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ORIGINAL ARTICLE

EFFECT OF SODIUM CHLORIDE ON THE GROWTH AND PHYSIOLOGY OF FOUR AFRICAN VARIETIES OF *Sesamum indicum L.*

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ABSTRACT

Introduction: Arable land and agricultural production are decreasing in Senegal and in the world due to the continually increasing soil salinization. **Context:** This growing phenomenon reduces soil fertility and leads to food insecurity. Using salt tolerant cultivation would help recover salty soils and improve production. **Objective:** The aim of this work is to assess the effect of NaCl on the growth and physiology of four African sesame varieties at the vegetative and early reproductive stages. **Methods:** The effect of five NaCl concentrations (0 mM; 17 mM; 34 mM; 68 mM; 136 mM) was evaluated on the growth and physiology of four African sesame varieties from Mali (AS09), Cameroon (AS14), Sudan (AS15) and Togo (AS25) under controlled conditions at 28 and 44 days after sowing (DAS). **Results**: The results showed that all growth parameters (diameter at the collar, stem length, fresh biomass and dry biomass) decreased with the increase in the NaCl concentration within the same variety. The analysis of physiological parameters (chlorophyll a, chlorophyll b and total chlorophylls contents) globally showed a decrease in the amounts of chlorophyll with the increase in NaCl concentrations at 28 DAS. After 44 DAS, an increase in the chlorophylls content is noted mainly for all the varieties with the increase in the NaCl concentration. **Conclusion:** The growth parameters decreased in proportion to the salinity. The latter resulted in a decrease in the quantities of chlorophyll at 28 DAS and their increase at 44 DAS. The sesame variety AS15 is the most tolerant to sodium chloride.

Key words: *NaCl, Sesame, Biomass, Chlorophylls*

1. INTRODUCTION

Land salinization is a global problem, particularly in Africa where it is the main environmental problem [1]**.** It is linked to climatic conditions and human activities. The area of agricultural land affected by salinity mainly due to NaCl keeps increasing [2, 3]. In Senegal, it was estimated at 1,700,000 ha in 1997, representing 45% of the country's total arable area. This phenomenon is more serious in the groundnut basin [1]. The permanent increase in salty land results in the reduction of plants growth, the drop in agricultural production [4] and will likely put in a situation of food insecurity people dependent on agriculture in the affected areas [1].

Salinity affects photosynthesis and thereby reduces plants growth and production [5]. It causes morphological, physiological, biochemical and molecular changes. Thus, it negatively affects the growth and metabolism of plants. However, cultures react differently to salinity and some may be tolerant [6]. The use of salinity-tolerant species is a strategy for developing salty soils [7] and combating food insecurity. Sesame (*Sesamum indicum* L.) is cultivated for its seeds rich in vitamins, proteins and high quality oil resistant to rancidity [8, 9]. Sesame cultivation reduces soil nematodes and improves texture and retention capacity [10]. Sesame (*Sesamum indicum* L.) is introduced in Senegal in the context of crop rotation, diversification of crops to increase the incomes of rural populations and fight against food insecurity. Sesame, sensitive to the sowing and germination stages, is moderately tolerant of drought and salinity [11]. Salinity most affects plants in the vegetative and early reproductive stages [12]. These phases are around the 28^{th} and 44^{th} days after sowing for sesame seeds [6]. The aim of this work is to evaluate the effect of different NaCl concentrations on the growth and physiology of four African varieties of sesame on the vegetative and early reproductive stages. More specifically, it will be a question of determining the impact of salinity on the one hand on certain dendrometric parameters (diameter at the collar, apical growth, fresh and dry biomass) and on the other hand on physiological parameters (contents in chlorophylls a, b and total) of the four varieties of sesame.

2. MATERIALS AND METHODS

2.1 Plant material and growing medium

The plant material obtained after screening with NaCl is composed of the seeds of four African sesame varieties from Mali (AS09), Cameroon (AS14), Sudan (AS15) and Togo (AS25). The substrate is the soil of the botanical garden of the Faculty of Science and Technology (FST) of Cheikh Anta Diop University (UCAD) in Dakar. The physicochemical characteristics of the substrate are summarized in Table 1.

Table 1: The table presents the characteristics of the soil (substrate).

pHeau 1/ 2,5	CE 1/ 10 µs/Cm	%C	%MO	%N	C/N	Ca meq/100g	Mg meq/100g	Na meq/100g	K meq/100g	P ppm	S meq/100g	CEC meq/100g	T %	PSE %	A %	LF %	LG%	SF %	SM %	SG %
7,4	65	2,37	4,086	0,21	11	6,9	0,525	0,0425	0,139	48	7,606	15	51	0,3	10,75	2,5	1,29	48,315	36,66	0,485

T: base saturation rate; PSE: Percentage of Exchangeable Sodium; A: clay; LF: fine silt; LG: coarse silt; SF: fine sand; SM: medium sand; SG: coarse sand.

2.2 Experimental apparatus

The experimental system consists of randomized blocks with two factors and three repetitions. The sesame variety factor consists of four modalities (AS09, AS14, AS15 and AS25) and the abiotic contraint factor (NaCl) comprises five modalities (0 mM; 17 mM; 34 mM; 68 mM; 136 mM). The experimental unit was a pot containing 1 kilogram of the cultivation substrate. In each pot, five seeds of a variety were sown. Seven days after sowing, we proceeded to thinning out, keeping two plants in each pot. The salt constraint is applied by watering beginning a week after germination until data are taken 28 days after sowing and 44 days after sowing [6]. Watering to the capacity in the field [13] is done daily with the corresponding solution (non-saline for the control and saline for the other treatments) in order to avoid any water deficit.

2.3 Measured parameters

The best (most developed) plant of each pot is selected to determine the following parameters: chlorophyll content (Chl a, Chl b and Chl) of the fresh leaves, collar diameter (CD), stem length (SL), fresh biomass (FB) dry biomass (DB). The collar diameter is determined with an electronic display caliper [13]. The length of the stem is measured using a double decimeter. Fresh biomass is measured immediately at harvest and dry biomass after drying in an oven at 70 °C for 48 hours [13, 14]. Arnon's method (1949) was used to estimate the quantities of chlorophylls [15]. 100 mg of fresh plant material (leaves) were ground with 10 ml of 80 % acetone; the ground product is centrifuged at 4000 rpm. The surviving product which contains the pigments is recovered. The optical densities are read at the wavelengths 645 nm and 663 nm. The chlorophyll content is determined according to Arnon's equations [15]:

$$\text{Chl a (g/l)} = 0.0127 \times \text{DO}(663) - 0.00269 \times \text{DO}(645) \text{ (g/l)} \quad \textbf{(1)}$$

$$\text{Chl b (g/l)} = 0.0229 \times \text{DO}(645) - 0.00468 \times \text{DO}(663) \text{ (g/l)} \quad \textbf{(2)}$$

$$\text{Chl (g/l)} = \text{Chla} + \text{Chlb} = 0.0202 \times \text{DO}(645) + 0.00802 \times \text{DO}(663) \text{ (g/l)} \quad \textbf{(3)}$$

2.4 Statistical analyses

Statistical analyses are made with software R version 3.6.3 (2020-02-29). All data was subjected to the Shapiro-Wilk normality test. Statistical processing of data with normal distribution is carried out by adopting a parametric approach with analysis of variance (ANOVA). For data with non-normal distribution a non-parametric approach is applied with an analysis of variance on the ranks of the averages. The Tukey test at the probability threshold of 5 % is performed in order to compare and classify the averages or the ranks on the averages of the variables evaluated.

3. RESULTS

2.1 Effect of salinity on dendrometric parameters (collar diameter (CD), stem length (SL), fresh biomass (FB) and dry biomass (DB)).

2.1.1. Effect of salinity on dendrometric parameters at 28 days after sowing (28 DAS)

Table 1 summarizes the results of the statistical analyses in the Tukey test for the collar diameter (CD), the stem length (SL), the fresh biomass (FB) and the dry biomass (DB) of the four African varieties of sesame 28 days after sowing (28 DAS). The differences are statistically very significant for all the parameters studied: CD (p-value = $6.9e^{-10\ ***}$), SL (p-value = $2.06e^{-11\ ***}$), FB (p-value = $2.48e^{-10\ ***}$) and DB (p-value = $7.79e^{-12\ ***}$) (Table 1).

In the presence of sodium chloride, the largest diameter at the collar is obtained with the variety AS25 in the presence of 17 mM, this same variety also gave the smallest diameter at 136 mM. The collar diameter of the AS09 variety at 17 mM NaCl increased compared to the control. Based on the collar diameter, AS25 appears to be the most salt tolerant sesame variety, the AS09 variety being the most sensitive. The diameter of the collar decreased with the increase in the concentration of sodium chloride (Table 1).

For the length of the stem, the variety AS14 has the smallest stem under salt constraint at 136 mM and AS15 the longest at 34 mM, it is slightly higher than that of the same variety under 17 mM NaCl but less than the length of the control's stem. The increase in salinity caused a decrease in stem length in all varieties of sesame. The length of the stem shows that the AS15 variety is more tolerant of salinity and AS25 is the most sensitive (Table 1).

In the presence of NaCl, the largest fresh biomass is obtained with the sesame variety AS15 at 17 mM and the lowest by AS14 at 136 mM. From the point of view of fresh biomass, all the varieties have approximately the same tolerance to salinity even if AS09 seems less sensitive (Table 1).

In the presence of salt, the largest dry biomass is obtained with the sesame variety AS09 at 17 mM and the lowest with AS25 at 136 mM. Sodium chloride led to a decrease in dry biomass compared to the controls. For all varieties except AS25 whose biomass at 34 mM is higher than that under 17 mM NaCl. The dry biomass shows that the sesame variety AS09 is more tolerant to NaCl and AS25 the most sensitive. Whatever the variety of sesame considered, the parameter evaluated decrease with increasing NaCl concentration (Table 1).

Table 1: The table presents the collar diameter; stem length, fresh biomass and dry biomass of the four African varieties of sesame at 28 days after sowing (28 DAS).

Sesame varieties	NaCl	Rank CD (mm)	Rank SL (cm)	FB (mg)	Rank DB (mg)
AS09	0 mM	38.17 ± 12.96 abcde	47.33 ± 10.25 abc	2645.33 ± 279.53 abcd	51.67 ± 6.11 ab
	17mM	39.33 ± 6.81 abcd	42.50 ± 10.58 abcd	2811.33 ± 303.15 abc	47.17 ± 9.09 abc
	34mM	27.50 ± 4.44 abcde	43.33 ± 6.71 abcd	2478.67 ± 60.50 abcde	44.00 ± 2.65 abc
	68mM	12.00 ± 2.00 ef	24.00 ± 6.54 cdefg	1900.67 ± 224.71 bcdef	19.67 ± 7.09 defgh
	136mM	7.33 ± 5.51 f	13.50 ± 5.41 fg	1594.33 ± 185.61 def	10.33 ± 5.03 fgh
AS14	0 mM	42.50 ± 15.80 abcd	42.17 ± 7.75 abcd	3283.33 ± 1020.37 a	55.00 ± 7.00 a
	17mM	40.17 ± 13.66 abcd	39.17 ± 12.21 abcde	2613.33 ± 288.27 abcd	43.00 ± 4.58 abcde
	34mM	40.17 ± 12.57 abcd	37.00 ± 9.50 abcdef	2400.00 ± 396.87 abcde	30.00 ± 6.00 bcdef
	68mM	20.00 ± 10.54 cdef	16.00 ± 6.56 efg	1918.67 ± 59.72 bcdef	23.83 ± 4.31 cdefgh
	136mM	10.33 ± 5.86 f	3.67 ± 1.53 g	976.00 ± 50.24 f	4.33 ± 3.21 gh
AS15	0 mM	52.50 ± 3.12 a	54.33 ± 7.75 a	2992.67 ± 505.34 ab	43.33 ± 6.66 abcd
	17mM	45.50 ± 8.05 abcd	50.33 ± 5.58 ab	2957.67 ± 487.45 ab	39.83 ± 20.82 abcde
	34mM	24.67 ± 10.60 bcdef	51.83 ± 9.93 ab	2422.33 ± 154.44 abcde	33.33 ± 2.08 abcdef
	68mM	19.00 ± 3.00 def	15.17 ± 2.25 efg	1820.00 ± 441.40 cdef	19.00 ± 13.11 efgh
	136mM	10.67 ± 7.1 f	5.33 ± 3.79 g	1378.00 ± 369.81 ef	14.67 ± 6.66 fgh
AS25	0 mM	53.50 ± 6.95 a	34.83 ±13.81 abcdef	3494.00 ± 379.57 a	55.67 ± 3.51 a
	17mM	47.83 ± 11.18 ab	27.83 ± 3.75 bcdefg	2498.00 ± 333.83 abcde	28.00 ± 11.79 bcdefg
	34mM	46.33 ± 3.79 abc	35.67 ± 9.31 abcdef	2561.33 ± 139.23 abcd	29.17 ± 2,57 bcdef
	68mM	29.17 ± 10.10 abcdef	19.33 ± 4.48 defg	1771.33 ± 84.58 cdef	14.33 ± 4.51 fgh
	136mM	3.33 ± 2.08 f	6.67 ± 4.04 g	1149.33 ± 119.07 f	3.67 ± 2.52 h
Mean		30.5	30.5	2283.32	30.5
CV		28.90	26.28	16.06	25.61
p-value		6.9e-10 ***	2.06e-11 ***	2.48e-10 ***	7.79e-12 ***

Meaning of codes: 0 (very significant) '***'; 0.001 (significant) '**'; 0.01 (not much significant) '*'. On the same column, the means with different letters allow them to be classified into different groups from the highest rate (a) to the lowest (f).

2.1.2. Effect of salinity on dendrometric parameters at 44 days after sowing (44 DAS)

Table 2 shows the results of the statistical analyses in the Tukey test for the diameter at the collar (DC), the length of the stem (ST), the fresh biomass (FB) and the dry biomass (DB) of the four African varieties of sesame to 44 days after sowing (44 DAS). Whatever the parameter studied, CD (p-value = 7.57e-04 ***), SL (p-value = 2.56e-08 ***), FB (p-value = 2.09e-05 ***) and DB (p-value = 5.43e-07 ***), the differences are statistically very significant. Only the AS15 variety survived under 68 mM NaCl (Table 2).

In the presence of NaCl, the largest collar diameter is that of the AS09 variety at 17 mM, the smallest is that of the AS14 variety at 34 mM but it remains greater than the collar diameter of AS15 at 68 mM NaCl. The collar diameter presents the sesame variety AS09 as the most salt tolerant and AS14 the most sensitive. The collar diameter decreased with increasing salinity (Table 2).

For the length of the stem, the variety AS15 has the largest stem at 17 mM and the shortest but at 68 mM where this variety is the only one to survive. The length of the stem shows that the variety AS15 is more tolerant and AS25 was the most sensitive (Table 2).

Regarding fresh biomass, the AS09 variety at 17 mM has the largest fresh biomass and the lowest is obtained with AS14 at 34 mM but it is higher than that of the AS15 variety at 68 mM. In the presence of sodium chloride, the sesame variety AS14 produced the largest biomass at the concentration of 17 mM and also the lowest at 34 mM but it was greater than that of the variety AS15 at 68 mM (Table 2).

The fresh and dry biomass respectively classify the sesame varieties AS09 and AS15 as the most tolerant, then the varieties AS14 and AS25 more sensitive to NaCl. The increase in the NaCl concentration led to a reduction in the parameter evaluated for all the four African varieties of sesame.

Table 2: The table presents the collar diameter, stem length, fresh biomass and dry biomass of the four African varieties of sesame at 44 days after sowing (44 DAS).

Sesame varieties	NaCl	Rank CD (mm)	SL (cm)	FB (mg)	DB (mg)
AS09	0 mM	37.00 ± 1.00 a	59.37 ± 0.67 abc	14585.33 ± 1480.09 a	2883.33 ± 365.57 a
	17mM	30.67 ± 4.16 ab	54.47 ± 1.75 bcd	10414.00 ± 2529.54 abc	1990.33 ± 395.59 abcd
	34mM	10.50 ± 7.86 bc	44.87 ± 2.32 de	9117.67 ± 1825.72 bcd	1608.33 ± 434.02 cde
	68mM	Nd	Nd	Nd	Nd
	136mM	Nd	Nd	Nd	Nd
AS14	0 mM	23.33 ± 9.5 abc	56.03 ± 4.96 bcd	10536.00 ± 217.11 abc	2417.67 ± 171.74 abc
	17mM	13.83 ± 13.18 abc	52.53 ± 3,04 bcd	9831.00 ± 2144.76 bc	2166.33 ± 306.88 abcd
	34mM	5.00 ± 3.61 c	47.63 ± 2.89 cd	6457.67 ± 450.57 cd	1311.67 ± 43.02 de
	68mM	Nd	Nd	Nd	Nd
	136mM	Nd	Nd	Nd	Nd
AS15	0 mM	30.50 ± 11.43 ab	69.73 ± 7.52 a	11395.33 ± 2847.44 ab	2566.67 ± 503.32 ab
	17mM	23.17 ± 7.97 abc	60.67 ± 2.00 ab	9762.67 ± 244.07 bc	2055.00 ± 23.90 abcd
	34mM	22.50 ± 7.05 abc	44.80 ± 0.53 de	9794.33 ± 1058.47 bc	1918.33 ± 67.99 bcd
	68mM	7.67 ± 5.13 bc	33.90 ± 3.00 e	5005.00 ± 607.58 d	923.00 ± 33.78 e
	136mM	Nd	Nd	Nd	Nd
AS25	0 mM	23.17 ± 8.58 abc	57.93 ± 8.35 abc	10716.67 ± 527.83 abc	2547.67 ± 486.63 ab
	17mM	19.50 ± 2.00 abc	51.33 ± 6.01 bcd	8668.33 ± 467.68 bcd	1742.33 ± 105.98 bcde
	34mM	13.17 ± 10.42 bc	44.07 ±3.78 de	9031.00 ± 1735.79 bcd	1525.33 ± 259.64 cde
	68mM	Nd	Nd	Nd	Nd
	136mM	Nd	Nd	Nd	Nd
Mean		20	52.10	9639.61	1974.54
CV		39.55	8.27	15.74	15.26
p-value		7.57^{e-04} ***	2.56^{e-08} ***	2.09^{e-05} ***	5.43^{e-07} ***

Meaning of codes: 0 (very significant) '***'; 0.001 (significant) '**'; 0.01 (not much significant) '*'. nd: not determined; On the same column, the means assigned different letters allow them to be classified into different groups from the highest rate (**a**) to the lowest **(e**).

2.2 Effect of salinity on physiological parameters (Chlorophylls: Chl a, Chl b and Chl)

2.2.1 Effect of salinity on physiological parameters at 28 days after sowing (28 DAS)

Table 3 shows the results of the Tukey test statistical analyses for chlorophyll a (Chl a), chlorophyll b (Chl b) and total chlorophyll (Chl) of the four African varieties of sesame at 28 days after sowing (28 DAS). The differences are statistically very significant (Chl a and Chl: p-value <$2e^{-16}$ *** and Chl b: p-value = $1.13e^{-07}$ ***) for all treatments between varieties and within the variety (Table 3).

In the presence of NaCl, the lowest production of chlorophylls is noted in the sesame variety AS14 at 136 mM, and the highest in AS15 at 17 mM. The largest quantities of chlorophylls are obtained with the AS15 variety at 17 mM NaCl and the lowest with AS14 at 136 mM. The quantities of chlorophyll a of controls are lower than those at 17 mM for the varieties AS09, AS15 and AS25. The chlorophyll a and b levels produced by the AS25 variety increased with salinity before decreasing to 136 mM. The sesame varieties AS09 and AS25 gave more abundant chlorophylls at 68 mM than at 34 mM sodium chloride and in the absence of NaCl. The chlorophyll content decreased overall for all sesame varieties with the increase in the concentration of NaCl (Table 3).

Table 3: The table presents the chlorophyll a, chlorophyll b and total chlorophyll content of the four African varieties of sesame at 28 days after sowing (28 DAS).

Sesame varieties	NaCl	Chl a(mg/g MF)	Chl b (mg/g MF)	Chl (mg/g MF)
AS09	0 mM	1.34 ± 0.01 gh	0.41 ± 0.01 bcd	1.75 ± 0.02 hijk
	17mM	1.47 ± 0.01 cde	0.43 ± 0.01 bcd	1.91 ± 0.02 efg
	34mM	1.32 ± 0.00 ghi	0.41 ± 0.01 bcd	1.73 ± 0.01 ijk
	68mM	1.38 ± 0.01 fg	0.44 ±0.01 bcd	1.82 ± 0.01 ghi
	136mM	1.27 ± 0.08 ij	0.46 ± 0.15 abcd	1.73 ± 0.12 hijk
AS14	0 mM	1.41 ± 0.01 ef	0.41 ± 0.01 bcd	1.82 ± 0.02 fgh
	17mM	1.34 ± 0.01 ghi	0.39 ± 0.02 cde	1.73 ± 0.02 jk
	34mM	1.38 ± 0.01 fg	0.42 ± 0.02 bcd	1.80 ± 0.01 hij
	68mM	1.24 ± 0.01 j	0.37 ± 0.01 de	1.61 ± 0.02 l
	136mM	1.04 ± 0.01 k	0.30 ± 0.01 e	1.33 ± 0.02 m
AS15	0 mM	1.50 ± 0.01 cd	0.46 ± 0.01 abcd	1.97 ± 0.02 de
	17mM	1.81 ± 0.02 a	0.56 ± 0.01 a	2.37 ± 0.03 a
	34mM	1.53 ± 0.00 c	0.48 ± 0.01 abc	2.01 ± 0.01 cd
	68mM	1.28 ± 0.01 hij	0.40 ± 0.01 bcde	1.69 ± 0.01 kl
	136mM	1.35 ± 0.01 fg	0.46 ± 0.01 abcd	1.81 ± 0.02 hij
AS25	0 mM	1.53 ± 0.01 c	0.45 ± 0.01 bcd	1.98 ± 0.02 de
	17mM	1.53 ± 0.01 c	0.46 ± 0.01 abcd	1.99 ± 0.01 de
	34mM	1.62 ± 0.01 b	0.49 ± 0.01 abc	2.11 ± 0.02 bc
	68mM	1.64 ± 0.00 b	0.51 ± 0.01 ab	2.15 ± 0.01 b
	136mM	1.45 ± 0.00 de	0.47 ± 0.01 abcd	1.91 ± 0.01 ef
Mean		1.42	0.44	1.86
CV		1.45	8.10	1.61
p-value		$<2^{e-16}$ ***	1.13^{e-07} ***	$<2^{e-16}$ ***

Meaning of codes: 0 (very significant) '***'; 0.001 (significant) '**'; 0.01 (not much significant) '*'; On the same column, the means with different letters allow them to be classified into different groups from the highest rate (**a**) to the lowest (**m**).

2.2.2 Effect of salinity on physiological parameters at 44 days after sowing (44 DAS)

Table 4 shows the results of the statistical analyses in the Tukey test for chlorophyll a (Chl a), chlorophyll b (Chl b) and total chlorophyll (Chl) of the four African varieties of sesame at 44 days after sowing (44 DAS). The differences are statistically very significant within the variety and between varieties (Chl a and Chl: p-value $<2e^{-16}$ *** and Chl b: p-value = $4.65e^{-15}$ ***). The highest chlorophyll contents are obtained with the sesame variety AS15 at 34 mM NaCl and the lowest with AS14 at 17 mM. The quantities of chlorophylls at 17 mM NaCl decreased for the sesame varieties AS14 and AS15 compared to those of their controls. At 68 mM NaCl, only the chlorophyll a and b contents of the variety AS15 are determined, they remain higher than those of all the sesame varieties at 17 mM and in the absence of salt. The chlorophyll contents (Chl a, Chl b, Chl) increased with salinity for the four African varieties of sesame (Table 4).

Tableau 4: The table presents the chlorophyll a, chlorophyll b and total chlorophyll content of the four African varieties of sesame at 44 days after sowing (44 DAS).

Sesame varieties	NaCl	Rank Chl a (mg/g MF)	Rank Chl b (mg/g MF)	Rank Chl (mg/g MF)
AS09	0 mM	17.00 ± 1.00 fg	18.00 ± 3.00 de	17.67 ± 1.53 fg
	17mM	20.00 ± 0.87 ef	18.00 ± 3.00 de	19.33 ± 2.08 ef
	34mM	29.00 ± 1.00 c	26.50 ± 1.73 bc	28.00 ± 1.00 c
	68mM	Nd	Nd	Nd
	136mM	Nd	Nd	Nd
AS14	0 mM	11.00 ± 0.87 hi	10.83 ± 1.44 efg	11.00 ± 1.00 hi
	17mM	5.00 ± 0.87 jk	3.50 ± 2.60 g	5.00 ± 0.87 jk
	34mM	23.00 ± 1.00 de	21.67 ± 3.21 cd	23.00 ± 1.00 de
	68mM	Nd	Nd	Nd
	136mM	Nd	Nd	Nd
AS15	0 mM	34.00 ± 0.00 b	32.67 ± 1.53 ab	34.00 ± 1.00 ab
	17mM	14.00 ± 0.87 gh	16.17 ± 4.37 def	14.00 ± 1.00 gh
	34mM	38.00 ± 1.00 a	38.00 ± 1.00 a	38.00 ± 1.00 a
	68mM	26.00 ± 1.00 cd	31.00 ± 4.00 ab	27.00 ± 2.65 cd
	136mM	nd	Nd	Nd
AS25	0 mM	2.00 ± 1.00 k	3.67 ± 1.44 g	2.00 ± 0.87 k
	17mM	8.00 ± 0.87 ij	8.17 ± 1.76 fg	8.00 ± 1.00 ij
	34mM	33.00 ± 2.65 b	31.83 ± 3.82 ab	33.00 ± 2.65 b
	68mM	nd	Nd	Nd
	136mM	nd	Nd	Nd
Mean		20	20	20
CV		5.67	13.75	7.49
p-value		$<2^{e-16}$ ***	4.65^{e-15} ***	$<2^{e-16}$ ***

Meaning of codes: 0 (very significant) '***'; 0.001 (significant) '**'; 0.01 (not much significant) '*'. **Nd**: not determined; On the same column. The means with different letters allow them to be classified into different groups from the highest rate (**a**) to the lowest (**k**).

4. DISCUSSION

Our study revealed that all the growth parameters (diameter at the collar, length of the stem, fresh biomass and dry biomass) decreased in proportion to the concentration of NaCl within the same variety. The statistical analyses showed high significant differences at 28 days after sowing (CD: p-value = $6.9e^{-10}$ ***, SL: p-value = $2.06e^{-11}$ ***, FB : p-value = $2.48e^{-10}$ *** and DB: p-value = $7.79e^{-12}$ ***) and 44 days after sowing as well (CD: p-value = $7.57\ e^{-04}$ ***, SL: p-value = $2.56e^{-08}$ ***, FB: p-value = $2.09e^{-05}$ *** and DB: p-value = $5.43e^{-07}$ ***) for the collar diameter (DC), stem length (LT), fresh biomass (BF) and dry biomass (BS) of the four African varieties of sesame (Table 1 and 2). These results agree in part with those of Bekele et al. (2017) who showed a significant difference in plant length and dry biomass at 28 days after sowing and 44 days after sowing for fifteen varieties (cultivars) of sesame in the presence of 50, 100 and 150 mM NaCl. These same results also gave a negative correlation between stem length, biomass and salinity [6].

The collar diameter of all sesame varieties is significantly reduced to 28 days after sowing and 44 days after sowing with NaCl, the reduction is proportional to the concentration (Table 1 and 2). This depressive effect of NaCl on the collar diameter was found in 13 varieties of roselle [16], in *Jatropha curcas* L. [13] and in six varieties of *Acacia* [7].

The increase in NaCl concentrations resulted in a very significant reduction in the stem length of all African varieties of sesame regardless of the period considered (Table 1 and 2). These results agree with those of Bekele et al., (2017) who showed a reduction in the length of the stem very significantly in different varieties of sesame (*Sesamum indicum* L.) [6]. This reduction of the stem by salinity has been noted in different plant species: roselle [16], *Atriplex* [17], wheat (*Triticum aestivum* L.) [18], *Acacia* [7]. The fresh biomass is negatively affected by the salinity for all varieties of sesame in the two periods (28 DAS and 44 DAS) (Table 1 and 2). Similar results are obtained by Bouda and Haddioui (2011) who observed in six species of *Atriplex* a decrease in fresh biomass (fresh weight) with the increase in NaCl concentration [17]. The results of Bahrani and Joo (2012) corroborate also in wheat (*Triticum aestivum* L.) [18].

Moreover, their NaCl concentration caused a significant drop in dry biomass at 28 days and 44 days after sowing for the four African varieties of sesame (Table 1 and 2). Bekele et al., (2017) had identical results at the same periods with fifteen varieties (cultivars) of sesame in the presence of 50, 100 and 150 mM NaCl [6]. This negative effect of NaCl on dry biomass is noted in various species such as roselle [16], wheat (*Triticum aestivum* L.) [18], pepper (*Capsicum annuum* L.) [19], green bean (*Phaseolus vulgaris* L.) [20], *Acacia* [7].

All the growth parameters (collar diameter, stem length, fresh biomass and dry biomass) of the four African varieties of sesame are reduced in proportion to the different NaCl concentrations (Table 1 and 2). A similar result was found by Bahrani and Joo (2012) in wheat (*Triticum aestivum* L.) [18]. The reduction in plant growth is explained by the fact that salinity inhibits cell division and growth [21, 22]. The depressive effect of salt (NaCl) is also accompanied by nutritional changes [23]. Statistical analyses on the Tukey test showed very significant differences both at 28 days (Chl a and Chl: p-value $<2e^{-16}$ *** and Chl b: p-value = $1.13e^{-07}$ ***) only 44 days after sowing (Chl a and Chl: p-value $<2e^{-16}$ *** and Chl b: p-value = $4.65e^{-15}$ ***) chlorophyll a, b and total contents of the four African varieties of sesame (Table 3 and 4).

The chlorophyll contents (Chl a, Chl b and Chl) of the four African varieties of sesame (*Sesamum indicum* L.) overall decreased significantly as a function of the NaCl concentration at 28 days after sowing (Table 3). This reduction in the amount of chlorophylls by increasing NaCl concentrations is obtained in tomatoes (*Lycopersicon esculentum* and *Lycopersicon sheesmanii*) [24], peanut [25], bananas (*Musa acuminata* L) [26], pepper (*Capsicum annuum* L.) [19] and green bean (*Phaseolus vulgaris* L.) [20]. It is explained by the stimulation of the enzymatic activity of chlorophyllase by salinity [27] or by the destruction of the precursors of chlorophyll or the conversion of the latter into other pigments [28]. The chlorophyll contents of the sesame varieties AS09, AS15 and AS25 at 17 mM NaCl are higher than those of the controls. These results agree with those of Sivasankaramoorthy (2013) who observed an increase in photosynthetic pigments (chlorophylls a, b, total and carotenoids) in *Cajanus cajan* L. at concentrations 5 and 10 mM NaCl [28]. The quantities of chlorophylls from varieties AS09 and AS25 at 68 mM increased compared to those at 34 mM and the absence of NaCl. These results corroborate those of Thouraya et al., (2013) who showed an increase in chlorophyll a and total in a variety of pepper (*Capsicum annuum* L.) at 50 mM compared to 25 mM and in the control [19].

The chlorophyll contents (Chl a, Chl b, Chl) of the four African sesame varieties increased with salinity to 44 days after sowing (Table 4). The AS15 variety has the highest amounts of chlorophylls. Hussein et al. (2012) showed an increase proportional to the salinity of the quantities of chlorophylls a, b and total in the pepper [29]. These results also agree with those of Akhzari and Aghbash (2013) who obtained an increase in the quantity of chlorophylls with salinity in vetiver grass (*Vetiveria zizanioides* stapf.) [30]. Moreover, the increase in the amounts of chlorophylls is due to the inhibition of the activity of chlorophyllase since its decrease results from the stimulation of the activity of this enzyme [30, 27].

5. CONCLUSION

The effect of sodium chloride (NaCl) on the growth and physiology of four African sesame varieties was studied in the greenhouse at 28 days and 44 days after sowing. All the growth parameters (diameter at the collar, length of the stem, fresh biomass and dry biomass) decreased in proportion to the concentration of NaCl within the same variety. The physiological parameters (chlorophyll a, chlorophyll b and total chlorophyll contents) showed two different responses for the two evaluation periods. At 28 days after sowing the amounts of chlorophylls generally decreased with the increase in NaCl concentrations, while at 44 days after sowing these contents increased with salinity. The depressive effect of sodium chloride (NaCl) on the parameters studied varied according to the four African varieties of sesame (*Sesamum indicum* L.) and salt concentrations. The results showed that variety of sesame AS15 is more tolerant to salinity.

6. REFERENCES

1. Faye, B., Tine, D., Dethié, N., Cheikh, D., Faye, G., and Ndiaye, A. Évolution des terres salées dans le nord de l'estuaire du Saloum (Sénégal). *Géomorphologie : relief, processus, environnement*. 2019; 25(2) : 81‑90. Available: http://journals.openedition.org/geomorphologie/13125
2. Munns, R., and Tester, M. Mechanisms of Salinity Tolerance. *Annual Review of Plant Biology*. 2008; 59(1): 651‑681. Available: https://www.annualreviews.org/doi/pdf/10.1146/annurev.arplant.59.032607.092911
3. Fahramand, M., Mahmoody, M., Keykha, A., Noori, M., and Rigi, K. Influence of abiotic stress on proline, photosynthetic enzymes and growth. *Int Res J Appl Basic Sci*. 2014; 8(3) : 257–265. Available: http://www.irjabs.com/files_site/paperlist/r_2135_140515005216.pdf
4. Ndiaye, A., Faya, E., and Touré, M. Effets du stress salin sur la germination des graines de *Gossypium hirsutum* L. *Journal of Applied Biosciences*. 2014; 80(1) : 7081 – 7092. Available: http://dx.doi.org/10.4314/jab.v80i1.5
5. Denden, M., Bettaieb, T., Salhi, A., and Mathlouthi, M. Effet de la salinité sur la fluorescence chlorophyllienne, la teneur en proline et la production florale de trois espèces ornementales. *Tropicultura*, 2005; 4(23): 220‑225. Available: http://www.tropicultura.org/text/v23n4/220.pdf
6. Bekele, A., Besufekad, Y., Adugna, S., and Yinur, D. Screening of selected accessions of Ethiopian sesame (*Sesamum indicum* L.) for salt tolerance. *Biocatalysis and Agricultural Biotechnology*. 2017; 9 : 82‑94. Available: http://dx.doi.org/10.1016/j.bcab.2016.11.009
7. Cherifi, K., Anagri, A., Boufous, E. H., and Mousadik, A. E. Effet du Chlorure de sodium (NaCl) sur la croissance de six espèces d'*Acacia*. *American Journal of Innovative Research and Applied Sciences.* 2017; 4(4): 105-113. Available: https://hal.archives-ouvertes.fr/hal-01635942
8. Mishra, P. K., Paroha, S., and Prakash Mishra, R. Assessment of Storage Dependent Physiological Parameters of *Sesamum indicum* seeds. *International Journal of Current Microbiology and Applied Sciences*. 2016; 5(1): 641‑653. Available: http://dx.doi.org/10.20546/ijcmas.2016.501.065
9. Walter, O.-A., Patrick, R., Paul, G., and Patrick, O. Genotype by environment interaction in sesame (*Sesamum indicum* L.) cultivars in Uganda. *African Journal of Plant Science*. 2016; 10(10): 189‑202. Available: https://pdfs.semanticscholar.org/3e0a/27842f0e1d0bae477646b6e48d07b98c6034.pdf
10. Sene, B., Sarr, F., Diouf, D., Sow, M. S., Traore, D., Kane, A., and Niang, M. Synthèse des connaissances et quelques acquis de recherche sur le sésame (*Sesamum indicum* L.) au Sénégal. *International Journal of Biological and Chemical Sciences*. 2018; 12(3): 1469-1483. Available: https://www.ajol.info/index.php/ijbcs/article/view/179442
11. Harfi, M. E., Hanine, H., Rizki, H., Latrache, H., and Nabloussi, A. Effect of Drought and Salt Stresses on Germination and Early Seedling Growth of Different Color-seeds of Sesame (*Sesamum indicum* L.). *International Journal of Agriculture and Biology*. 2016; 18(06): 1088‑1094. Available: https://pdfs.semanticscholar.org/7696/7ea79b957e2cb5ffd52dd788f982fef49162.pdf
12. Maas, E. V., and Poss, J. A. Salt sensitivity of cowpea at various growth stages. *Irrigation Science*. 1989; 10: 313-320. Available: https://link.springer.com/article/10.1007/BF00257496
13. Ly, M., Kumar, D., Diouf, M., Nautiyal, S., and Diop, T. Effet de la salinité sur la croissance et la production de biomasse de deux provenances de *Jatropha curcas* L. cultivés en serre. *International Journal of Biological and Chemical Sciences*. 2014; 8(1): 46. Available: https://www.ajol.info/index.php/ijbcs/article/view/104031
14. Faye, E., Camara, M., Toure, M., and Mbaye, A. Evaluation et amélioration du comportement de *Atriplex lentiformis* (Torr.) S. Watson en milieux salés au Sénégal. *International Journal of Biological and Chemical Sciences*. 2015; 8(4): 1697. Available: https://www.ajol.info/index.php/ijbcs/article/view/111404
15. Arnon, D. I. Copper enzymes in isolated chloroplasts. *Polyphenoloxidase in Beta vulgaris. Plant Physiology*. 1949; 24(1), 1‑15. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC437905/
16. Lepengue, A. N., Mouaragadja, I., Cherif, M., and M'Batchi, B. Effet du chlorure de sodium (NaCl) sur la croissance de la roselle au Gabon. *Afrique Science.* 2009; 5(3), 97‑110. Available: http://www.afriquescience.info/docannexe.php?id=1689
17. Bouda, S., and Haddioui, A. Effet du stress salin sur la germination de quelques espèces du genre *Atriplex*. *Nature & Technologie*. 2011; 72‑79. Available: https://www.univ-chlef.dz/RevueNatec/art_05_09.pdf
18. Bahrani, A., and Joo, M. H. Response of Some Wheat (*Triticum aestivum* L.) Genotypes to Salinity at Germination and Early Seedling Growth Stages. *World Applied Sciences Journal*. 2012; 16 (4): 599-609. Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.390.496&rep=rep1&type=pdf
19. Thouraya, R., Imen, I., Imen, H., Riadh, I., Ahlem, B., and Hager, J. Effet du stress salin sur le comportement physiologique et métabolique de trois variétés de piment (*Capsicum annuum* L.). *Journal of Applied Biosciences.* 2013; 66(0): 5060 – 5069. Available: https://www.ajol.info/index.php/jab/article/view/95004
20. Taïbi, K., Taïbi, F., Ait Abderrahim, L., Ennajah, A., Belkhodja, M., and Mulet, J. M. Effect of salt stress on growth, chlorophyll content, lipid peroxidation and antioxidant defence systems in *Phaseolus vulgaris* L. *South African Journal of Botany*. 2016; 105: 306‑312. Available: http://dx.doi.org/10.1016/j.sajb.2016.03.011
21. Maaouia-Houimli, S. I., Denden, M., and Dridi-Mouhandes, B. Caractéristiques de la croissance et de la production en fruits chez trois variétés de piment (*Capsicum annuum* L.) sous stress salin. *Tropicultura*. 2011; 29(2): 75‑81. Available: http://www.tropicultura.org/text/v29n2/75.pdf
22. Zhu, J.-K. Salt and Drought Stress Signal Transduction in Plants. *Annual Review of Plant Biology*. 2002; 53(1): 247‑273. Available: http://dxdoi:10.1146/annurev.arplant.53.091401.143329

23. Khaled, L. B., Ouarraqi, E. M., and Zid, E. Impact du NaCl sur la croissance et la nutrition de la variété de blé dur Massa cultivée en milieu hydroponique. *Acta Botanica Gallica*. 2007; 154(1) : 101‑116. Available: http://dx.doi.org/10.1080/12538078.2007.10516047
24. El-Iklil, Y., Karrou, M., Mrabet, R., and Benichou, M. Effet du stress salin sur la variation de certains metabolites chez *Lycopersicon esculentum* et *Lycopersicon sheesmanii*. *Canadian Journal of Plant Science*. 2002; 82(1): 177‑183. Available: https://www.nrcresearchpress.com/doi/pdf/10.4141/P00-175
25. Al-Khaliel, A. S. Effect of salinity stress on mycorrhizal association and growth response of peanut infected by *Glomus mosseae*. *Plant, Soil and Environment*. 2010; 56(7) : 318‑324. Available: https://www.agriculturejournals.cz/publicFiles/204_2009-PSE.pdf
26. Belfakih, M., Ibriz, M., and Zouahri, A. Effet de la salinité sur les paramètres morphophysiologiques de deux variétés de bananier (*Musa acuminata* L*). Journal of Applied Biosciences*, 2013; 70(1): 5652– 5662. Available: https://www.ajol.info/index.php/jab/article/view/98808
27. Reddy, M. P., and Vora, A. B. Salinity induced changes in pigment composition and chlorophyllase activity of wheat. Indian I. Plant Phy,Iol., 1986; XXIX(4): 331‑334. Available: https://www.samviti.com/img/1341/society/publication/ijpp-29o-4-006.pdf
28. Sivasankaramoorthy, S. Effect of NaCl salinity on germination, growth and photosynthetic pigments of *Cajanus cajan* L.. International *Journal of Research in Plant Science*. 2013; 3(4): 68‑71. Available: https://www.japsonline.com/abstract.php?article_id=709&sts=2
29. Hussein, M. M., El-Faham, S. Y., and Alva, A. K. Pepper plants growth, yield, photosynthetic pigments, and total phenols as affected by foliar application of potassium under different salinity irrigation water. *Agricultural Science*. 2012; 03(02): 241‑248. Available: http://dx.doi.org/10.4236/as.2012.32028
30. Akhzari, D., and Aghbash, F. G. Effect of Salinity and Drought Stress on the Seedling Growth and Physiological Traits of Vetiver Grass (*Vetiveria zizanioides* stapf.). *Ecopersia*. 2013; 1 (4): 339-352. Available: https://journals.modares.ac.ir/files/ecopersia/user_files_749497/archive_global-A-24-1000-6226-c157565.pdf

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