ORIGINAL ARTICLE

EFFECT OF ARBUSCULAR MYCORRHIZATION ON THE PRODUCTIVITY OF FOUR AFRICAN VARIETIES OF SESAME UNDER CONTROLLED CONDITIONS

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ABSTRACT

Introduction: Arbuscular mycorrhizal fungi form common and widespread associations with 80 % of terrestrial plants. Mycorrhizae are beneficial for plants and environment, especially in arid and semi-arid areas. Mycorrhization varies depending on plants and fungi. **Objective:** The aim of this work is to assess the impact of mycorrhization on the productivity of four African varieties of sesame (*Sesamum indicum* L.) under controlled conditions. **Methods:** The effect of *Gigaspora rosea* and *Rhizophagus intraradices* inoculation on four African sesame varieties (AS09, AS14, AS15 and AS25) was evaluated in the greenhouse. **Results:** The experimental system consists of randomized blocks with two factors and three repetitions. The results showed that, on sterile soil without inoculation there is no mycorrhization. The frequency of mycorrhization is greater than 80 % for inoculated plants, it is 100 % with *Gigaspora rosea*. The intensity of mycorrhization for *R. intraradices* is less than 50 % but greater than this value with *G. rosea*. Mycorrhization increased the mass yield of seeds per plant. **Conclusion:** Mycorrhization is more significant with *G. rosea* which has led to an increase in the number of seeds per capsule for the sesame varieties AS09, AS14 and AS15. Yield and mycorrhizal parameters are related to mycorrhizal fungi and sesame varieties. *G. rosea* forms the best symbiotic couple with the four varieties of sesame (*Sesamum indicum* L.).

Key words: *Sesamum indicum L., yield, Gigaspora rosea, Rhizophagus intraradices*

1. INTRODUCTION

Arbuscular mycorrhizal fungi form symbiotic associations with more than 80% of terrestrial plants [1, 2]. These terrestrial plant symbioses are the most common and widespread in the world [3]. They have a global impact on the mineral nutrition of plants [2]. The term mycorrhiza, a reciprocal benefit association, comes from the two Greek terms "mukês" for fungus and "rhiza" for root and designates a symbiotic association between a fungus and the roots of a plant [4, 5, 6].

Mycorrhizal fungi increase the resistance of plants to soil pathogens through the synthesis of antibiotics and the induction of tannin formation. They secrete phytohormones (auxin, gibberellin, cytokynin, ethylene) which promote the growth of plants [4]. Mycorrhizal fungi protect the host plant through the synthesis of antibiotics and pathogen-inhibiting substances, as well as the use of root exudates and stimulation of the development of protective microflora in the rhizosphere [7].

Arbuscular mycorrhizal fungi have crucial roles for plant ecology and physiology, they are ecologically and economically important [8, 9]. They allow long-term maintenance of soil fertility and health [10] by modifying the microflora and increasing the rate of organic matter [3]. Mycorrhizae are beneficial for the plant and have enormous agricultural potential [5]. Mycorrhizal symbiosis greatly improves adaptation, hydromineral nutrition, plant growth in arid and semi-arid zones [11] under controlled conditions [12]. Mycorrhizal fungi can be used as biofertilizers to increase the yield of sesame [12, 13]. The degree of response to arbuscular mycorrhizal inoculation of sesame depends on the varieties and fungal strains used [13]. Determining the best symbiotic couple is necessary to exploit the agricultural potential of mycorrhizal fungi [12, 13].

The general objective of this work is to assess the impact of mycorrhization on the productivity of four varieties of sesame under controlled conditions. Achieving this objective involves: assessing (i) the intensity and frequency of mycorrhization of these varieties in the presence of the mycorrhizal fungi *Gigaspora rosea* and *Rhizophagus intraradices*; assess (ii) their effects on certain yield parameters (weight of seeds per plant, number of mature capsules per plant and number of seeds per capsule) and (iii) determine the best symbiotic couples.

2. MATERIALS AND METHODS

2.1 Plant material and growing medium

The plant material obtained after screening with salinity consists of the seeds of four African varieties of sesame (*Sesamum indicum* L.) from Mali (AS09), Cameroon (AS14), Sudan (AS15) and Togo (AS25).

The fungal material consists of mycorrhizal fungi from the collection of the Mushroom Biotechnologies laboratory of the Plant Biology department of UCAD: *Rhizophagus intraradices* (NC Schenck and GS Sm.) C. Walker and A. Schuessler (formerly *Glomus intraradices*) and Gigaspora rosea TH Nicolson and NC Schenck.

The substrate is the soil, sterilized at 120 ° C for 72 h, from the botanical garden of the Faculty of Science and Technology of the Cheikh Anta Diop University 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 setup consists of randomized blocks with two factors and three repetitions. The sesame variety factor (*Sesamum indicum* L.) consists of four modalities (AS09, AS14, AS15 and AS25) and the inoculation factor includes three modalities (uninoculated control (NI), inoculated with *Rhizophagus intraradices* (Ri) and inoculated with *Gigaspora rosea* (Gr)). The experimental unit is represented by a pot containing 1.5 kilograms of the culture substrate sterilized at 120 ° C [13] for 72 h. Inoculation of sesame plants is carried out one week after sowing the seeds [14]. It consists in putting 20 g of inoculum in holes of 2 to 3 cm in contact with the root system of the plants [12, 15]. A light watering is then carried out to compact the soil. The control received 20 g of sterile soil [16]. In each pot two plants were kept. Watering at capacity in the field is done every two days with tap water until the end of the plant cycle (maturity of the capsules) in order to avoid any water deficit [13, 17, 18].

2.3 Measured parameters

Mycorrhization and yield parameters were assessed at harvest [19]. Histological examination under an optical microscope at x100 magnification made it possible to verify mycorrhization after staining of the roots [14]. The roots are rinsed thoroughly with tap water to remove the sand particles. They are then placed in test tubes containing a 10% KOH solution. The tubes are brought to the boil in a 95 ° C water bath for 1 hour to discolor the roots and empty the cytoplasmic content of the root cells. The discolored roots are rinsed 3 times with tap water and then stained with 5% Trypan blue. After coloring, 10 root fragments of 1 to 2 cm are mounted between blade and coverslip in a drop of glycerol.

The frequency and intensity of root mycorrhization were evaluated according to the method proposed by Trouvelot et al. (1986) [20].

The yield parameters determined among others include: seed yield, number of capsules per plant [19] and number of seeds per capsule [21]. The number of capsules per plant is counted at maturity. Three capsules chosen at random for each plant are opened for counting the number of seeds. The seed yield in grams per plant was determined by weighing with a precision balance.

2.4 Statistical analyses

Statistical analyses are carried out 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 using a parametric approach with analysis of variance (ANOVA). For non-normal distribution data a non-parametric approach is applied with an analysis of variance on the ranks of the means. The Tukey test at the probability threshold of 5% is carried out in order to compare and classify the means or the ranks on the means of the evaluated variables. The frequency and intensity of mycorrhization are also subjected to the Pearson Chi-square test.

3. RESULTS

3.1 Frequency and intensity of mycorrhization of four varieties of sesame inoculated with Gigaspora rosea and Rhizophagus intraradices.

The frequency and intensity of mycorrhization was estimated at the end of the harvest. The roots observed under an optical microscope show that the colonization of arbuscular mycorrhizal fungi consists of intraracinary hyphae and vesicles (Figure 1).

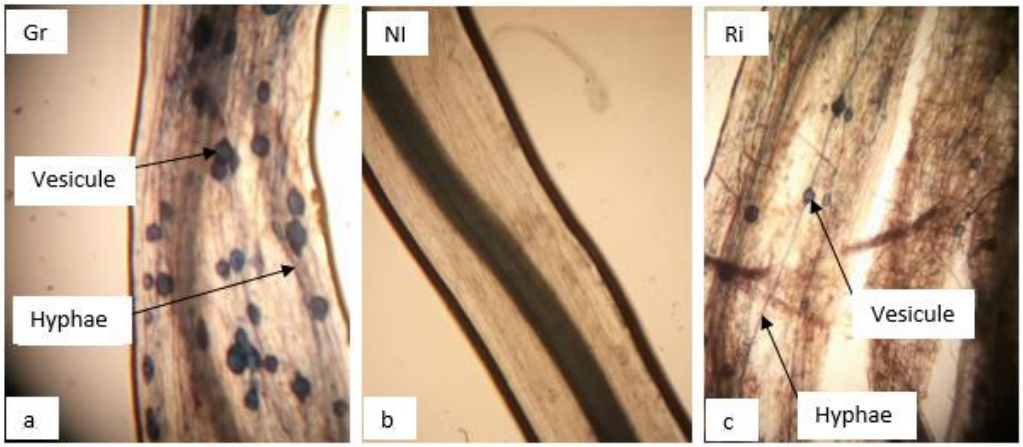

Figure 1: Sesame roots observed under an optic microscope at harvest (x100 magnification):

Gr: *Gigaspora rosea* NI: Not inoculated Ri: *Rhizophagus intraradices*

The frequency and intensity of mycorrhization are zero in the control treatments (NI) for all varieties (Figures 1b and 3). The frequency of mycorrhization varies between 96.67% (AS14) and 100% (AS09, AS15 and AS25) for Gigaspora rosea (Gr) and 90.00% (AS14) and 100% (AS25) for *Rhizophagus intraradices* (Ri). For all treatments with the exception of controls, the frequencies of mycorrhization do not show any significant difference (Figure 2 and Table 2).

The intensity of mycorrhization is between 51.03% (AS14) and 67.17% (AS25) with *G. rosea* (Gr); in the presence of *R. intraradices* (Ri), it varies between 25.23% (AS09) and 48.23% (AS15). The intensity of mycorrhization presents a significant difference within and between varieties, especially compared to the controls (Figure 2 and Table 2).

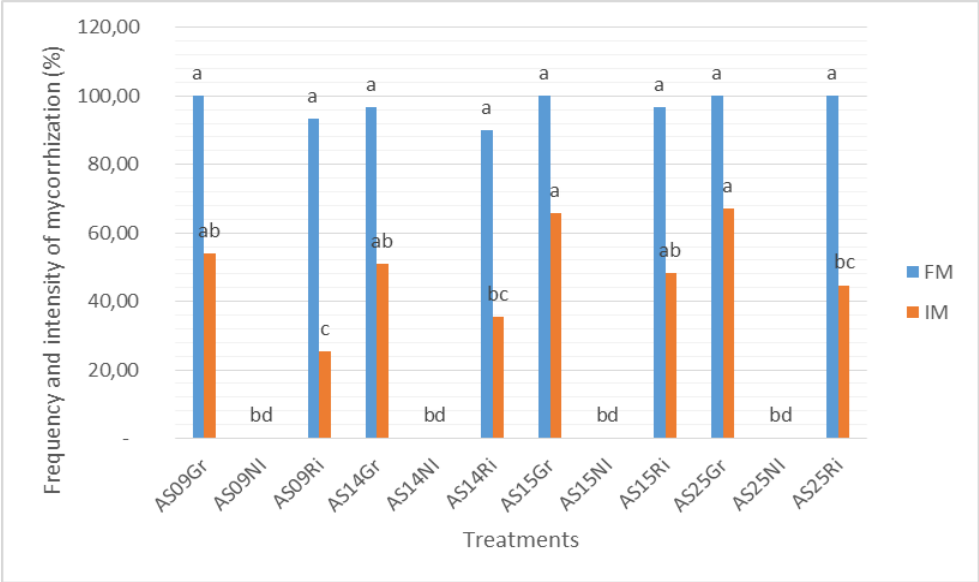

Figure 2: Frequency and intensity of mycorrhization of four varieties of sesame inoculated with *Gigaspora rosea* and *Rhizophagus intraradices*.
Bars of the same color with the same letters are not significantly different at the 5% threshold according to the Tukey test.

Table 2 summarizes the results of Pearson's Chi square test for the frequency and intensity of mycorrhization of the four sesame varieties. These results show significant differences for the different treatments for the frequency and intensity of mycorrhization.

Table 2: Pearson's Chi-square test results for the frequency and intensity of mycorrhization.

Pearson's Chi-squared test	X-squared	df	p-value
Frequency of Mycorrhization (FM)	3341.6	35	<2.2e-16
Intensity of Mycorrhization (IM)	1114.7	35	<2.2e-16

3.2 Effect of *Gigaspora rosea* and *Rhizophagus intraradices* on the yield parameters of four varieties of sesame (AS09, AS14, AS15 and AS25).

Table 3 shows the results of the parameters evaluated at harvest. Statistical analyses show an insignificant difference in seed yield per plant (p-value = 0.0183 *). The number of seeds per capsule (p-value = 0.00151 **) and the number of ripe capsules per plant (p-value = 0.00133 **) show significant differences (Table 3).

The largest mass of seeds per plant is 2,039.33 ± 132.58 mg. It is obtained with the AS15 variety inoculated with the *Rhizophagus intraradices* strain. The lowest is 815.00 ± 378.59 mg and is produced by the sesame variety AS09 in the very presence of the mycorrhizal fungus mentioned above. Inoculation resulted in an overall increase in seed yield per plant (Table 3).

The largest number of seeds per capsule is 68.00 ± 2.00. It is obtained with the sesame variety AS15 inoculated with *Gigaspora rosea*. However, the smallest number of seeds per capsule is 46.67 ± 1.15, it is produced by the AS25 variety inoculated with *R. intraradices*. The arbuscular mycorrhizal fungus *G. rosea* resulted in an increase in the number of seeds per capsule compared to controls for all African varieties of sesame. While *R. intraradices* induced an increase in this parameter for two varieties: AS09 and AS14 (Table 3).

The number of ripe capsules per plant is greater in the controls (NI). The largest number of mature capsules per plant (16.00 ± 1.00) is obtained with the control of the AS25 sesame variety. On the other hand, the lowest number (6.33 ± 0.58) is given by the AS15 variety inoculated with the *G. rosea* strain (Table 3).

Table 3: The table showed the effect of *Gigaspora rosea* and *Rhizophagus intraradices* on the yield parameters of four varieties of sesame.

Sesame varieties	Inoculations	Seed yield/plant (mg)	Number of seeds/capsule	Number of ripe capsules /plant
AS09	Gr	1 806,00 ± 237,99 ^{ab}	55,00 ± 2,00 ^{ab}	10,67 ± 2,08 ^{abc}
	NI	1 199,67 ± 455,46 ^{ab}	46,33 ± 2,89 ^{b}	10,67 ± 1,53 ^{abc}
	Ri	815,00 ± 378,59 ^{b}	48,33 ± 4,04 ^{b}	7,67 ± 2,08 ^{bc}
AS14	Gr	1 428,00 ± 150,05 ^{ab}	51,33 ± 7,23 ^{b}	11,67 ± 2,08 ^{abc}
	NI	1 392,67 ± 275,07 ^{ab}	48,00 ± 10,00 ^{b}	13,67 ± 3,79 ^{ab}
	Ri	1 453,00 ± 239,11 ^{ab}	51,00 ± 9,85 ^{b}	11,67 ± 2,08 ^{abc}
AS15	Gr	1 413,00 ± 116,43 ^{ab}	68,00 ± 2,00 ^{a}	6,33 ± 0,58 ^{c}
	NI	1 897,33 ± 182,21 ^{ab}	60,33 ± 3,79 ^{ab}	9,67 ± 1,15 ^{abc}
	Ri	2 039,33 ± 132,58 ^{a}	58,00 ± 6,08 ^{ab}	9,00 ± 0,00 ^{abc}
AS25	Gr	1 732,67 ± 957,70 ^{ab}	49,00 ± 1,00 ^{b}	15,00 ± 3,61 ^{a}
	NI	1 042,00 ± 311,79 ^{ab}	53,33 ± 4,62 ^{ab}	16,00 ± 1,00 ^{a}
	Ri	1 061,67 ± 434,36 ^{ab}	46,67 ± 1,15 ^{b}	13,33 ± 4,51 ^{abc}
Mean		1440,03 ± 1149,72	52,94 ± 16,06	11,28 ± 7,11
CV		27,12	10,3	21,41
p-value		0,0183*	0,00151**	0,00133**

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 (**c**).

4. DISCUSSION

Our study revealed that the frequency and intensity of mycorrhization are zero in the control treatments (NI) for all varieties of sesame (Figures 1b and 2). These results are reminiscent of those of Orłowska et al. (2012) who showed an absence of mycorrhization in the controls of *Plantago lanceolata* L. on sterile substrate [22]. These results are also consistent with those of Haro et al. (2012) where no control (uninoculated) was mycorrhizal in four varieties of cowpea (*Vigna unguiculata* L. Walp.) [23]. These results proved that the soil is well sterilized [24] and that the control treatments are free of any contamination [25, 26]. These results suggest that the differences observed for the different parameters are due to the effect of inoculation [27].

The mycorrhizal response varied from one variety of sesame to another and depending on the inoculated arbuscular mycorrhizal fungi (AMF), hence the need to select the best symbiotic couples to better exploit the agricultural potential of AMF (Figure 2). These results corroborate those of Diouf et al., (2009) showing that in sesame the degree of response to arbuscular mycorrhizal inoculation depends on the variety and the fungal strain [13].

The frequency of mycorrhization does not present a significant difference within or between varieties for the two fungi (Gr and Ri) but the difference is significant with the controls (not mycorrhized). These results agree with those of Haro et al. (2016a) [27]. All the inoculated plants had a mycorrhization frequency greater than more than 80% (Figure 2). These results join those of Orłowska et al., (2012) who obtained a mycorrhizal frequency of more than 80% in *Plantago lanceolata* inoculated with *R. intraradices*, *R. clarus*, *Funneliformis geosporum* and *Glomus sp* [22]. These results are contradictory with those of Ricardos et al. (2020) who obtained a mycorrhization frequency of less than 45% in maize (*Zea mays* L.) in the greenhouse, they justify this low mycorrhization by the low concentration of oxygen around the roots confined in the pots [24]. According to Haro et al. (2016b), it can also be linked to a good availability of nutrients in the soil for plants [28].

The intensity of mycorrhization presents a significant difference between the inoculated treatments and the controls (Figure 2 and Table 2). These results are consistent with those of Haro et al., (2016a) [27]. The intensity of mycorrhization is less than 50% with *R. intraradices* for all varieties of sesame (Figure 2). These results are contrary to those of Orłowska et al., (2012) who showed a mycorrhization intensity of more than 50% of the plants of *Plantago lanceolata* in the presence of *R. intraradices* [22]. However, the mycorrhization intensity of the four sesame varieties exceeds 51% with the strain of *G. rosea* (Figure 2). This last result agrees with those of Orłowska et al., (2012) [22]. These results are inconsistent with those of Ricardos et al. (2020) who showed in greenhouse in maize (*Zea mays* L.) a mycorrhization intensity of less than 30% due to the low availability of oxygen [24].

The frequency of mycorrhization is very high compared to the intensity (Figure 2). Haro and Sanon (2020) obtained similar results in sesame (*Sesamum indicum* L.) [26]. Mycorrhization parameters (frequency and intensity) are negatively influenced by the increase in total available phosphorus which can become a limiting factor for them [29]. Haro et al., (2016b) have shown that the availability of nutrients in the soil reduces mycorrhization [28]. Soils poor in phosphorus in particular favor mycorrhization [30].

Statistical analyses show an insignificant difference in seed yield per plant (p-value = 0.0183 *). The number of seeds per capsule (p-value = 0.00151 **) and the number of ripe capsules per plant (p-value = 0.00133 **) show significant differences (Table 3). These significant differences are explained by the improvement in arbuscular mycorrhizal fungi of the mineral nutrition of inoculated plants [25]. Mycorrhization improves the growth and mineral nutrition of sesame (*Sesamum indicum* L.) under controlled conditions (12). Zougari-Elwedi et al., (2012) have shown an improvement in nitrogen, phosphorus, potassium, copper and zinc nutrition in date plants (*Phoenix dactylifera* L. var. Deglet Nour) inoculated with arbuscular mycorrhizal fungi [31]. The mycorrhizal symbiosis improves hydromineral nutrition and therefore the productivity of plants [11]. Mycorrhizae improve the nutrition of sesame, which promotes an increase in its growth, its productivity [26] and consequently its yield [28]. It can increase the yields of sesame (*Sesamum indicum* L.) in Senegal [13]. Arbuscular mycorrhization can be used by farmers to reduce the use of chemical fertilizers, improve soil fertility and increase their yields [31].

5. CONCLUSION

The effect of arbuscular mycorrhization on the productivity of four African sesame varieties was evaluated under controlled conditions (greenhouse). The witnesses (not inoculated) were not mycorrhizal. The frequency of mycorrhization is more than 80% for all inoculated plants; it is 100% for the sesame variety AS25. The intensity of mycorrhization is more than 50% for all varieties in the presence of *G. rosea* while it is less than 50% with *R. intraradices*. The frequency and intensity of mycorrhization are greater with *G. rosea* for all four African varieties of sesame (*Sesamum indicum* L.).

Mycorrhizal inoculation overall increased the mass yield of seeds per plant. The fungus *G. rosea* has increased the number of seeds per capsule for the sesame varieties AS09, AS14 and AS15. Inoculation did not increase the number of mature capsules per plant.

The mycorrhization parameters showed a greater affinity of the AS15 sesame variety to *G. rosea* while the seed yield and the number of mature capsules more associate this variety with the mycorrhizal fungus *R. intraradices*. The mycorrhization and yield parameters show that *G. rosea* forms the best symbiotic couples with each of the sesame varieties AS09, AS14 and AS25.

6. REFERENCES

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