassanzadeh et al., 2009, Tantawy et al., 2007). Therefore, it is important to accurately determine the actual quantitative water requirements of the sesame and development phases, where it is more prone to water deficit in order to obtain maxima. It is in this context that this study examines the influence of temporary water deficit on the development and productivity of 4 varieties and 6 sesame descendants grown under semi-controlled conditions (under glass).

Material and methods

Plant material

The plant material used consists of four varieties and six descendants of sesame obtained in 2011 by selection by mutagen of the S-42 variety at the National Institute of the Environment and Agricultural Research (INERA) of Kambouinsé (Burkina Faso). This is the Jaalgon 128 variety of Indian origin introduced in Burkina Faso under the code S42; Variety 32-15 from the cross of S4 (Argentina) with S30 (Brazil) and vulgarized in Burkina Faso; Two varieties of Ethiopian origin (Humera and Wollega) introduced in Burkina Faso through the Agricultural Development Program (PDA) (ILy, 2011) and SMK-1, SMK-2, SMK-3, SMK -4, SMK-5 and SMK-6. The characteristics of the different varieties and descendants are presented in Table 1.

Table 1: Characteristics of the 4 varieties and 6 sesame descendants

	Varieties				Descandants					
Caracteristics	S-42	32-15	Wollega	Humera	SMK-1	SMK-2	SMK-3	SMK-4	SMK-5	SMK-6
CS	White									
CF	WLDP		WSV	White	White + light dyet purplish					
HLSC	Very airy		Sparse		Very airy					
DE (DAS)	3	3	3	3	3	3	3	3	3	3
BF (DAS)	35	35	42	42	35	35	35	35	35	35
EF (DAS)	65	67	83	83	65	65	65	65	65	65
CM (DAS)	84	85	100	100	84	84	84	84	84	84
CT	90	90	105	105	90	90	90	90	90	90

Caption: WLDP: White + light dyet purplish; WSV: White + stip violets; CS: Color of seeds; CF: Color of flowers; HSLC: Hair on the stem, leaves and capsules; DE: Date of exercise; BF: Beginning of flowering; EF: End of flowering; CM: Capsule maturity; CT: Cycle time; DAS: Day after sowing

Experimental site

The experiment was conducted in the experimental garden of the UFR / SVT at the Université Ouaga 1 Pr Joseph KI-ZERBO, located in the centre of the city of Ouagadougou. The plants were grown in pots under a greenhouse who's GPS coordinates are as follows: Latitude 12°37 'North, Longitude 01°49' West. The city of Ouagadougou is located in a Sudano-Sahelian climate.

Preparation of the culture substrate

The soil used as a substrate was taken from the eastern periphery of the city of Ouagadougou to a depth of about 30 cm. Analyzes were carried out on a sample of this soil at the National Soil Laboratory (BUNASOLS) to determine its particle size and mineral composition (Table 2).

After drying for 48 hours in the sun and homogenizing with a shovel, the soil was placed in pots due to 15 kg.

Sowing

The experiment was conducted from 07 August to 19 November 2015. Plantings were carried out directly in the pots at a rate of ten seeds per pot and at a depth of about 1 cm. One-pot planting was carried out on the 14th day after sowing (DAS).

Experimental apparatus

A total of 90 pots (4 varieties and 6 lines x 3 pots / variety or descendant x 3 replicates) arranged in "split-plot" were used for the experiment. The treatment represented the sub-plot, the pots corresponded to the elementary plots and the blocks constituted the repetitions.

Water treatments

Three levels of water treatments were applied:

S0: Water supply with watering every 02 days at the soil field capacity (control). The water quantity was 4470 ml / pot;
S1: Hydrous stress of 14 days at the vegetative stage from the 21st day after sowing (DAS);
S2: Water stress of 14 days at the flowering-fruiting stage from the 42nd DAS.

Water stress is caused by a complete.

Parameters studied:

The measurements were based on the height of the plants (HP) which was determined using a graduated scale. The number of capsules (NC) that was performed by manual counting. The total dry biomass (TDB), the mass of 1000 seeds (MMS) which were determined by weighing using a DENVER AC-1200D precision 0.001g electronic scale. The relative water content (TRE) relative to the fresh material of the 5th leaf from the top was evaluated by The following method of Barrs (1968):

RWC% = [(FW - DW) / (WFT - DW)] x 100

With RWC = Relative water content; FW = Fresh weight; DW = Dry weight; WFT = Weight of full turgor;
The total chlorophyll leaf content (TCC) was determined by the Mckinney method (1941):
[Total Chl] = [Chl a] + [Chl b]
With: [Chl a] = 12x (OD 663) -2.67x (OD 645)
[Chl b] = 22.5x (OD 645) -4.68x (OD 663) and
OD: optical density.

Foliar sodium (Na) and potassium (K) levels were determined using the flame photometer method. The determination of the magnesium (Mg) content was carried out using the atomic absorption method.

Data analysis

The data collected were subjected to an analysis of variance (ANOVA). The tests of comparison of the means were carried out according to the method of Student Newman-Keuls at the threshold of 5%. The XLSTAT 2007 software was used for this purpose.

Results

Granulometric and mineralogical composition of soil

The results are shown in Table 2. These results show that the soil is slightly acidic, sandy limon, relatively rich in iron and potassium but low in organic matter and nitrogen.

Table 2: Characteristics of the soil sample

		Granulometric composition			Mineral composition							
pH	OM	Clay %	Slit %	Sand %	C %	N %	C/N	P (ppm)	K (ppm)	Fe (ppm)	Ca (ppm)	Mg (ppm)
5,89	1,56	5,88	19,61	74,51	0,91	0,09	11	5,27	92,57	31,00	2,41	1,47

The final height of the plants at harvest

Figure 1 shows the impact of vegetative and flowering water deficit on plant height in varieties and sesame descendants. The analysis of variance revealed a highly significant difference (P <0.0001) between plant height within varieties, within lineages and between varieties and descendants in the absence of water stress (controls). The Humera and Wollega varieties were the highest with 162.8 cm and 152.2 cm respectively, while the S-42 variety showed the smallest height with 133.2 cm. Under the effect of water stress at the vegetative stage (S1), a highly significant difference (P <0.0001) in plant height was observed within the varieties, within the descendants and between the varieties and the descendants. The Humera and Wollega varieties remained the highest with 152.6 cm and 140.87 cm respectively and the S-42 variety remained the lowest with 122.3 cm. Water stress at the flowering stage (S2) also caused a significant difference (P <0.0001) in the height of plants within varieties, within lineages and between varieties and descendants. The Humera and 32-15 plants were the highest with 156.9 cm and 146.7 cm respectively. Plants of the S-42 variety were still shorter with 126.58 cm. In general, water stress at the flowering stage caused a smaller reduction in plant height of varieties and descendants. On the other hand, its effect at the vegetative stage caused a greater reduction (about 10 cm less than that of the control plants).

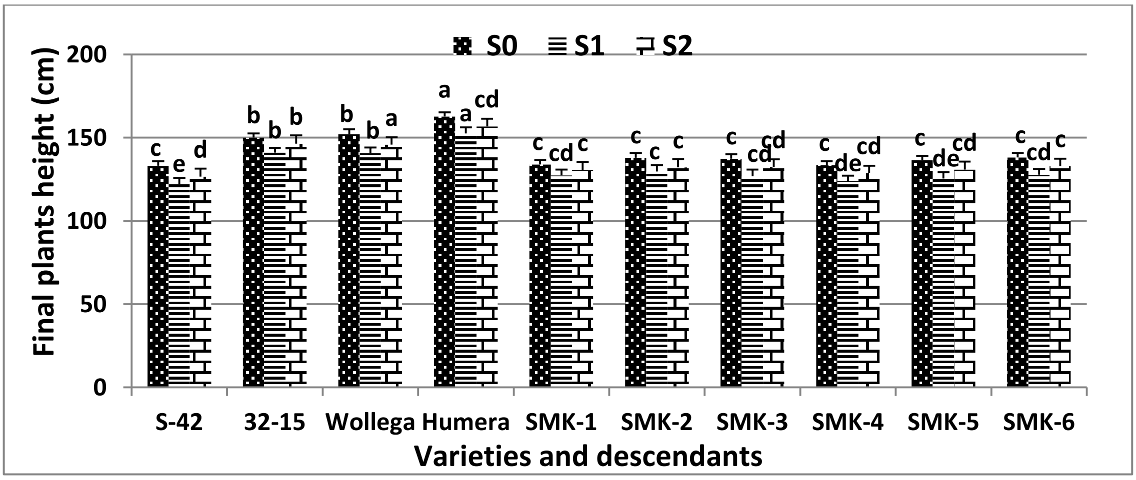

Figure 1: The final plant height (FPH) of the 4 varieties and 6 descendants in a non-stressful condition (S0), under water stress at the vegetative stage (S1) and at the bloom stage (S2).

The relative water content of the leaves (RWCL)

In Figure 2, we can observe the impact of vegetative and flowering water deficit on the relative water content (RWC) of the leaves in the 4 varieties and the 6 sesame descendants. The statistical analysis of RWC revealed a highly significant difference (P <0.0001) within varieties, within descendants, and between varieties and lines in both unrestricted (control) plants and those Stressed. During the two stages of development (vegetative and flowering), the relative water content of the leaves decreased in all varieties and descendants in the water deficit. The decrease in RWC was greater due to water stress at the bloom stage. In addition, when water stress occurred at the vegetative stage, Humera, S-42 and SMK-1 showed the following RWC: 71.4%, 70.3% and 72.1%, respectively. These RWC were lower than those presented by SMK-6 (78.1%), SMK-5 (78.3%), and SMK-4 (81.2%). In plants stratified with flowering, lower TRE were observed in S-42 (65.4%), Humera (64.7%) and SMK-2 (65.9%). Whereas SMK-6 (71.8%), SMK-4 (73.4%) and SMK-5 (75%) were the highest. Reduced leaf RWC was greater in both plant varieties than in lineage plants (18% on average) in flowering stressed plants than in those stressed in the vegetative stage where reduction was on average 12%.

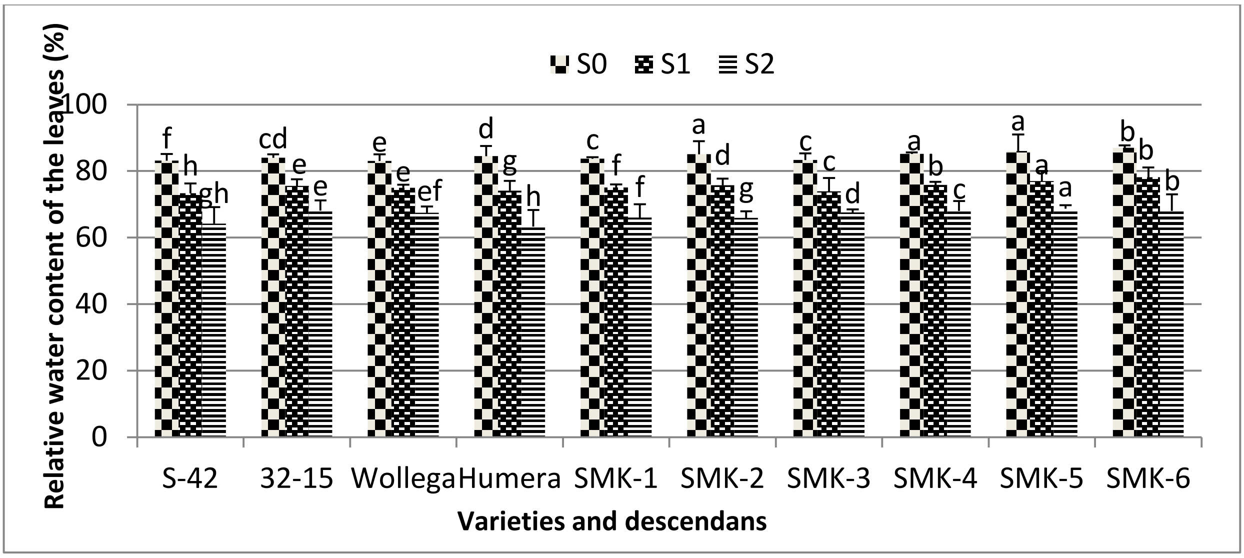

Figure 2: The relative water content of the leaves (RWCL) of the 4 varieties and 6 descendants in a non-stressful condition (S0), under water stress at the vegetative stage (S1) and at the bloom stage (S2)

The total chlorophyll content of the leaves (TCCL)

For total chlorophyll (TCT), the statistical analysis showed a highly significant difference (P <0.0001) between plants within varieties, within descendants, and between varieties and descendants within three Water treatment. In the control plants, variety S-42 had the highest total chlorophyll content (34.29 g / kgFM). On the other hand, the lowest level was found in the SMK-1 descendant (30.78 g / kgFM). In vegetative stressed plants, the highest chlorophyll content was determined in variety 32-15 (43.21 g / kgFM) and lowest in the SMK-6 descendants (33.28 G / kgFM). For flowering plants, we found the highest value (41.39 g / kgFM) in the 32-15 variety and the lowest (33.14 g / kgFM) in the SMK-6 descendants. It should be noted that in all plants of the varieties and descendants, the chlorophyll content was higher in the plants which underwent the water stress compared to that of the unstressed plants (controls).

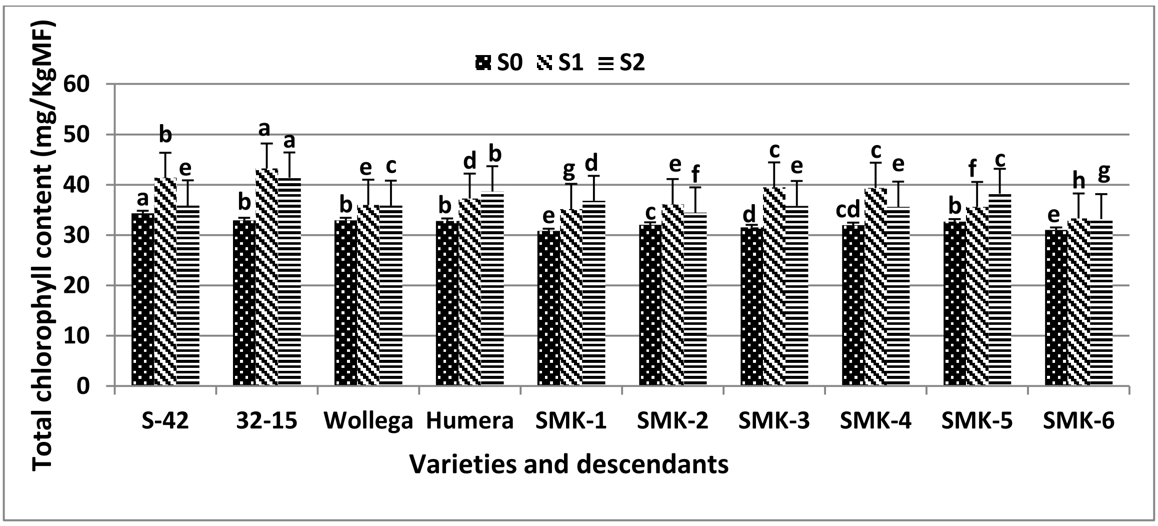

Figure 3: Total chlorophyll content (TCCL) of plants in the 4 varieties and 6 descendants under stress (S0) and water stress at the vegetative stage (S1) and flowering (S2)

The potassium content of the leaves (KCL)

In FIG. 4, the potassium content of the leaves of the 4 varieties and 6 strains under stress (S0) can be observed, under water stress at the vegetative stage (S1) and at the blooming stage (S2). Statistical analysis revealed a highly significant difference (P <0.0001) within varieties, within descendants, and across varieties and descendants. In unstressed plants (controls), the leaves of the SMK-1 and SMK-2 descendants showed higher potassium contents with respectively 30.61 and 29.92 g / kgDM. On the other hand, the leaves of the Wollega variety had a lower potassium content (19.48 g / kgDM). The application of water stress at the vegetative stage (S1) also showed a highly significant difference (P <0.0001) in the potassium content within the varieties, within the descendants and between the varieties and the descendants. The leaves of the SMK-4 and SMK-5 descendants were richer in potassium with respective values of 47.31 g / kgDM and 39.66 g / kgDM. In contrast, the leaves of the Wollega and Humera varieties showed the lowest levels with 29.92 g / kgDM and 29.22 g / kgDM, respectively. The application of water stress at the flowering stage (S2) also revealed a highly significant difference (P <0.0001) within the varieties, within the descendants and between the varieties and the descendants. The leaves of the Humera variety and the SMK-6 descendant showed the highest levels of potassium with 31.31 g / kgDM and 30.61 g / kgDM, respectively. On the other hand, the leaves of the SMK-2 and SMK-5 descendants had the lowest potassium leaf contents with 23.66 g / kgDM and 20.18 g / kgDM, respectively. In general, water stress at both the vegetative and flowering stages resulted in an increase in leaf potassium in all plants of the varieties and descendants compared to unaffected plants. Moreover, water stress at the vegetative stage caused a greater increase in potassium content compared to its effect at flowering, except in plants of the variety humera where water stress at flowering induced more accumulation of potassium in leaves than at the vegetative stage.

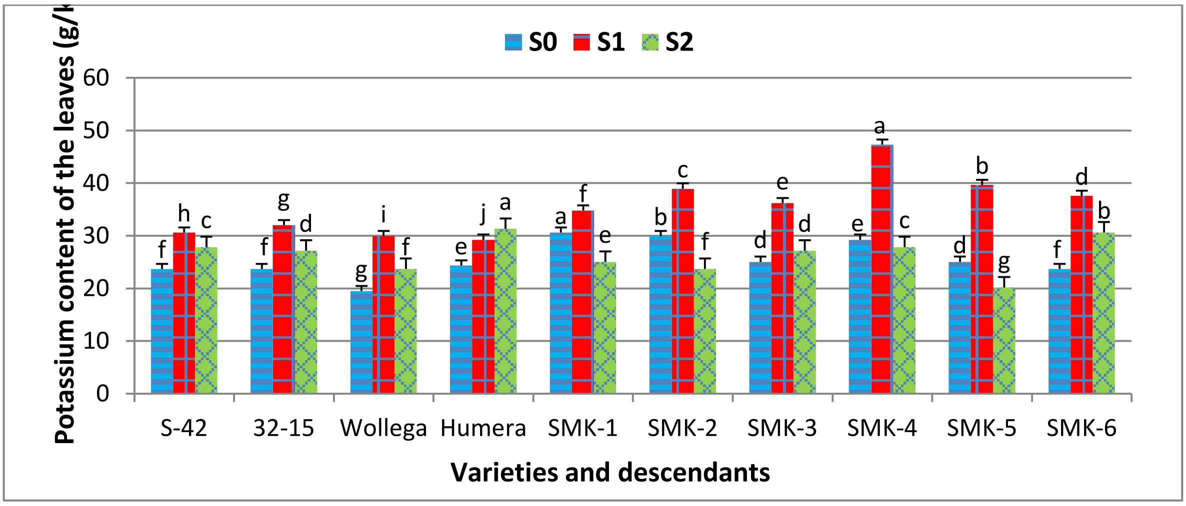

Figure 4: Potassium content of the leaves (KCL) of the four varieties and the six descendants under stress (S0) and water stress at the vegetative stage (S1) and at flowering (S2)

The sodium content of the leaves (NaCL)

The sodium content of the leaves of the 4 varieties and 6 strains under stress (S0) and water stress at the vegetative stage (S1) and flowering (S2) is shown in FIG 5. The statistical analysis revealed a highly significant difference (P <0.0001) within the varieties, within the descendants, and between the varieties and the lines as to their Na content in the stressed (control) plants. It is the leaves of the SMK-4 line that have accumulated the most Sodium (136.88 mg / kgDM). On the other hand, the leaves of varieties Wollega, 32-15 and Humera showed the lowest contents with 73.71 mg / kgDM, 84.24 mg / kgDM and 84.24 mg / kgDM respectively. Under the effect of water stress at the vegetative stage (S1), the Na content showed a highly significant difference (P <0.0001) within the varieties, within the descendants and between the varieties and the descendants. The leaves of the same SMK-4 descendant showed the highest content (121.09 mg / kgDM), while the leaves of the SMK-3 and Wollega lines showed the lowest content (115.82 Mg / kgDM). When water stress was applied at the flowering stage (S2), a significant difference (P <0.010) was revealed within the varieties, within the descendants, and between the varieties and the descendants. The leaves of the SMK-5 and SMK-6 descendants contained the highest levels of Na with 126.35 and 115.82 mg / kgDM, respectively. The lowest levels were found in S-42 (89.5 mg / kgDM) and Wollega (94.76 mg / kgDM) and in the SMK-3 (94.76 mg / kgDM). However, water stress at the vegetative stage, an increase in sodium content in all varieties and most descendants except in the SMK-4 descendants, where this content decreased from the value presented by the unstressed plants (Witness). As for the SMK-5 and SMK-6 descendants where this Na content did not vary whether the plants were stressed or not. Similarly, flowering water stress and an increase in sodium content in the 32-15, Wollega and Humera varieties and in most of the strains except in the S-42 variety and in the SMK-3 and SMK- 4 where this Na content is lowered relative to the value presented by the control plants.

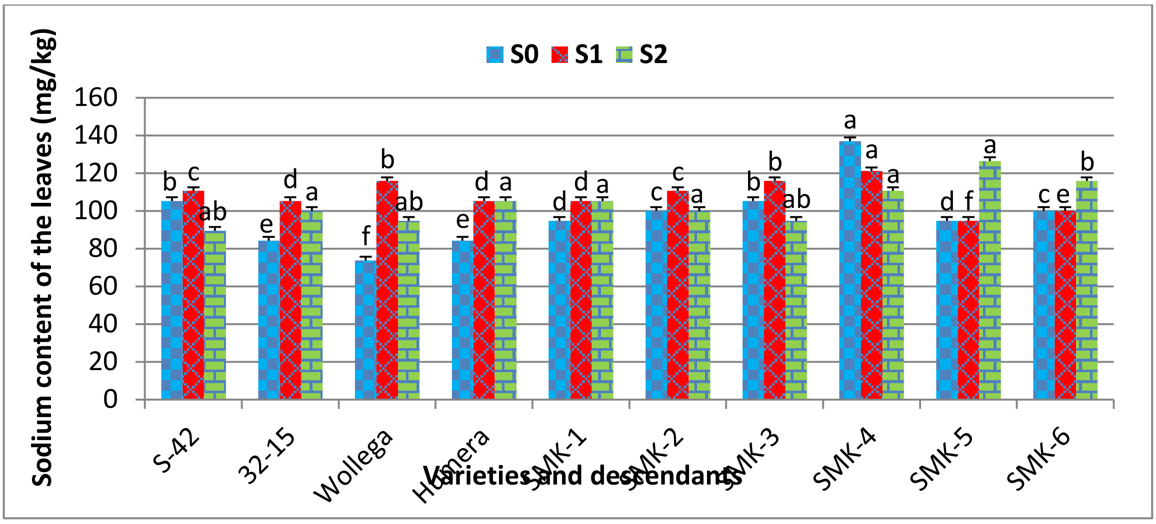

Figure 5: Sodium content of the leaves (NaCL) of the 4 varieties and 6 descendants under stress (S0) and water stress at the vegetative (S1) and flowering (S2) stages

The magnesium content of the leaves (MgCL)

Figure 6 shows the magnesium content of the leaves of the 4 varieties and 6 descendants under stress (S0) and water stress at the vegetative stage (S1) and at the flowering stage (S2). The statistical analysis revealed a significant difference (P <0.012) within the varieties, within the descendants and between the varieties and the descendants for the magnesium content of the leaves of the stressed (control) plants. The highest levels were found in the Wollega variety (1.7 g / kgDM) and in the SMK-2 descendant (1.8 g / kgDM). The lowest concentrations were in S-42 (1.28 g / kgDM) and in SMK-6 (1.11 g / kgDM). When water stress was applied at the vegetative stage (S1), a highly significant difference (P <0.0001) in the Mg content was revealed within varieties, within descendants, and across varieties and descendants. The highest levels were obtained in the Wollega variety (2.61 g / kgDM) and in the SMK-1 line (2.73 g / kgDM). As a result of water stress at flowering (S2), a highly significant difference (P <0.0001) in Mg content was also revealed within varieties, within descendants, and between varieties. Thus, the leaves of the SMK-5 and Wollega descendants showed magnesium levels higher than those of the other varieties and descendants, with respectively 2.17 and 2.8g / kgDM. On the other hand, the leaves of the Humera variety and the SMK-4 lineage accumulated less Mg with 1.37 and 1.16g / kgDM, respectively. It should be noted that vegetative-induced water stress induced an increase in magnesium content in S-42, Wollega and Humera plants and in those of most strains except in plants of variety 32-15 where This Mg content decreased with respect to the value obtained in the control plants. Similarly, flowering water stress induced an increase in magnesium content in S-42, 32-15 and Wollega plants, and in most of the descendants except Humera plants and those in plants Of the SMK-2 and SMK-4 descendants where this content decreased compared to the value presented by the control. Moreover, the increase in magnesium content was greater in most plants of the varieties and descendants when water stress occurred at the vegetative stage.

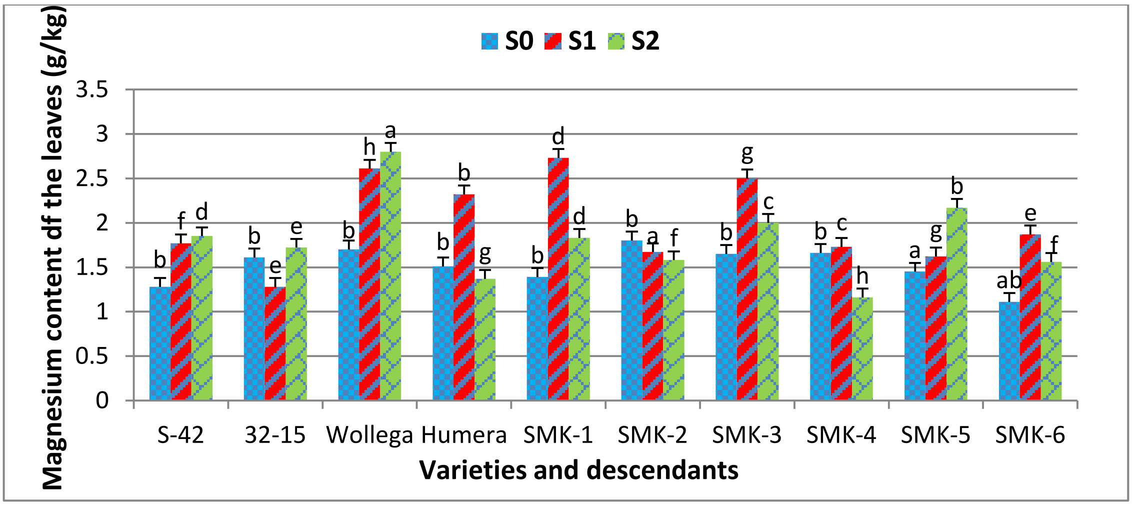

Figure 6: Magnesium content of the leaves (MgCL) of the four varieties and the six descendants under stress (S0) and water stress at the vegetative (S1) and flowering (S2) stages

The agronomic parameters

The results of the agronomic evaluation are presented in Table III. The statistical analysis revealed in the control plants a significant difference (P <0.0001) within the varieties, within the descendants and between the varieties and the descendants in terms of capsules per plant (NCP). The SMK-2 descendant was found to be the most productive in capsules with 160 cap / foot, while variety 32-15 was the least productive with 57 cap / foot. For caprine production, water stress at the vegetative stage (S1) revealed a highly significant difference (P <0.0001) within the varieties, within the descendants, and between the varieties and the descendants. The SMK-2 descendant was still the most productive with 103 head / foot, while the 32-15 and Wollega descendants were the least productive with 23 head / foot and 24 head / plant, respectively. However, water stress at the flowering stage revealed a highly significant difference (P <0.0001) within the varieties, within the descendants, and between the varieties and the descendants. SMK-2 and SMK-6 descendants produced the most capsules with 79 and 73 cap / plant, respectively. The Humera, Wollega and 32-15 varieties produced fewer capsules with 11, 14 and 17 cap / foot, respectively. In all varieties and descendants, water stress at the vegetative stage resulted in a reduction in yield of about 45% in capsules. Moreover, Wollega was the most affected at this stage of the cycle by water stress with a reduction of more than 71%, unlike the SMK-1 descendant, in which the reduction was only about 37%. Water stress at flowering reduced the yield of capsules by about 62% in varieties and descendants. At this stage, the Humera variety was the most affected, with a reduction rate of about 90%, in contrast to the SMK-2 and SMK-6 strains, where the reduction was only about 51%. For the number of seeds per capsule (NGP), a highly significant difference (P <0.0001) was observed within the varieties, within the descendants, and between the varieties and the lines in the control plants. The number of seeds per capsule was greater in the Humera and Wollega varieties with approximately 70 seeds / capsule each. On the other hand, this number was lower in variety 32-15 with an average of 53 seeds / capsule. Water stress at the vegetative stage (S1) revealed a significant difference (P <0.0001) within the varieties, within the descendants and between the varieties and the descendants. The capsules of the varieties (Humera and Wollega) produced the most seeds with respectively 71 and 72 seeds / capsules, in contrast to the variety 32-15 whose capsule filling averaged 55 seeds per capsule. Water stress at the flowering stage (S2) also revealed a highly significant difference (P <0.0001) within the varieties, within the descendants and between the varieties and the descendants compared to the filling of the capsules. Capsules of the Humera and Wollega varieties contained more seeds with an average of 57 and 58 seeds / capsule respectively. However, variety S-42 and all descendants had capsules with fewer seeds, an average of 50 seeds per capsule. It is important to note that the number of seeds per capsule increased (about 3 more seeds) in all varieties and lines when water stress occurs at the vegetative stage. On the other hand, when it occurred at the flowering stage, it caused a decrease of this number (about 10 seeds less) except in the 32-15 variety or this number has practically not decreased (about 1 seed less). As with the number of capsules per foot and the number of seeds per capsule, statistical analysis for the mass of one thousand seeds showed that there was a highly significant difference (P <0.0001) within varieties, within Of the lines and between the varieties and the descendants in the control plants. Varieties 32-15 had a mass of one thousand seeds higher with 3.5 g followed by the variety Humera (3.3 g) and the variety Wollega (3.11 g). The S-42 strains and variety had a mass of one thousand seeds slightly lower than the others, averaging 2.8 g. During the vegetative stage, statistical analysis showed that there was a highly significant difference (P <0.0001) within the varieties, within the descendants and between the varieties and the descendants. Indeed, the mass of one thousand seeds of varieties 32-15, Humera and Wollega was higher than that of the other varieties and descendants, with respectively 3.3 g, 3.13 g and 2.91 g. As for the descendants and variety S-42, the mass of one thousand seeds was less important, on average 2.5 g. Stressed at the flowering stage, statistical analysis revealed a significant difference (P <0.0001) within the varieties, within the descendants, and between the varieties and the descendants for the weight of one thousand seeds. (32-15, Humera and Wollega) had the highest 1000-seed weight with 2.24 g, 2.02 g and 1.84 g, respectively, contrary to S-42 and all Mass of one thousand seeds was less important (on average 1.5 g). From the total dry biomass, the control plants showed a highly significant difference (P <0.0001) and between the varieties and the descendants. The highest total biomass was found in Wollega (91.44 g) and lowest in the variety 32-15 (58.67 g). For this same parameter, a highly significant difference (P <0.0001) was found between the varieties and the descendants when the water stress was applied at the vegetative stage. The same Wollega variety had the highest dry biomass (80.21 g) and the variety 32-15 also kept the lowest value with 48.77 g. The application of water stress at the flowering stage produced a highly significant difference (P <0.0001) within the varieties, within the descendants and between the varieties and the descendants. At this stage, the dry biomass produced was even greater in the Wollega variety (85.9 g) and the smallest in the variety 32-15 (41.2 g). The effect of water stress at the flowering stage reduced total dry biomass production by about 5 g in S-42 and all descendants and about 10 g in Wollega and Humera 32-15. On the other hand, water stress at the vegetative stage reduced the production of this total biomass (more than 10 g less) in the S-42 variety and all the strains and about 15 g in the 32-15, Wollega and Humera.

Table 3: Analysis of variance of yield and its components of the 4 varieties and 6 descendants according to the three water treatments

Parameters		F of Fisher	P at threshold of 5%	Varieties				Descendants					
	S0			S-42	32-15	Wollega	Humera	SMK-1	SMK-2	SMK-3	SMK-4	SMK-5	SMK-6
NCP		11,016	< 0,0001**	145,00a	57,00c	84,00bc	106,00ab	138,00a	160,00a	144,00a	146,00a	155,00a	81,33bc
NSC		289,105	< 0,0001*	62,12b	53,40c	70,20a	69,90a	62,60b	62,14b	62,09b	62,65b	61,79b	62,09b
MTS (g)		6,260	< 0,0001**	2,80b	3,50a	3,11ab	3,30ab	2,78b	2,15c	2,79b	2,79b	2,81b	2,85b
TDB (g)		607,055	< 0,0001*	59,34g	58,67g	91,44a	79,78c	81,63b	72,76d	69,21e	62,78f	80,42bc	63,28f

Parameters		F of Fisher	P at threshold of 5%	Varieties				Descendants					
	S1			S-42	32-15	Wollega	Humera	SMK-1	SMK-2	SMK-3	SMK-4	SMK-5	SMK-6
NCP		127,64	< 0,0001**	88,00b	23,00d	24,00d	56,00c	83,00b	103,00a	88,00b	85,00b	94,00b	93,00b
NSC		87,830	< 0,0001**	65,30c	55,40d	72,60a	71,00b	65,40c	65,50c	64,70C	65,00c	64,66c	64,18c
MTS (g)		31,033	< 0,0001**	2,60d	3,30a	2,91c	3,13b	2,56d	2,64d	2,58d	2,53d	2,63d	2,61d
TDB (g)		1557,364	< 0,0001**	50,52g	48,77h	80,21a	72,47b	72,02b	63,66d	60,06e	53,51f	70,94c	53,81f

Parameters		F of Fisher	P at threshold of 5%	Varieties				Descendants					
	S2			S-42	32-15	Wollega	Humera	SMK-1	SMK-2	SMK-3	SMK-4	SMK-5	SMK-6
NCP		127,64	< 0,0001**	88,00b	23,00d	24,00d	56,00c	83,00b	103,00a	88,00b	85,00b	94,00b	93,00b
NSC		87,830	< 0,0001**	65,30c	55,40d	72,60a	71,00b	65,40c	65,50c	64,70C	65,00c	64,66c	64,18c
MTS (g)		31,033	< 0,0001**	2,60d	3,30a	2,91c	3,13b	2,56d	2,64d	2,58d	2,53d	2,63d	2,61d
TDB (g)		1557,364	< 0,0001**	50,52g	48,77h	80,21a	72,47b	72,02b	63,66d	60,06e	53,51f	70,94c	53,81f

Legend: ** highly significant difference; * Significant difference at the 5% threshold; F = Fisher variable; P = Probability associated. One letter for one parameter: not significant difference; Two letter for one parameter: Significant difference; More than two letters for one parameter: Highly significant difference. NCP: Number of capsules per plant; NSC: Number of seeds per capsule; MTS: mass of one thousand seeds; TDB: total dry biomass.

Discussion

In the 4 varieties and the 6 six sesame descendants, water stress at the vegetative stage caused a greater reduction of the height of the plants compared to that at flowering. These results are similar to those of Comparé (2011) who reported that water deficit at the vegetative stage greatly reduces the size of sesame plants compared to a flowering water deficit. Like Lauer (2005) who, working on the behavior of maize in dry weather, observed that water stress during vegetative development leads to a marked reduction in stem expansion. In addition, Nana (2010) reported that okra plants stressed at the vegetative stage showed a smaller size than those stressed at the bloom stage. This may be explained by the fact that the vegetative stage is a full-growing stage of plants during which a lack of water slows down the key mechanisms of growth, namely Meresis and Attrition (Nana, 2010). According to Aidaoui (1994), a plant's response to water stress is complex because it depends on both the severity of the stress, its duration, the stage of development of the plant and the state in which it was located the plant when the stress took place. The comparative analysis of the relative water content showed a highly significant difference within the varieties, within the lines and between the varieties and the descendants. This can be attributed to the osmotic adjustment power for maintaining cell turgescence and physiological activities (Bayoumi and al., 2008). Moreover, the relative water content of the stressed plants was less than that of the control plants. These results are similar to those of Compaoré (2011) and Seyni and al. (2010) on sesame and that of Nana (2010) on okra. This result is mainly due to the difference in water availability of the soil which would have subsequently affected the maintenance of cell turgescence. Indeed, many authors including Compaoré (2011) and Seyni and al. (2010) showed that to resist water deficit conditions, sesame plants adapt their vegetative apparatus by reducing radial and vertical growth, leaf area and leaf water content. However, the RWC of plants stressed at the vegetative stage remained higher than that of plants stressed at the flowering stage. This result is similar to that of Nana (2010) who reported that the leaf water content of stressed plants at the flowering stage was lower than that of plant leaves stressed at the vegetative stage. This could mean that the effect of water stress was more pronounced on the relative water content at the flowering stage. According to (Zerrad and al., 2008), in order to keep the turgor potential as high as possible, after the very remarkable drop in water content, plants accumulate certain osmoticums inside their cells, including proline and sugars Reducers. Thus, sesame plants would have had the ability to accumulate osmoticums in vegetative phase rather than flowering. As for the total chlorophyll foliar content, the water stress at the vegetative stage as well as at the flowering stage caused its increase. However, the total chlorophyll content was greater in plants stressed at the vegetative stage than in plants stressed at flowering. The increase in total chlorophyll levels is a consequence of the reduction in foliar cell size due to water stress, which leads to greater concentration (Siakhène, 1984). However, it should be noted that the chlorophyll content of leaves can be influenced by several morphological factors such as leaf age, leaf position, and environmental factors such as light, temperature and soil water availability (Hikosaka and al., 2006). The varieties and descendants studied showed a behavioral diversity with respect to the foliar accumulation of the mineral elements potassium (K), sodium (Na) and magnesium (Mg). Thus, water stress at the vegetative stage induced an increase in the K content in all varieties and lines. Also, water stress at the flowering stage induces an increase in the K content in all varieties and in the SMK-3 and SMK-6 descendants except for SMK-1, SMK-2, SMK-4 and SMK-5 Where this content decreased compared to the value found in the control plants. Similar results were reported by Diallo (2009), on rice. Indeed, this increase in the potassium content of the leaves is linked to the water deficit given its role in the water balance of the plant. Indeed, this element increases the osmotic pressure of the cellular juice by promoting the absorption of water and its accumulation in the tissues (Diallo, 2009). Similarly, Zaid (2006) and Soltner (1994) have shown that potassium regulates the economy of water in the plant and reduces evaporation. It would therefore increase its resistance to drought. In addition, foliar potassium content decreased in SMK-1, SMK-2, SMK-4 and SMK-5 following water-stress in the vegetative stage. This may be explained by the fact that for these strains at this stage and under water stress, there was insufficient supply of K. Car, Mouna and al., 2010, reported that under the effect of the water deficit, some nutrients are badly accumulated by plants to benefit others.

For foliar sodium (Na) content, water stress at the vegetative stage led to an increase in all varieties and some descendants; The SMK-4 line decreased from the value presented by the control plants. In the SMK-5 and SMK-6 descendants, this content remained constant relative to the value presented by the control plants. Similarly, flowering water stress induced an increase in this Na foliar level in most varieties and lines except in the S-42 variety and in the SMK-3 and SMK-4 descendants where this content decreased Relative to the value found in the control plants. These results are similar to those of Mouna and al., 2010, on wheat which reported that under water stress some varieties accumulated more sodium in their leaves as opposed to others that accumulated only a few. Two explanations are necessary. Indeed, a decrease in the accumulation of Na in the aerial parts maintains this element at relatively low levels in the photosynthetic tissues and allows a better protection of their photosynthetic apparatus, which supports less the aggression of the water stress (Mouna and al ., 2010). Furthermore, (Slama, 1982) states that genotypes that are unable to transport Na easily in their leaves are significantly more sensitive to water deficiency than others, as their inability to export this material is probably less protective than the reflection of water a deficiency in cell compartmentalization systems. Slama, 1982 and Lessani and al., 1978, have shown that these varieties are incapable of ridding the cytoplasm of Na, which results in its continual transport to the roots of the plant. Mouna et al., 2010, have shown that the ability to accumulate large amounts of Na in leaves, as is the case with most of our varieties and our sesame lines, a weak conduction of this element in the phloem. As for foliar magnesium (Mg) content, water stress at the vegetative stage resulted in an increase in magnitude in the S-42, Wollega and Humera varieties, as well as in all strains except for variety 32-15 where this Foliar magnesium content decreased from the value presented by the control plants. Similarly, water stress at the flowering stage induced an increase in this level in most varieties and descendants except Humera and SMK-2 and SMK-4, where this content decreased in relation to the value Obtained in the control plants. It should be noted that magnesium is an element directly linked to the resistance of the plant to drought (Zaid 2006). Indeed, magnesium is a constituent of chlorophyll. It promotes the synthesis, as well as that of the xanthophylls and that of the carotenes. It is used in the composition of essential organic compounds such as Phytin and Pectin Zaid (2006). It is also an enzyme activator, especially those that are responsible for proteosynthesis and lipid synthesis (Zaid, 2006). Hence its role in the resistance of plants to drought because the accumulation of lipids is a biochemical mechanism triggered by plants to resist water stress (Arradeau, 1998). On the basis of this, it can be said that most of these varieties and sesame lines apart from varieties 32-15 and Humera and SMK-2 and SMK-4 lines showed good resistance to water deficit, as in this situation of water stress, they saw their magnesium content increased. In all varieties and descendants, water stress at the vegetative stage resulted in a reduction in yield of about 45% in capsules. The latter occurred at the flowering stage and resulted in about 62% (Table III). This shows that the water deficit at flowering had a more negative effect on the production of capsules compared to its effect at the vegetative stage. Our results are consistent with those reported by Compaoré (2011) on sesame and by Nana (2010) on okra. The low production of capsules in stressed plants at the flowering stage is due to the fall of flower buds, flowers and even young fruits during the period of water stress (Nana, 2010). Vegetative stressed plants would have had time to correct the detrimental effects of water deficit. However, it should be noted that previous work has shown that the effect of water stress on fruit yield and its components depends on the varieties and stage of development of the plant during which the deficit occurs because, Nana (2010)) Reported that yields of capsules increased in some okra varieties that experienced water stress at the vegetative stage. In terms of yields in capsules, the comparison between the varieties and the sesame lines in this study showed that, due to vegetative stage water deficit, Wollega was the most affected because its yield Capsules was reduced by more than 71%, unlike the SMK-1 lineage in which the reduction was only about 37%. On the other hand, when water stress occurred at flowering, Humera was the most affected with a considerable reduction in its capsule production (about 90%), in contrast to SMK-2 And SMK-6 in which the reduction was only about 51%. The number of seeds per capsule increased in all varieties and strains stressed at the vegetative stage. On the other hand, this number decreased when the stress occurred at the flowering stage except in the variety 32-15 in which the number of seeds per capsule has practically not varied. Seyni et al. (2010) also reported an increase in the number of seeds per capsule when sesame plants were subjected to water deficit. Under the effect of water stress, the greater the number of seeds per capsule, the lower the 1000-seed mass. Thus, the capsules of the variety 32-15 contain less seeds however it is its seeds which had the highest mass of 1000 seeds. The decrease in seed mass would be the result of a change in the transfer of assimilates caused by the water deficit which would have led to poor seed filling. Total dry biomass decreased in plants stressed at the vegetative stage as well as in those stressed at flowering, but this decrease was greater in plants stressed at the vegetative stage than in those stressed at flowering. Similar results were reported by Diallo (2009) on rice, Nana (2010) on okra and Compaore (2011) and Seyni and al. (2011) on sesame. This may be justified by the fact that at the flowering stage the plant has already produced the maximum amount of biomass as opposed to the vegetative stage which represents the phase of full growth and therefore the production of this biomass. Moreover, the decline in biomass production in stressed plants can be justified by the reduction in their growth. Indeed, according to Albouchi et al. (2003), the lack of water in plants results in a decrease in the relative water content and a reduction in the production of the biomass concomitant with a reduction in the diameter and height Rods. Thus, by comparison of these varieties and sesame lines, it can be said that under water-deficient conditions, the S-42 variety and the lines are the best producers of total biomass, contrary to varieties 32-15, Wollega and Humera in which the water deficit had a more pronounced reducing effect.

Conclusion

Tolerance to water deficiency resulted in a reduction in plant height in all varieties and in the sesame descendants studied. However, there appears to be a significant difference between the varieties and the descendants in relation to the total chlorophyll content under the water stress applied at the vegetative stage indicating a better tolerance of the S-42 and 32-15 varieties at this stage of development. However, all four varieties and six descendants were adaptive to water shortage by maintaining leaf water content at both the vegetative and flowering stages at relatively high levels to ensure plant development. The variety S-42 and all descendants were the best in preserving their water content. In response to both vegetative and flowering water deficits, the varieties and descendants studied increased their foliar levels of mineral elements potassium (K), sodium (Na) and magnesium (Mg). The SMK-2 descendant was less effective in the foliar accumulation of magnesium in a water deficit situation. The vegetative stage water deficit caused a significant reduction in the yield of capsules in all the varieties and descendants. However, at the time of flowering, this effect was reduced in capsules, more marked in Humera, Wollega and 32-15 varieties. Under water stress at the vegetative stage, the number of seeds per capsule and the seed weight were inversely proportional. Under the flowering stage, the number and seeds weight were very small in all varieties and descendants.

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