International Journal of Science, Environment and Technology, Vol. 9, No 6, 2020, 834 – 843

ISSN 2278-3687 (O)
2277-663X (P)

EFFECT OF ARBUSCULAR MYCORRHIZAL FUNGI ON SESAME PRODUCTIVITY UNDER SALINITY CONDITIONS

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Abstract: Salinity, a constantly increasing global phenomenon, limits the supply of water and mineral elements to plants and their productivity, especially in arid and semi-arid areas. Arbuscular mycorrhizal fungi improving the hydromineral nutrition of plants and their tolerance to biotic and abiotic stresses make it possible to combat the negative effect of salinity. The general objective of this work was to study the effect of salinity on mycorrhization and sesame production in the greenhouse.

The impact of salinity on mycorrhization, yield of four African sesame varieties (AS09, AS14, AS15 and AS25) inoculated with *Gigaspora rosea* and *Rhizophagus intraradices* was evaluated in the greenhouse. The experimental set-up was in randomized blocks with three factors and three replicates.

The frequency of mycorrhization (73.33 to 100%) is high and remains higher than the intensity of mycorrhization (9.17 to 67.17%). The increase in NaCl reduced the rate of mycorrhization. The number of mature capsules per plant and the yield decreased with increasing concentration of NaCl, the fungus and the sesame variety. Salinity reduced yield and yield components. *G. rosea* reduces the depressive effect of NaCl on sesame yield.

Keyswords: Salinity, Sesame, yield, *Gigaspora rosea*, *Rhizophagus intraradices*.

INTRODUCTION

Salinity is an environmental problem. It causes soil degradation, limits the growth and productivity of plants, especially in arid and semi-arid regions (Diallo et al., 2016; Hanin et al., 2016; Djighaly et al., 2018). The rehabilitation of salty lands is a priority to improve food security in semi-arid areas including Senegal (Djighaly et al., 2018) where saline lands have increased by an average of 1,000 hectares per year since 1994 (Faye et al., 2019). Soil salinity reduces water uptake by plants (Munns, 2010). Adapting crops to salinity is one of the greatest challenges of modern agriculture (Hanin et al., 2016).

*Received Oct 16, 2020 * Published Dec 2, 2020 * www.ijset.net*

In semi-arid areas poor in nutrients, plant growth is highly dependent on soil microorganisms, in particular arbuscular mycorrhizal fungi (Nouaim et Chaussod, 1996 ; Bonfante et Genre, 2010).

Indeed, arbuscular mycorrhizal fungi are an alternative and a sustainable strategy for increasing production in saline soils (Hanin et al., 2016). They constitute a promising means for improving sesame productivity in semi-arid zones (Diouf et al., 2009). Selection of the appropriate mycorrhizal fungus is necessary to increase plant productivity on saline soils (Djighaly et al., 2018). Mycorrhizal symbiosis improves hydromineral nutrition, increases plant biomass and plant resistance to stress including salinity (Perrin, 1985; Nouaim et Chaussod, 1996 ; Bonfante et Genre, 2010). The impact of mycorrhization on the productivity of sesame has not yet been studied in Senegal in a salty environment. Thus, in a context of galloping land salinization, it would be important to determine the symbiotic couples capable of minimizing the depressive effect of salinity on sesame productivity.

The objective of this work was to evaluate the effect of salinity on mycorrhization and production of four African varieties of sesame inoculated with Gigaspora rosea and Rhizophagus intraradices.

MATERIAL AND METHODS

1. Plant material, fungal and growing medium

The plant material obtained after screening with salinity consists of the seeds of four African varieties of sesame from Mali (AS09), Cameroon (AS14), Sudan (AS15) and Togo (AS25). The fungal material consists of arbuscular mycorrhizal fungi (AMF) *Rhizophagus intraradices* (NC Schenck & GS Sm.) C. Walker & A. Schuessler and Gigaspora rosea TH Nicolson & NC Schenck, from the collection of the Mushroom Biotechnology Laboratory of the department of plant biology from the Faculty of Sciences of the University Cheikh Anta Diop in Dakar. The substratum consists of soil taken between 0 and 20 cm deep in the botanical garden of the said department. The physicochemical characteristics of the substrate are listed in Table 1

Table 1: Soil characteristics

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. Experimental setup

The experimental set-up consists of randomized random blocks with three factors and three repetitions. The sesame variety factor is made up of four modalities (AS09, AS14, AS15 and AS25), the salinity factor has three modalities (0 mM, 17 mM and 34 mM) and the inoculation factor consists of two modalities (inoculated with *Rhizophagus intraradices* (Ri) and inoculated with *Gigaspora rosea* (Gr)). The mycorrhizal inoculum composed of a mixture of spores, fungal propagules, fragments of mycorrhizal roots and soil. The experimental unit is represented by a pot containing 1.5 kg of the culture medium. Inoculation of sesame plants is done one week after sowing the seeds (Diallo et al., 2016). It consists of placing 20 g of inoculum in 2 to 3 cm holes in contact with the root system of the plants (Leye et al., 2015). A light watering is then carried out to compact the soil. The control received 20 g of sterile soil (Boureima et al., 2008). In each pot two plants were kept. The saline constraint is applied by watering from three weeks after inoculation in order to allow the installation of the mycorrhization (Manga et al., 2017). Watering to capacity in the field is done every two days with the corresponding solution (non-saline for the controls and saline for the other treatments) until the end of the plant cycle (maturity of the capsules) in order to avoid any water deficit (Diouf et al., 2009; Ly et al., 2014).

3. Measured parameters

The mycorrhization of the roots is verified by histological examination under an optical microscope at x100 magnification (Diallo et al., 2016). The mycorrhization and yield parameters are evaluated at harvest (Djatta et al., 2014). The roots are rinsed thoroughly with tap water to remove sand particles. They are then placed in test tubes containing a 10% KOH solution. The tubes are brought to the boil in a water bath at 95 ° C. for 1 hour to discolor the roots and empty the cytoplasm of the root cells. The discolored roots are rinsed 3 times with tap water and then stained with 5% Trypan blue. Then, 10 root fragments of 1 to 2 cm are mounted between slide and coverslip in a drop of glycerol. The intensity of mycorrhization of the roots is evaluated according to the method of Trouvelot et al. (1986).

The seed yield, the number of capsules per plant and the number of mature capsules per plant were determined. The number of capsules per plant is counted at maturity. The seed yield in grams per plant was weighed with a precision balance.

4. Statistical analyses

Statistical analyses are performed with R software version 3.6.3 (2020-02-29). All data were subjected to the Shapiro-Wilk normality test. Statistical processing of normally distributed data is performed 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 means. The Tukey test at the 5% probability threshold is performed in order to compare and rank the means or ranks on the means of the variables evaluated. The frequency and intensity of mycorrhization are also tested by Pearson's Chi-square test.

RESULTS

1. Effect of NaCl on mycorrhization.

The mycorrhization frequency (FM) is 100% for the control treatments of the sesame varieties AS09, AS15 and AS25 inoculated with *Gigaspora rosea* (Gr). The lowest frequency of mycorrhization (73.73 ± 5.77%) is noted in the presence of 17 mM of NaCl by the variety of sesame AS09 inoculated with the same fungus (*G. rosea*). The highest intensity of mycorrhization (67.17 ± 2.84%) is obtained in the absence of salinity (control) with the sesame variety AS25 inoculated with the AMF *G. rosea*, the lowest (9.17 ± 6.55 %) is recorded with 34 mM NaCl in the sesame variety AS09 inoculated with the same fungus. The intensity of mycorrhization is reduced by increasing the concentration of NaCl. This intensity is greater than 25% in the sesame variety AS15 for all treatments. The frequency of mycorrhization is greater than 70% for all treatments. The intensity of mycorrhization is greater than 25% in the AS15 sesame variety regardless of the treatment (Figure 1).

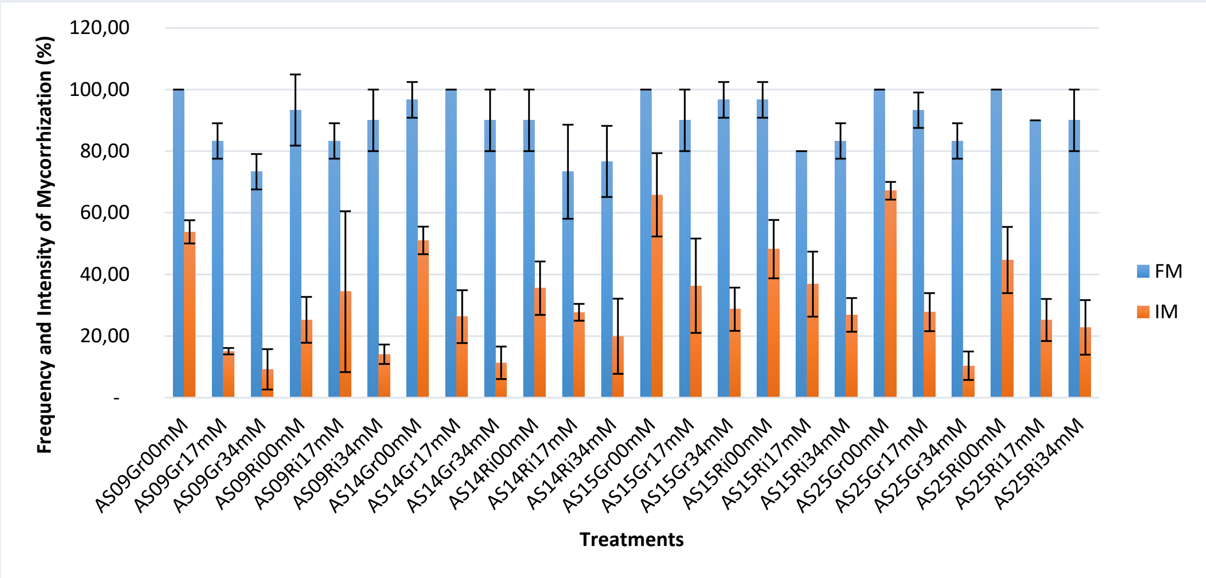

Figure 1: Frequency and intensity of mycorrhization under salt stress of four African varieties of sesame (AS09, AS14, AS15 and AS25) inoculated with *Gigaspora rosea* (Gr) and *Rhizophagus intraradices* (Ri).
Gr: *Gigaspora rosea*; Ri: *Rhizophagus intraradices*; FM: frequency of mycorrhization; MI: intensity of mycorrhization

2. Effect of NaCl on the number of mature capsules per plant

The greatest number of mature capsules per plant is 16.33 ± 1.53. It is obtained in the presence of 17 mM of NaCl in the variety of sesame AS25 inoculated with *R. intraradices*. Inoculated with the same fungus, the AS15 variety gave the lowest number of mature capsules per plant with 17 and 34 mM NaCl. Inoculation of the sesame variety AS09 with *G. rosea* increased the number of mature capsules per plant compared to that with *R. intraradices*. The number of mature capsules produced by the sesame variety AS25 is higher than that of the other varieties regardless of the treatment considered (Table 2).

Table 2: Number of mature capsules per plant produced in the presence of different concentrations of NaCl by four African varieties of sesame (AS09, AS14, AS15 and AS25) inoculated with *Gigaspora rosea* and *Rhizophagus intraradices*.

		Number of mature capsules		
Sesame Varieties	**Inoculations**	**0 mM**	**17 mM**	**34 mM**
AS09	Gr	10,67 ± 2,08 ^{abcde}	9,33 ± 2,08 ^{abcde}	9,33 ± 3,79 ^{abcde}
	Ri	7,67 ± 2,08 ^{cde}	7,67 ± 2,08 ^{cde}	8,33 ± 2,08 ^{bcde}
AS14	Gr	11,67 ± 2,08 ^{abcde}	14,00 ± 3,61 ^{abc}	11,33 ± 1,15 ^{abcde}
	Ri	11,67 ± 2,08 ^{abcde}	15,00 ± 3,46 ^{ab}	10,67 ± 1,53 ^{abcde}
AS15	Gr	6,33 ± 0,58 ^{de}	6,33 ± 0,58 ^{de}	6,33 ± 0,58 ^{de}
	Ri	9,00 ± 0,00 ^{bcde}	6,00 ± 1,00 ^{e}	6,00 ± 1,00 ^{e}
AS25	Gr	15,00 ± 3,61 ^{ab}	14,00 ± 1,00 ^{abc}	11,67 ± 1,53 ^{abcde}
	Ri	13,33 ± 4,51 ^{abcd}	16,33 ± 1,53 ^{a}	11,33 ± 3,21 ^{abcde}
Mean			10,37	
CV			22,05	
p-value			1,77e^{-07} ***	

Significant. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '' 1. In the same column, the means assigned the same letters do not show significant differences.

3. Effect of NaCl on seed yield per plant

The greatest seed weight per plant of 2111.67 ± 453.18 mg is produced in the presence of 17 mM NaCl by the sesame variety AS25 inoculated with *G. rosea*. The smallest weight (815.00 ± 378.59 mg) is obtained as the control of the variety AS09 inoculated with *R. intraradices*. Salinity from 17 mM caused a decrease in seed yield per plant. This yield is higher in sesame varieties AS09 and AS25 inoculated with *G. rosea* compared to inoculation with *R.*

intraradices. The yields are generally higher especially in the presence of NaCl for inoculation with *G. rosea* (Figure 2).

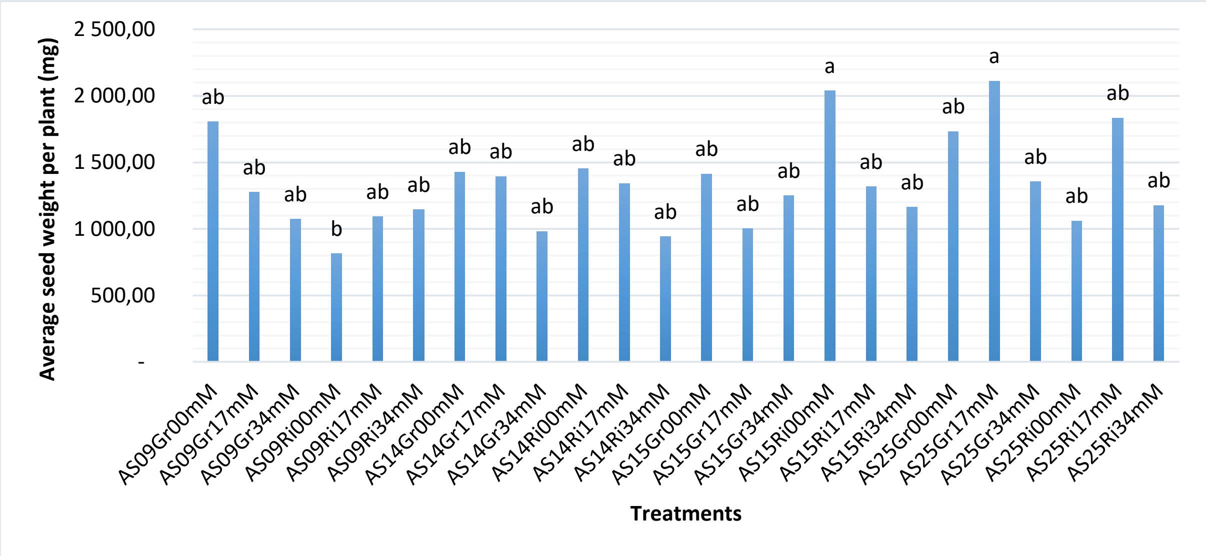

Figure 2: Effect of salinity on the average seed yield per plant in four African varieties of sesame (AS09, AS14, AS15 and AS25) inoculated with *Gigaspora rosea* and *Rhizophagus intraradices*.

Bars with the same letters are not significantly different at the 5% threshold according to the Tukey test.

DISCUSSION

Statistical analyses show a significant decrease in the frequency and intensity of mycorrhization with increasing NaCl concentration (Figure 1). This reduction is explained by the salinity which decreases the infectivity and the number of spores of arbuscular mycorrhizal fungi (Djighaly et al., 2020). Salinity influences the structure of mycorrhizal fungi and negatively affects their development (Samba-Mbaye et al., 2020). Mycorrhization depended on the strain inoculated and overall decreased with increasing salinity (Figure 1). Djighaly et al. (2018) showed a significant decrease in mycorrhization due to increased salinity in *Casuarina equisetifolia* L. and *Casuarina glauca* Sieb. These results agree with those of Manga et al. (2017) who obtained, in *Acacia seyal* inoculated with different fungal isolates, a variation in mycorrhization depending on the isolate used and its reduction with increasing salinity. Similar results were obtained in Fenugreek (*Trigonella foenum-graecum*) inoculated under salt stress with *Rhizophagus intraradices* (formerly *Glomus intraradices*) (Evelin et al., 2012). Salinity reduces mycorrhization and spore formation by *Gigaspora rosea* and *Rhizophagus clarus* (Ertump et al., 2019). The reduction in mycorrhization with increasing salinity is explained by a decrease in the ability of the fungus to colonize the roots due to a decrease in antioxidant activities and the synthesis of non-enzymatic antioxidant molecules. Despite its decrease, mycorrhization remains beneficial and improves tolerance to salt stress for the host plant (Evelin and Kapoor, 2014).

The frequency of mycorrhization of the four sesame varieties decreased significantly with increasing salinity when inoculation with *G. rosea*. However, it increased significantly with NaCl for inoculation with *Rhizophagus intraradices* (Ri), but it was still lower than that of the controls (0 mM NaCl) (Figure 1). Each strain of mycorrhizal fungus is characterized by a specific interaction with the host plant resulting in a diversity of responses associated with NaCl concentrations (Manga et al., 2017).

The intensity of mycorrhization is reduced by the increase in salinity, it remains below 50% (Figure 1). Diallo et al. (2016) obtained similar results in castor bean (*Ricinus communis* L.). This reduction does not prevent mycorrhization from being beneficial to the host plant (Evelin and Kapoor, 2014).

The number of capsules per plant (Table 2) and the seed yield (Figure 2) varied according to the varieties of sesame. These different parameters depend on the variety of sesame (Ismaan et al., 2020). The increased salinity resulted in a decrease in the number of mature capsules per plant (Table 2). Ben Ahmed et al. (2008) found in foxtail (*Setaria verticillata* L.) a reduction in yield components with increasing NaCl. This decrease in the morphological parameters of the fruit by the increase in salinity has been observed in chili peppers (Maaouia-Houimli et al., 2011). This reduction results from an inhibition of plant growth caused mainly by difficulties in the supply of water and nutrients, and / or the toxicity of ions accumulated in excess in the plant (Ben Ahmed et al., 2008).

Statistical analysis of the results shows a very significant difference (p-value = $1.77^{e\text{-}07\ ***}$) for the number of mature capsules per plant (Table 2). Maaouia-Houimli et al. (2011) showed a reduction in the number of fruits per plant in chili peppers but without significant difference between the different concentrations of NaCl.

The seed yield per plant decreased with increasing salinity for all sesame varieties and regardless of the fungus used in inoculation (Figure 2). Reduction in seed yield by salinity has been observed in soybeans (Ghassemi-Golezani et al., 2011). Salinity decreases the enzymatic activity of plants, the osmotic potential of the soil; which negatively affects the hydromineral nutrition of the plant, its growth and its production (Doudech et al., 2008; Hanin et al., 2016).

The number of capsules per plant (Table 2) is more negatively affected by salinity than the seed yield (Figure 2). These results are contrary to those of Suassuna et al. (2017) who showed in three sesame genotypes that the number of capsules per plant is less affected by salinity than the mass of seeds per plant. Salinity reduces the growth and mineral nutrition of soybeans (*Glycine max*) even in the presence of mycorrhization (Ertump et al., 2019).

CONCLUSION

The effect of salinity was evaluated on mycorrhization and sesame production in the greenhouse. Mycorrhization decreased with increasing salinity. The number of capsules per plant, and the seed yield depend on the variety of sesame. The salinity caused a decrease in the number of mature capsules per plant. Inoculation of sesame with *G. rosea* further improved yields especially in the presence of NaCl.

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