Plant Archives Volume 20 No. 2, 2020 pp. 5427-5442 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

DIVERSITY OF ENDOMYCORRHIZAL FUNGI ASSOCIATED WITH BARLEY (*HORDEUM VULGARE*) IN NORTH WEST OF MOROCCO

Hajar Jamai, Zineb Faddoul, Soumaya El-Gabardi, Mohamed Chliyeh, Karima Selmaoui, Amina Ouazzani Touhami, Rachid Benkirane and Allal Douira*

Laboratory of Botany, Biotechnology and Plant Protection, Faculty of Sciences, University Ibn Tofail, Kenitra, Morocco.

Abstract

Surveys were carried out in April-May, 2017 in plots of barley located in different localities of northwest Morocco. Root and soil samples were taken under barley feet growing in these plots. The spores were isolated from the soil samples by wet sieving and the roots were stained with Cresyl blue. The observation of barley plants roots fragments from the sites of the localities studied made it possible to highlight the presence of several endomycorrhizal structures, with a frequency of root mycorrhization which varies between 73.33 and 100%. The mycorrhizal intensity of the roots is high at the level of locality Mogren B and low (3.13%) at the level of Souk El Arbaâ, respectively of 17.26 and 3.13%. The contents of the roots in arbuscules are higher (12.286%) at the level of the locality of Mogren B and low at the level of that of Souk El Arbaâ (1.596%). As for the vesicular contents, they vary from one site to another between 0% and 5.511%. The density of spores in the rhizosphere of barley plants in the studied localities varies between 13.33 (locality of Mogran A) and 35 spores / 100 g of soil (locality of Ouazzane). The preliminary morphological identification of these spores made it possible to note the presence of 90 different morphotypes divided into twelve genera: *Glomus* and *Acaulospora* (28 species for each); *Entrophospora, Funneliformis* and *Scutellospora* (5 species for each); *Claroideoglomus, Diversispora, Pacispora, Racocetra* and *Rhizophagus* (3 species for each); *Gigaspora* (2 species); *Sclerocystis* (one species). *Glomus versiforme, Glomus macrocarpum a*nd *Scutellospora nigra* is spread in the different studied sites with a dominance compared to *Glomus deserticola, Rhizophagus intraradices, Funneliformis mosseae, Racocetra castanea* which are recorded in sites and not in others whereas certain species are specific to a single site such as *Acaulospora alpina, Acaulospora denticulate* and *Acaulospora mellea.*

Key words: Barley, Muscular mycorrhizal arbuscular, diversity.

Introduction

Barley (*Hordeum vulgare*) is a cereal that belongs to the Poaceae family. It is cultivated in several regions of the world on a large type of soils and climates and occupies the fourth rank in terms of cereal production after rice, corn and wheat, with a production of 137 Millions (FAO STAT, 2014).

Barley is one of the most important species in Morocco and it is cultivated in a wide range of varied agro climatic conditions. It plays a vital role in both human and animal nutrition (Alaoui, 2003).

More than 95% of terrestrial plants can live in symbiosis with symbolic mushrooms (Smith and Read, 1997). Basidiomycetes, Ascomycetes and Glomeromycetes are the only three groups of known fungi capable of contracting a symbiotic association with the roots of plants to form mycorrhizae (Garbaye, 2013).

The mycorrhizal symbiosis and in particular the arbuscular mycorrhizal symbiosis, which concerns more than 80% of terrestrial plants and almost all cultivated plants, allows both better growth and better resistance of plants to many biotic (Dalpé, 2005; Gianinazzi *et al*., 2010; Pozo *et al*., 2013) and abiotic stresses (Smith and Read, 2008; Debiane *et al*., 2008, 2009; Campagnac *et al*., 2010; Miransari *et al*., 2010). The potential of arbuscular mycorrhizal fungi (MACs) as bio-control agents has been described for various root infections (Khaosaad *et al*., 2007; Fiorilli *et al*., 2011; Castellanos-Morales *et al*., 2012) but very little in the protection against leaf diseases (Gallou *et al*., 2011; Campos-Soriano *et al*., 2011; Li *et al*., 2013;

***Author for correspondence :** E-mail: machkalyoussi@yahoo.fr

Maffei *et al*., 2014) and not at all in the case of biotrophic fungal pathogens.

In this work, the diversity of arbuscular mycorrhizal fungi (CMA) is highlighted in the rhizosphere of barley plants growing in different localities in northwest Morocco. In Morocco, in the literature, mycorrhization of barley has not yet been reported.

Materials and methods

Surveys and sampling

Surveys were conducted in different northern communities west of Morocco, two paths were followed: 1/ Kenitra, Sidi Yahia, Sidi Slimane, Sidi Kacem and Had Kourt and 2/ Kénitra, Souk Larbaa, Larache, Belksiri and Ouazzane. Six stations containing plots of barley were chosen in these localities. The collected soils are placed in white plastic bags bearing the indications relating to their origin (place and date of sampling) and brought back to the laboratory.

Measuring the root mycorrhizal rate

The roots were prepared according to the method of Koské and Gemma, 1989). They were first washed with water; the finest were cut to a length of 1 cm then immersed in a 10% KOH solution and placed in the oven at 90°C for one hour to remove intracellular constituents. At the end of this period, the roots were rinsed and transferred to a solution of H_2O_2 (hydrogen peroxide) for 20 min at 90°C until the roots whiten. The roots were then rinsed, then stained with 0.05% cresyl blue by submersion (Philips and Hayman, 1970 modified) modified at 90°C for 15 min.

After a final rinsing, thirty fragments of colored roots 1 cm in length were chosen at random and mounted in groups of 10 to 15 segments in the glycerin between blade and coverslip (Kormanik and McGraw, 1982). The remaining roots were kept in water or in acidic glycerol. The slides were observed under a microscope, each fragment being carefully checked over its entire length, at magnifications of ×100 and ×400 to note the mycorrhizal structures: arbuscules, partitions of hyphae, vesicles, intra- and intercellular hyphae, extramatric hyphae and even endophytes..

The frequency and the arbuscular and vesicle contents of endomycorrhizal fungi inside the root bark are measured by assigning a mycorrhization index ranging from 0 to 5 (Derkowska *et al.,* 2008):

0: absence; 1: traces; 2: less than 10%; 3: 11 to 50%; 4: 51 to 90%; 5: more than 91%

Mycorrhizal frequency

The mycorrhizal frequency (F%), reflects the importance of infection of the root system of the host plant by mycorrhizal fungi :

$$F\% = 100\ (N\text{-}No) / N$$

With N: number of fragments observed and No: number of non-mycorrhized fragments.

Mycorrhizal intensity

The intensity of mycorrhization (M%) expresses the portion of the colonized cortex in relation to the entire root system:

$$M\% = (95n5 + 70n4 + 30n3 + 5n2 + n1)/N$$

In this formula n5, n4, n3, n2 and n1 respectively denote the number of fragments noted 5, 4, 3, 2 and 1.

Arbuscular content (A%) of the mycorrhizal part

$$A\% = (100mA3 + 50mA2 + 10mA1) /100$$

Where mA3, mA2, mA1 are the % affected respectively of the notes A3, A2, A1, with mA3 = (95 n5 A3 + 70 n4 A3 + 30 n3 A3 + 5 n2 A3 + n1 A3) / N. Similarly, for A1, A2. In this formula, n5A3 represents the number of fragments noted 5 with A3; n4A3 the number of fragments noted 4 with A3.

A0: no trees; A1: few 10% lowercase; A2: moderately abundant arbuscules 50%; A3: very abundant arbuscules: 100%.

Vesicular content (V%)

The vesicular content is calculated in the same way as that of the arbuscular content:

$$V\% = (100\ mV3 + 50\ mV2 + 10\ mV1) / 100$$

Where mV3, mV2, mV1 are the% affected respectively of the notes V3, V2, V1mV3 = (95 n5 V3 + 70 n4 V3 + 30 n3 V3 + 5 n2 V3 + n1 V3) / N. Similarly, for V1, V2,

In this formula, n5V3 represents the number of fragments noted 5 with V3; n4V3 the number of fragments noted 4 with V3; …..

V0: no vesicles; V1: few vesicles 10%; V2: moderately abundant vesicles 50%; V3: very abundant vesicles: 100%.

Spore extraction

The spores are extracted according to the wet sieving method described by Gerdemann and Nicolson, (1963). In a 1L beaker, 100 g of each composite soil sample is submerged in 0.5 L of running water and stirred for 1 min with a spatula. After 10 to 30 seconds of decantation, the supernatant is passed through four superimposed sieves with decreasing mesh (500, 200, 80 and 50 µm). This operation is repeated twice. The content retained by the 200, 80 and 50 µm sieves is distributed into two tubes and

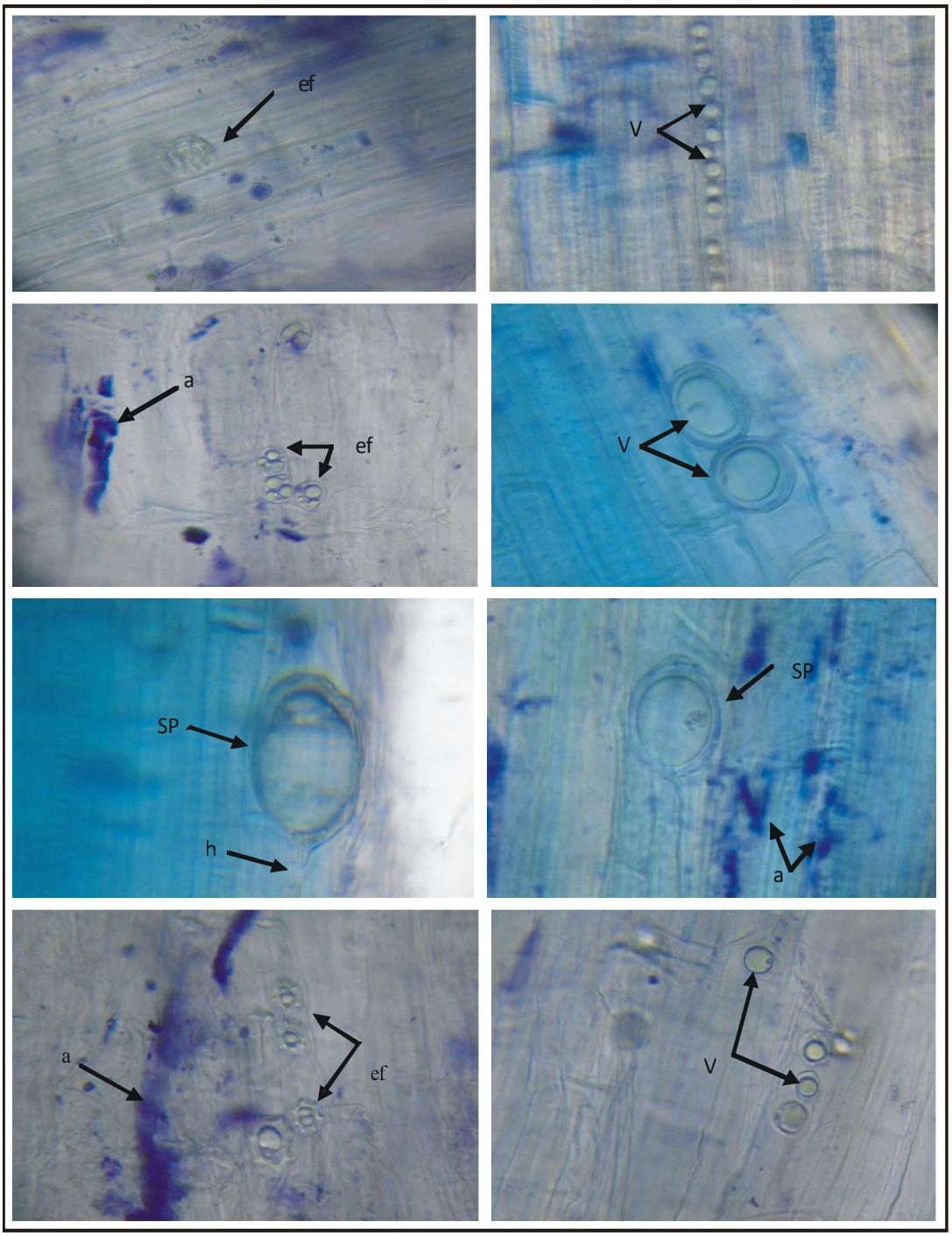

Fig. 1: Different endomycorrhizal structures of the roots of barley plants. (SP: spores; V: vesicules; ef:

centrifuged for 4 min at 9000 rpm. The supernatant is discarded and a viscosity gradient is therefore created by adding 20 ml of a 40% sucrose solution to each centrifuge tube (Walker *et al.,* 1982). The mixture is quickly stirred and the tube put back into the centrifuge for 1 min at 9000 rpm.

Unlike the first centrifugation step, the supernatant is poured onto the sieve with a mesh of 50 microns; the resulting substrate was rinsed with distilled water to remove the sucrose and then disinfected with an antibiotic solution (Streptomycin). The spores are then collected with a little distilled water in an Erlenmeyer flask.

Specific richness and spores appearance frequency

The specific richness represents the total number of species observed by sampling site and the frequency of appearance of the species corresponds to the percentage of sites where each species is detected.

Results

Microscopic examination of the barley plants roots

Fig. 2: Frequency of barley root mycorrhization at the studied sites.

fragments prepared by the technique of Philips and Hayman, (1970) and stained with cresyl blue, showed that all the roots were colonized by mycorrhizal fungi and that the cytological organization of these mycorrhizae was of the arbuscular type, with the presence of vesicles of different shapes (globular, oval and amorphous) and endomycorrhizogenic hyphae (Fig. 1).

The rate of colonization of barley roots varies from site to site (Fig. 2). This colonization is total at the Sidi Allal Tazi B, Souk Tlet El Gharb and Mogrene B sites (with F = 100%) and high at the Souk El Arbaâ, Ouezzane (with F = 93.33%), in Mograne A (F = 86.66%) and in Oulad Sellam (F = 80%) and average in Sidi Allal Tazi A (F = 73.33%).

The intensity of mycorrhization or the mycorrhizal intensity corresponds to the percentage of the mycorrhized root cortex, the highest value was observed in the roots of barley plants growing at the Mograne B site (17.26%) and the lowest in those of the plants. the Souk el Arbaâ (3.13%) and Sidi Allal Tazi A (4.03%) sites (Fig. 3).

The arbuscular and vesicle contents of barley roots are higher at the Mograne B site (A = 12.28% and V = 5.51%) and low in the roots of barley plants at the site of Souk El Arbaâ, with a percentage of 1.59 in arbuscules

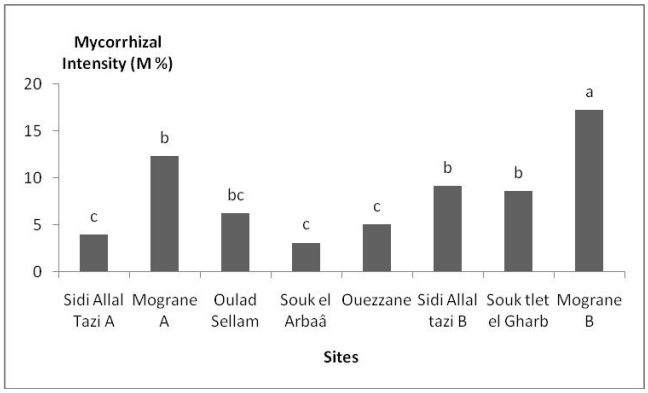

Fig. 3: Mycorrhizal intensity of barley root at the studied sites.

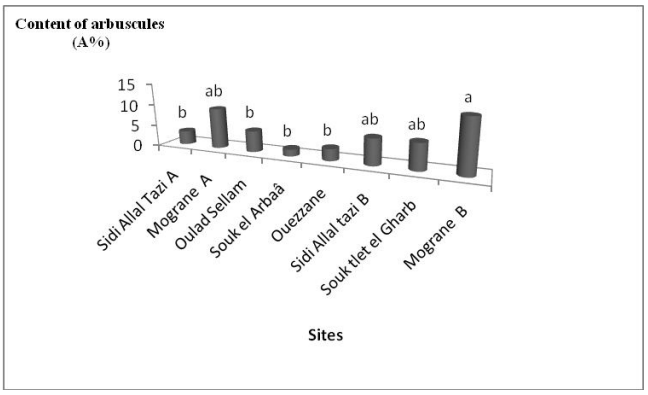

Fig. 4: Arbuscular contents of barley roots in the studied sites.

and 0.13% in vesicles. The roots of the barley plants at the Sidi Allal Tazi A and Oulad Sellam sites did not show vesicles (Fig. 4 and 5).

Diversity of spores of arbuscular mycorrhizal fungi (AD)

The number of endomycorrhizal fungal spores isolated from the rhizosphere of barley plants varies from site to site (Table 2). The number of spores recorded in the rhizosphere of barley plants from Mogran B sites (34 spore / 100g of soil), Ouazzane (35 spore / 100g of soil), Souk Tlet el Gharb (31 spore / 100g of soil) and Souk el Arbaâ (24 spores / 100g of soil) is higher. It is average at the level of the rhizosphere of the barley plants of the Sidi Allal Tazi site (20 spores / 100g of soil) and low of the Mograne A sites (13 spores / 100g of soil) and Oulad Sellam (14 spores / 100g of soil) (Fig. 6).

The preliminary morphological identification of the isolated spores made it possible to highlight the presence of 90 morphotypes in the rhizosphere of the barley plants of the sites studied (Table 1 and Fig. 6). All the morphotypes noted belong to 8 families: *Glomeraceae*, Pacisporaceae, Acaulosporaceae, Diversisporaceae, Gigasporaceae, *Claroideo-Glomeraceae*, *Entrophosporaceae* and Archaeosporaceae, to twelve genres: *Glomus* and *Acaulospora* (28 species); *Entrophospora, Funneliformis* and *Scutellospora* (5

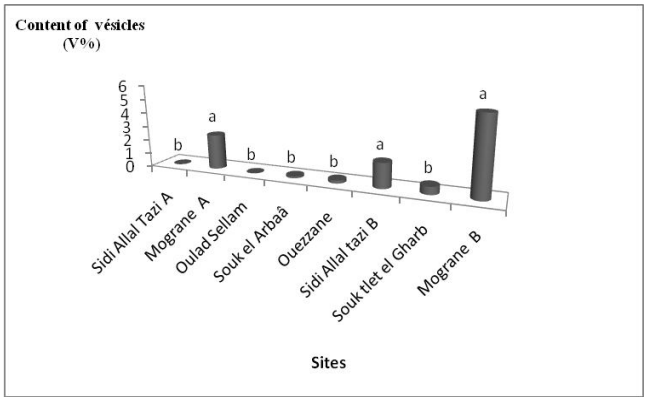

Fig. 5: Vesicular contents of barley root in the studied sites

Table 1: Identification of endomycorrhizae isolated from the barley rhizosphere of the different sites studied.

No.	Name	Form	Color	Spore's shape (μm)	Hyphas length (μm)	Spore's Surface
1	*Funneliformis mosseae*	Globular	Clear yellow	166.5	-	Smooth
2	*Rhizophagus clarus*	Oval	Dark yellow	199.8	-	Granular
3	*Glomus. macrocarpum*	Globular	Dark yellow	73.26	13.32	Smooth
4	*Glomus* sp1	Globular	Light yellow	109.89	36.63	Smooth
5	*Glomus sp2*	Globular	Dark yellow	76.59	-	Smooth
6	*Glomus versiform*	Globular	Brown yellow	66.6	16.65	Granular
7	*Glomus deserticola*	Globular	Brown	116.55	-	Smooth
8	*Scutellospora nigra*	Globular	Black	33.3	-	Smooth
9	*Glomus verruculosum*	Subglobular	Black	83.25	-	Smooth
10	*Claroideoglomus walkeri*	Globular	orange	66.6	-	Smooth
11	*Acaulospora. dilatata*	Globular	yellow	119.88	-	Granular
12	*Acaulospora* sp1	Oval	Clear yellow	83.25	-	Smooth
13	*Diversispora* sp.	Oval	white	106.56	33.3	Smooth
14	*Rhizophagus intraradices*	Subglobular	Brown	99.9	-	Smooth
15	*Racocetra gregaria*	Oval	Brown yellow	99.9	-	Smooth
16	*Claroideoglomus lamellosum*	Globular	Light yellow	53.28	-	Granular
17	*Racocetra. castanea*	Subglobular	Dark brown	149.85	-	Granular
18	*Archaeospora trappei*	Oval	white	69.93	-	Granular
19	*Glomus. microcarpum*	Globular	Brown yellow	69.93	-	Smooth
20	*Glomus sp3*	Subglobular	Dark brown	86.58	-	Smooth
21	*Acaulospora. gedanensis*	Globular	Light yellow	99.9	-	Smooth
22	*Acaulospora* sp2	Globular	Yellow	89.91	-	Granular
23	*Pacispora* sp1	Subglobular	White yellow	119.88	-	Granular
24	*Glomus glomerulatum*	Subglobular	Light yellow	49.95	26.64	Smooth
25	*Rhizophagus. fasciculatus*	Globular	Brown yellow	179.82	49.95	Smooth
26	*Acaulospora. kentinensis*	Oval	Light yellow	66.6	13.32	Smooth
27	*Glomus ambisporum*	Globular	Brown yellow	133.2	-	Smooth
28	*Glomus* sp4	Globular	White yellow	66.6	-	Granular
29	*Scutellospora heterogama*	Globular	Brown yellow	116.55	-	Smooth
30	*Funneliformis. geosporum*	Globular	Orange	53.28	26.64	Smooth
31	*Septoglomus constrictum*	Globular	Dark brown	213.12	-	Smooth
32	*Rhizophagus manihotis*	Globular	Brown yellow	99.9	-	Smooth
33	*Claroideoglomus etunicatum*	Ellipsoid	Dark yellow	39.96	-	granular
34	*Scutellospora aurigloba*	Ellipsoid	Orange	199.8	-	Smooth
35	*Diversispora aurantium*	Globular	Brown yellow	99.9	-	Smooth
36	*Glomus lacteum*	Oval	Yellow	116.55	-	Smooth
37	*Acaulospora foveata*	Globular	Orange	133.2	-	Granular
38	*Acaulospora longula*	Ellipsoid	Brown yellow	99.9	166.5	Smooth
39	*Racocetra minuta*	Subglobular	Orange	133.2	-	Smooth
40	*Glomus brohultii*	Globular	Orange	66.6	-	Smooth
41	*Acaulospora reducta*	Globular	Clear yellow	99.9	-	Granular
42	*Pacispora* sp2	Globular	Light yellow	66.6	-	Granular
43	*Pacispora* sp3	Globular	Yellow	56.61	-	Granular
44	*Acaulospora* sp(2)3	Globular	Dark brown	116.55	-	Smooth
45	*Glomus macrocarpum*	Subglobular	Clear yellow	76.59	-	Smooth
46	*Glomus intraradices*	Ellipsoid	Light yellow	166.5	-	Granular
47	*Acaulospra* sp4	Globular	Clear yellow	143.19	33.3	Granular
48	*Glomus* sp5	Globular	White yellow	133.2	399.6	Smooth

Table 1 Continue ...

Continue Table 1 ...

49	*Glomus* sp6	Globular	Brown yellow	99.9	166.5	Smooth
50	*Ambispora fecundispora*	Globular	Orange	166.5	133.2	Granular
51	*Rhizophagus fasciculatus*	Globular	Clear yellow	99.9	-	Granular
52	*Acaulospora alpina*	Globular	Brown yellow	143.19	123.21	Granular
53	*Acaulospora mellea*	Globular	Brown yellow	99.9	-	Smooth
54	*Acaulospora* sp5	Globular	orange	103.23	-	Granular
55	*Glomus.Monosporum*	Oval	Clear yellow	106.56	-	Granular
56	*Glomus* sp7	Globular	Brown yellow	59.94	49.95	Smooth
57	*Acaulospora laevis*	Globular	White yellow	113.22		Smooth
58	*Glomus brohultii*	Globular	Brown yellow	63.27	39.96	Smooth
59	*Scutellospora gilmorei*	Globular	Light yellow	66.6	-	Smooth
60	*Acaulospora spinosa*	Globular	Yellow	66.6	-	Smooth
61	*Acaulospora colombiana*	Subglobular	orange	173.16		Smooth
62	*Sclerocystis coremioides*	Oval	Brown yellow	76.59	53.28	Smooth
63	*Funneliformis constrictum*	Globular	Brown	66.6	-	Smooth
64	*Rhizophagus diaphanus*	Subglobular	White yellow	69.93	-	Granular
65	*Acaulospora delicata*	Oval	White yellow	133.2	-	Granular
66	*Gigaspora gigantea*	Globular	Light yellow	76.59	-	Granular
67	*Pacispora dominikii*	Globular	White yellow	109.89	-	Granular
68	*Acaulospora reducta*	Ellipsoid	White yellow	89.91	-	Granular
69	*Glomus* sp8	Globular	Yellow	86.58	-	Granular
70	*Glomus claroideum*	Globular	Yellow	76.59	-	Smooth
71	*Funneliformis caledonium*	Oval	Dark brown	69.93	-	Smooth
72	*Acaulospora* sp6	Subglobular	Light yellow	93.24	-	Smooth
73	*Acaulospora scrobiculata*	Oval	Light yellow	66.6	-	Smooth
74	*Acaulospora excavata*	Globular	Clear yellow	89.91	-	Granular
75	*Entrophospora. infrequens*	Globular	brown yellow	153.18	83.25	Granular
76	*Gigaspora margarita*	Globular	Yellow brown	99.9	39.96	Granular
77	*Glomus* sp9	Globular	Black brown	76.59	16.65	Smooth
78	*Acaulospora* sp7	Globular	Yellow brown	119.88	-	Smooth
79	*Glomus* sp10	Oval	White yellow	83.25	16.65	Smooth
80	*Acaulospora capsicula*	Oval	White yellow	73.26	-	Smooth
81	*Acaulospora* sp8	Globular	Light yellow	99.9	-	Granular
82	*Glomus* sp11	Oval	Yellow	66.6	-	Granular
83	*Acaulospora* sp9	Globular	White yellow	86.58	-	Granular
84	*Glomus. aggregatum*	Globular	Dark brown	49.95	-	smooth
85	*Glomus* sp12	Ellipsoid	Brown yellow	66.6	-	Smooth
86	*Diversispora spurca*	Oval	Brown yellow	83.25	-	Smooth
87	*Racocetra coralloidea*	Globular	Brown yellow	73.26	-	Granular
88	*Acaulospor* sp10	Globular	Brown yellow	126.54	-	Granular
89	*Glomus. macrocarpum*	Globular	Brown yellow	49.95	33.3	smooth
90	*Glomus intaradices*	Oval	White yellow	66.6	53.28	smooth

species); *Claroideoglomus, Diversispora, Pacispora, Racocetra* and *Rhizophagus* (3 species) ; *Gigaspora* (2 species) ; *Sclerocystis* (one species) and to three orders (Glomerales, Diversisporales, Archaeosporales).

The obtained results showed that the species *Glomus versiforme*, *Glomus macrocarpum* and *Scutellospora nigra* are widespread in the different studied sites (Table 2). *Glomus deserticola, Rhizophagus intraradices, Funneliformis mosseae, Racocetra castanea* have been observed at some sites and not at others. Other species have been noted at the level of a single site, case of the Souk el Arbaâ site: *Acaulospora alpina, Acaulospora denticulata, Acaulospora mellea, Acaulospora* sp3, *Acaulospora* sp4, *Acaulospora sp5, Glomus brohultii, Ambispora fecundispora, Glomus* sp6, *Glomus* sp7, *Pacispora* sp2, *Pacispora* sp3. The species *Acaulospora* sp1, *Acaulospora* sp2,

Table 2: Species of AM fungi present in the different study sites.

Mycorrhizal species	Number of spores per 100g of soil							
	Mogran A	Oulad Sellam	Sidi Allal Tazi A	Souk El Arbaâ	Sidi Allal Tazi B	Ouezzane	Mogran B	Souk Tlet El-Gharb
Acaulospora alpina	-	-	-	1	-	-	-	-
Acaulospora capsicula	-	-	-	-	-	-	-	1
Acaulospora colombiana	-	-	-	-	-	1	-	-
Acaulospora delicata	-	-	-	-	-	1	-	-
Acaulospora dilatata	3	-	-	-	-	1	-	-
Acaulospora elegans	-	-	-	-	-	1	-	-
Acaulospora excavata	-	-	-	-	-	-	1	-
Acaulospora gedanensis	-	2	-	-	-	1	-	-
Acaulospora leavis	-	-	-	-	-	1	-	1
Acaulospora foveata	-	-	2	-	-	-	-	-
Acaulospora longula	-	-	1	-	-	-	-	-
Acaulospora reducta	-	-	-	1	-	2	-	1
Acaulospora denticulata	-	-	-	1	-	-	-	-
Acaulospora mellea	-	-	-	1	-	-	-	-
Acaulospora scrobiculata	-	-	-	-	-	-	1	1
Acaulospora spinosa	-	-	-	-	-	1	-	-
Acaulospora kentinensis	1	-	1	-	-	-	-	1
Acaulospora sp1	1	-	-	-	-	-	-	-
Acaulospora sp2	1	-	-	-	-	-	-	-
Acaulospora sp3	-	-	-	2	-	-	-	-
Acaulospora sp4	-	-	-	1	-	-	-	-
Acaulospora sp5	-	-	-	1	-	-	-	-
Acaulospora sp6	-	-	-	-	-	1	-	-
Acaulospora sp7	-	-	-	-	-	-	1	-
Acaulospora sp8	-	-	-	-	-	-	-	1
Acaulospora sp9	-	-	-	-	-	-	-	1
Acaulospora sp10	-	-	-	-	-	-	-	1
Archaeospora trappei	1	-	-	-	-	-	-	-
Claroideoglomus lamellosum	1	-	-	-	-	1	-	-
Claroideoglomus etunicatum	-	-	5	-	-	-	-	-
Claroideoglomus walkeri	1	-	-	-	-	-	-	-
Diversispora spurca	-	-	-	-	-	-	-	1
Diversispora aurantium	-	-	1	-	-	-	-	-
Diversispora sp	1	-	-	-	-	-	-	-
Entrophospora. infrequens	-	-	-	-	-	-	2	-
Funneliformis caledonium	-	-	-	-	-	1	-	-
Funneliformis constrictum	1	-	1	-	-	1	-	-
Funneliformis geosporum	-	-	1	-	-	-	-	-
Funneliformis mosseae	1	-	-	-	-	1	1	-
Funneliformis verruculosum	1	-	-	-	-	-	-	-
Gigaspora gigantea	-	-	-	-	-	2	-	-
Gigaspora margarita	-	-	-	-	-	-	1	-
Glomus. aggregatum	-	-	-	-	-	-	3	-
Glomus ambisporum	-	-	5	-	-	-	-	-
Glomus brohultii	-	-	-	1	-	1	-	-
Glomus claroideum	-	-	-	-	-	1	-	1
Glomus clarum	1	-	-	-	-	-	-	3

Table 2 Continue ...

Continue Table 2 ...

Glomus deserticola	4	-	1	3	1	1	1	-
Glomus fasciculatum	-	-	3	1	-	2	-	1
G. fecundisporum	-	-	-	1	-	-	-	-
Glomus glomerulatum	-	-	2	-	-	-	-	-
Glomus intraradices	1	-	2	1	-	-	-	-
Glomus lacteum	-	-	1	-	-	-	-	-
Glomus.macrocarpum	7	5	12	1	1	-	-	-
Glomus.Monosporum	-	-	-	-	1	-	-	-
Glomus scintillans	-	-	-	-	-	1		
Glomus versiforme	5	10	11	2	6	5	9	-
Glomus sp1	1	-	-	-	-	-	-	-
Glomus sp2	1	-	-	-	-	-	-	-
Glomus sp3	-	1	-	-	-	-	-	-
Glomus sp4	-	-	1	-	-	-	-	-
Glomus sp5	-	-	1	-	-	-	-	-
Glomus sp6	-	-	-	1	-	-	-	-
Glomus sp7	-	-	-	1	-	-	-	-
Glomus sp8	-	-	-	-	1	-	-	-
Glomus sp9	-	-	-	-	-	1	-	-
Glomus sp10	-	-	-	-	-	-	-	1
Glomus sp11	-	-	-	-	-	-	-	1
Glomus sp12	-	-	-	-	-	-	1	-
Glomus sp13				-	-	-	-	1
Pacispora sp1	-	-	-	-	-	-	-	1
Pacispora sp2	-	-	-	1	-	-	-	-
Pacispora sp3	-	-	-	1	-	-	-	-
Racocetra gregaria	1	-	-	-	-	-	-	-
Racocetra castanea	1	-	-	-	-	-	1	2
Racocetra minuta	-	-	1	-	-	-	-	-
Rhizophagus diaphanus	-	-	-	-	-	1	-	-
Rhizophagus fasciculatus	-	-	1	-	-	-	-	-
Rhizophagus manihotis	-	-	1	-	-	-	-	-
Sclerocystis coremioides	-	-	-	-	-	1	-	-
Scutellospora aurigloba	-	-	1	-	-	-	-	-
Scutellospora coralloidea	-	-	-	-	-	-	-	1
Scutellospora gilmorei	-	-	-	-	1	-	-	-
Scutellospora heterogama	-	-	1	-	-	-	-	1
Scutellospora. nigra	5	25	1	2	9	5	12	9
Total	13	14	19	24	20	35	34	31

Archaeospora trappei, *Diversispora* sp., *Funneliformis verruculosum, Claroideoglomus walkeri, Glomus* sp1, *Glomus* sp2, *Racocetra gregaria* were observed in the rhizosphere of barley plants from the Mogran A site.

The species noted in the rhizosphere of the Ouazzane site are *Acaulospora colombiana***,** *Acaulospora delicata, Acaulospora spinosa, Acaulospora* sp6, *Funneliformis caledonium, Gigaspora gigantea, Glomus* sp9, *Glomus scintillans, Rhizophagus diaphanus, Sclerocystis coremioides*. The species observed at the Sidi Allal Tazi A site are *Acaulospora foveata, Acaulospora longula, Glomus ambisporum, Diversispora aurantium, Claroideoglomus etunicatum, Funneliformis geosporum, Glomus glomerulatum, Glomus lacteum, Rhizophagus manihotis, Glomus* sp4, *Glomus* sp5, *Scutellospora aurigloba, Racocetra minuta a*nd *Rhizophagus fasciculatus* and those of the Mograne B site are *Acaulospora excavata*, *Acaulospora* sp7, *Entrophospora infrequens*, *Gigaspora margarita*, *Glomus aggregatum*, *Glomus* sp12.

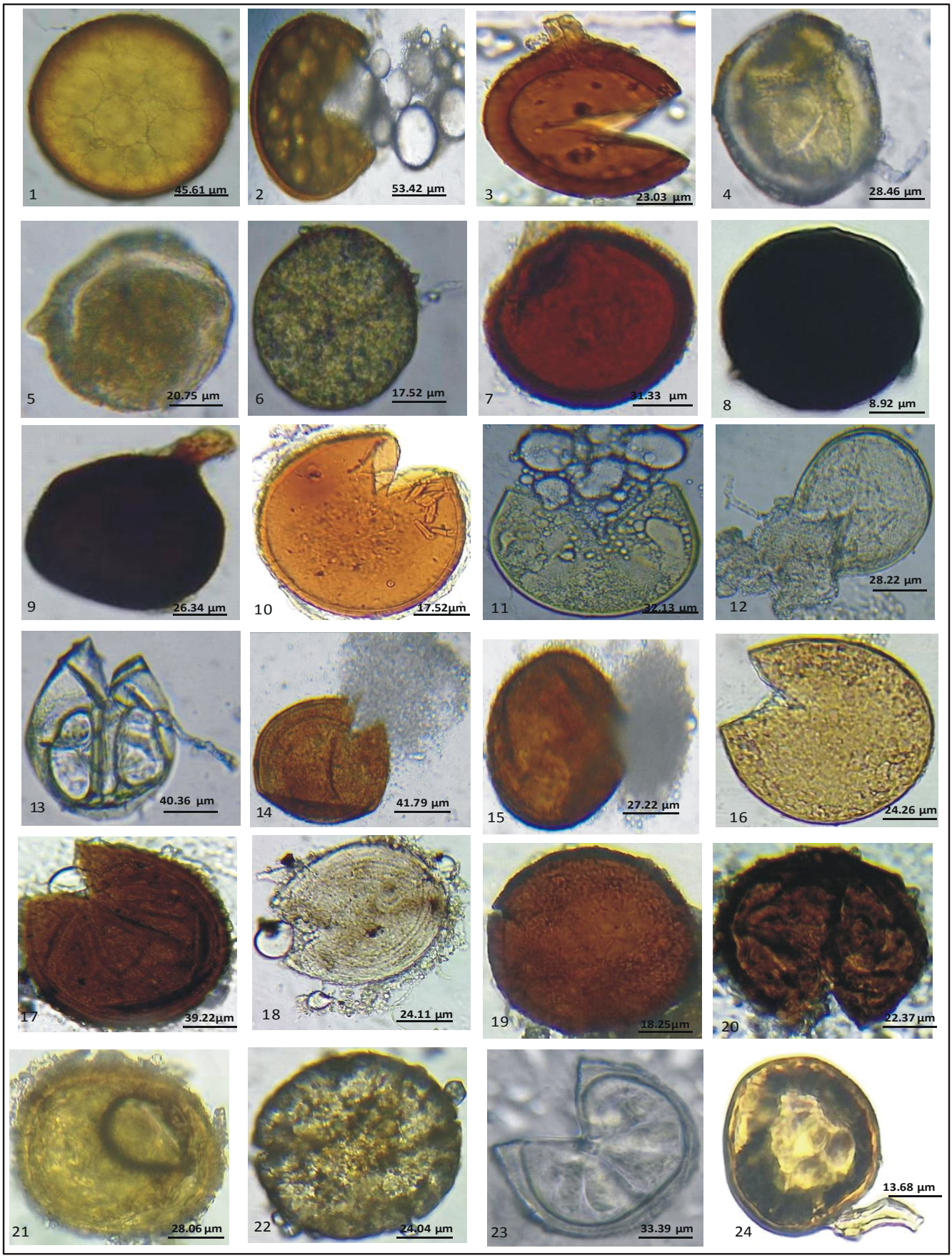

Fig. 6 Continue...

Fig. 6 Continue...

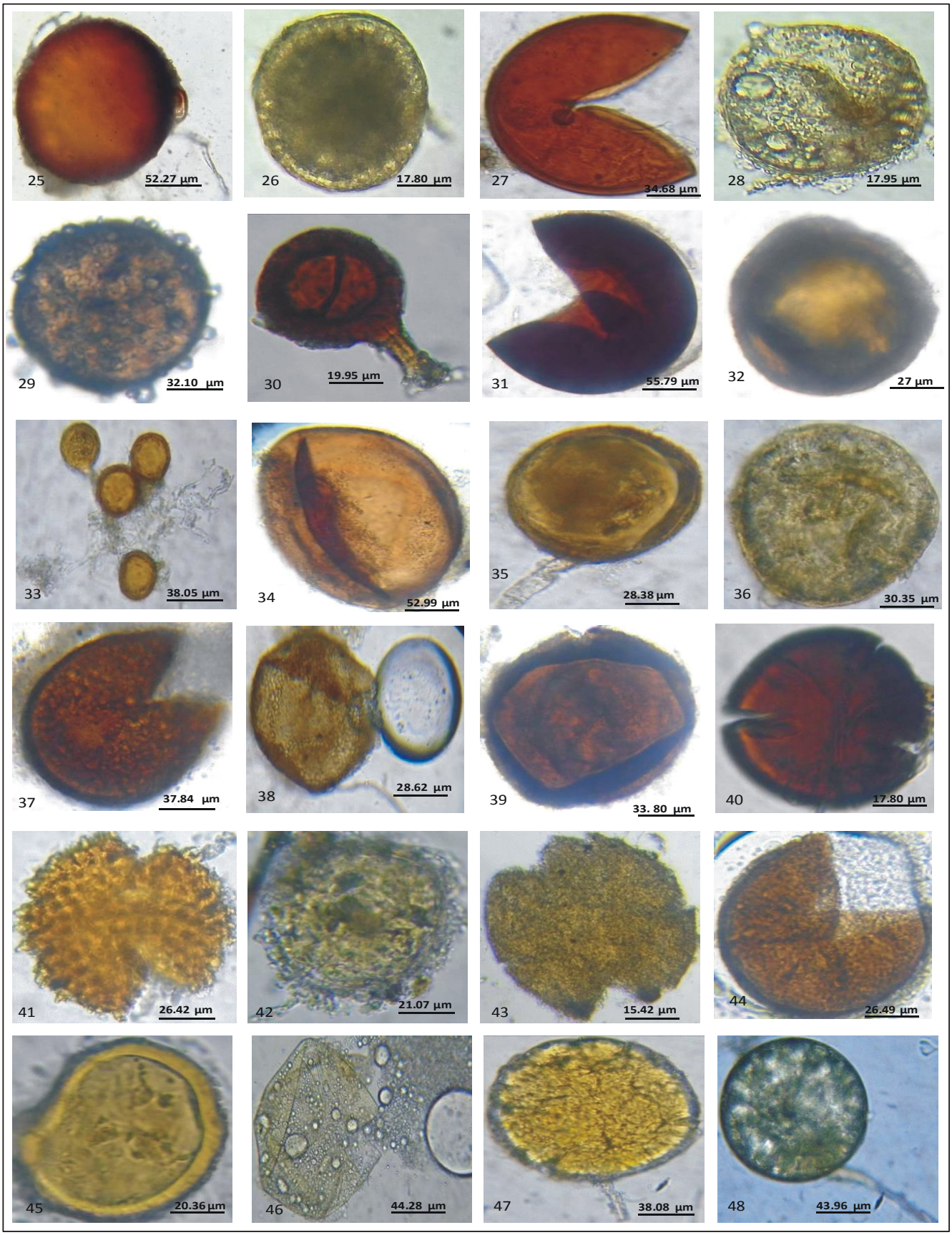

Fig. 6 Continue...

Fig. 6 Continue...

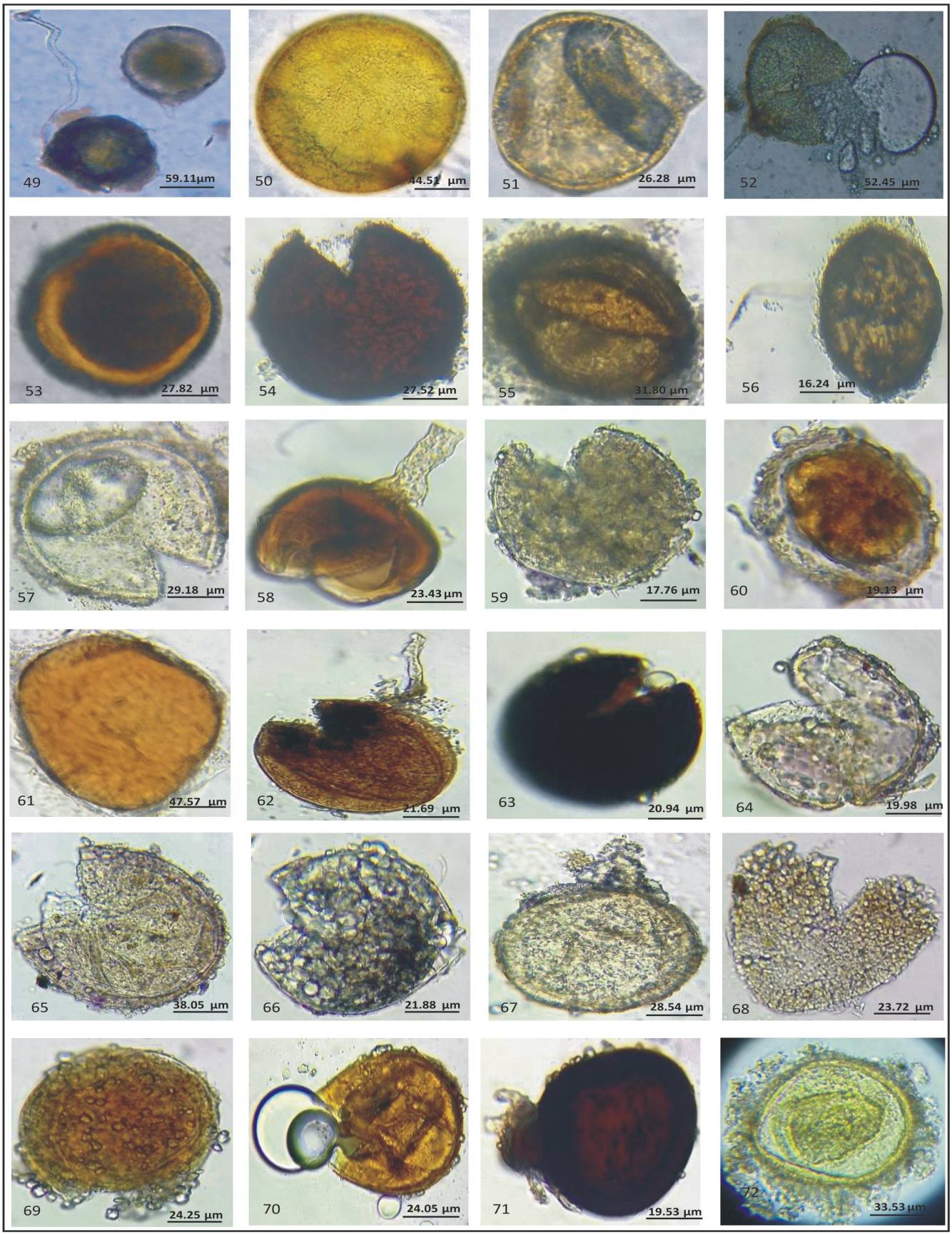

Fig. 6 Continue...

Fig. 6 Continue...

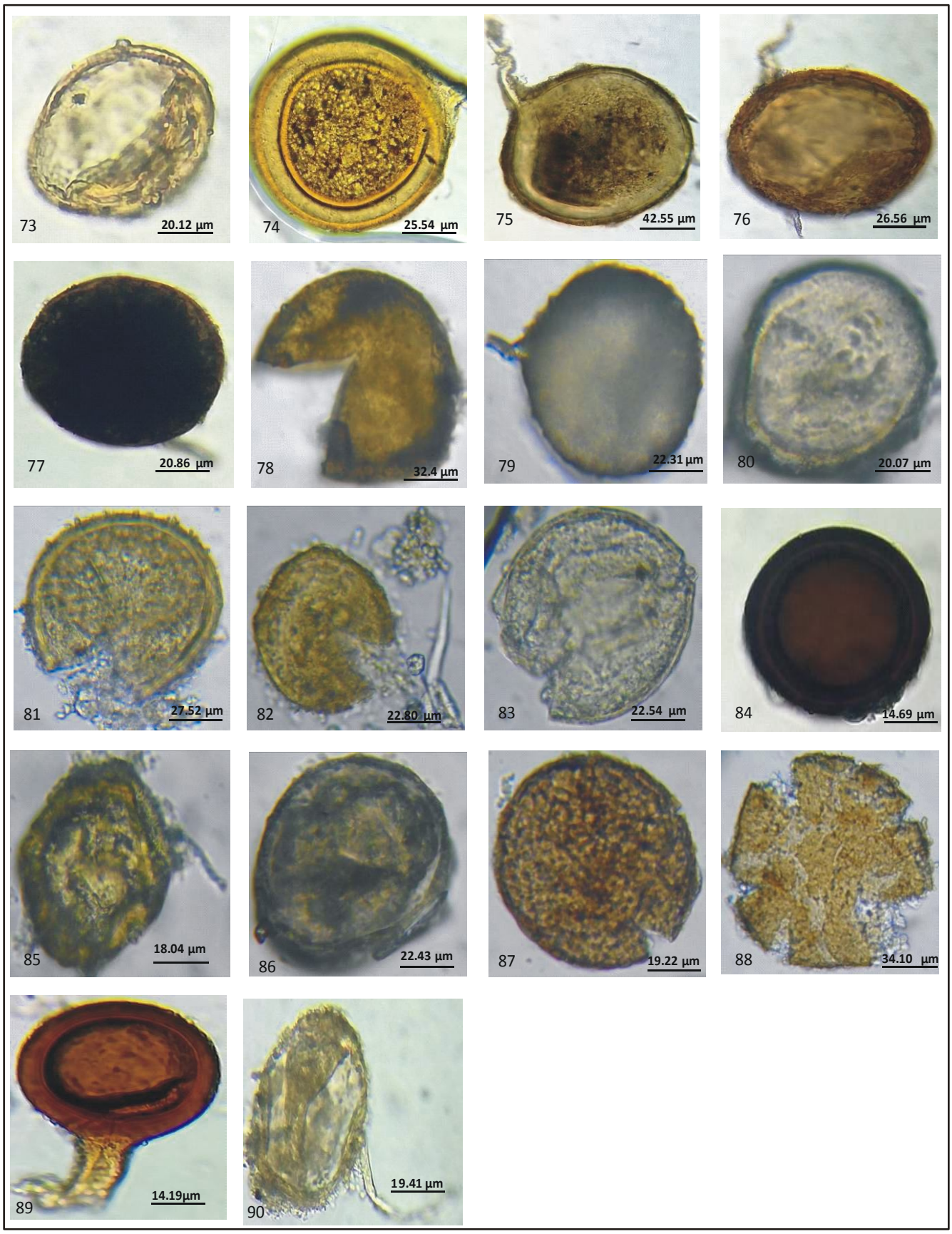

Fig. 6: Fungal species isolated from the barley rhizosphere.

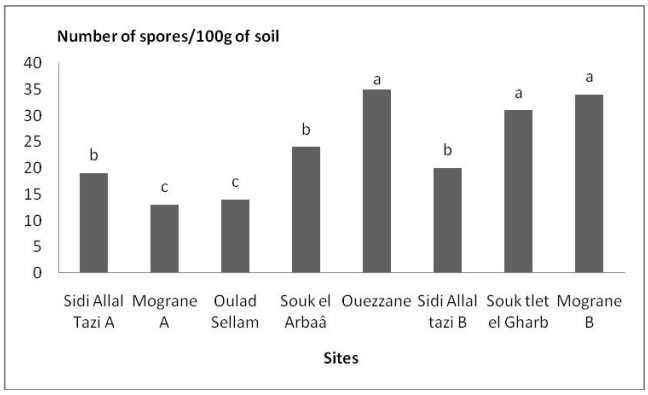

Fig. 6: Density of spores (number of spores /100g of soil) of AM fungi in the rhizosphere of barley roots in the studied sites.

Discussion

Soils are generally complex and specific environments. The loss of one or more of their properties degrades their ability to produce biomass. Environmental factors such as physicochemical characteristics, pH and soil moisture influence microbial populations (Anderson and Domsch, 1993; Stotzky, 1997).

The used parameters to estimate the degree of colonization of barley roots by endomycorrhizal fungi vary from one site to another. Thus, the values of the frequency of mycorrhization (F) and those of the intensity of root colonization (M), the highest can reach 100% respectively (Sidi Allal Tazi B, Souk Tlet el Gharb and Mograne B sites) and 17.26% (Mograne B site). The lowest values of the frequency and intensity of mycorrhization were observed at the roots of barley plants from the Sidi Allal Tazi A sites and at Souk el Arbaâ. Furthermore, the contents of arbuscules and vesicles are very variable, the highest were recorded in the roots of barley plants from the site of Mograne B. Jerbi *et al*., (2018) studied the variation of the natural biomass of arbuscular mycorrhizal fungi in the rhizosphere of the main Poaceae in northern Tunisia. These authors noted that the abundance of arbuscular mycorrhization is a function of the physicochemical characteristics of the soil (soil texture, pH, electrical conductivity, total and active lime content, organic matter content) and the host plant. They also reported that the most colonized species by AMFs is barley: 93.5% of the plants sampled and common wheat is the least mycorrhizal among the studied species.

Analysis of the spore communities of endomycorrhizal fungi found in the rhizosphere of barley plants shows a variation in spore density from one site to another, the highest average being around 35 spores / 100 g at the Ouazzane site. This observed variation can be attributed to the spore formation process and the degradation of their germination (Smith, 1980), the sampling season (Gemma *et al.,* 1999), the soil and climatic variations (Koske, 1987; Johnson *et al.,* 1991) and soil microorganisms (Dalpé, 1989).

The typical morpho diversity of MACs depends on the quality of the soil and the ability of the spores to adapt. Their symbiotic activity is variable depending on the functional specificity of each soil strain which can be specialized for a given function or be generalist (Ngonkeu *et al.,* 2013).

The counting of mycorrhizal fungi spores has shown a predominance of the *Glomus* genus. This dominance has also been found in Nigeria (Redhead, 1977), in Burkina Faso (Ba *et al.*, 1996), in Senegal (Diop *et al.*, 1994), in the soil of certain forests in Benin (Houngnandan *et al*., 2009), in the soil of certain orchards in Quebec (Dalpé *et al.*, 1986), in Malaysia, in the rhizosphere of *Octomelus sumatrana* and *Anthocephalis chinensis* (An Na Yan *et al.*, 2011).

The genera *Acaulospora*, *Gigaspora* and *Glomus* have already been observed in the Sudanian zone of Burkina Faso under the plantations of Acacia halosericea and A. mangion (Ba *et al*., 1996), in the Moroccan coastal dunes of Souss Massa (Hatim and Tahrouch, 2007), in soils under argan trees (Sellal *et al.,* 2017) and in the rhizosphere of *Casuarina* sp. in Morocco (Tellal *et al.,* 2008). Several AMF species including, *Glomus mosseae, G. hoï, G. versiformae, G. diaphanum, G. geosporum, G. cladonius, G. clarum, Ascaulosporum spp., Archacospora* spp., *Paragloms* spp. and others are often reported in association with rice roots resulting in an increase in the root surface for better acquisition of nutrients (Zhang *et al*., 2005, Gao *et al*., 2006; Raimam *et al*., 2007; Rajeshkannan *et al*., 2009; Fernández *et al*., 2011).

The work of Cimen *et al.,* (2010) found that applying AMFs to lettuce plants in the greenhouse increased leaf yields by more than 200% compared to uninoculated plants. On clover plants a 65% increase in biomass was observed (Ben khaled *et al.*, 2003) whereas in watermelon cultivation, Hamza, (2014) reported an increase of 29% and 31% in three months, respectively, in the weight of aerial and root dry matter of plants inoculated with AMF compared to plants not inoculated. In their work in Niger, Laminou *et al.,* (2009) have shown that inoculating AMFs (especially *G. intraradices*) with plants allows them to increase their total biomass yield. The mycorrhizal symbiosis provides the plant mainly with phosphorus (Ezawa *et al*., 2005) which is a nutrient little available to plants due to its reduced mobility in the soil and its partial solubility but also promotes access to Nitrogen complex forms (Govindarajulu *et al.*, 2005; Cruz *et al.*, 2007).

Inoculation of plants with Glomus mosseae allows better growth of clover plants than inoculation with other mycorrhizal fungi. Thus mycorrhization by this fungal isolate has resulted in a marked improvement in the number of leaves formed, the increase in leaf area and the height of the plant, in the face of a water deficit. Likewise, dry matter productions are improved compared to control plants. Similar responses have been reported for onion and lettuce inoculated with Glomus fasciculatum (Hirrel *et al.,* 1980; Ruiz-Lozano *et al.,* 1995; Tobar *et al*., 1994) and corn inoculated with *Glomus mosseae* (Kothari *et al.,* 1990).

According to Brundrett, (1991), rich soils in colloids are favorable for the formation of mycorrhizae. Soils rich in organic matter can stimulate the functioning of arbuscular mycorrhizal fungi (Ryan *et al*., 1994).

The soils of the aforementioned sites of the barley rhizosphere include a mycorrhizal biodiversity translated by the different types of spores dominated by the genus *Glomus* and *Acaulospora*.

The endomycorrhizal species found in the rhizosphere of barley plants can be exploited to promote the growth and protection of cereals against fungal diseases. Indeed, according to Wehner *et al*., 2010), plant protection is ensured by mycorrhizal colonization which results from a combination of stimulation of plant growth by better nutrition and compensation by symbiosis for damage caused by phytopathogenic agents.

Among the most feared fungal diseases of cereals, root rot induced by a variable fungal complex consisting of the species of the *Fusarium* genus, *Bipolaris sorokiniana* and *Curvularia spicifera* (Qostal *et al.,* 2019b and Qostal *et al.* 2019a). The potential of arbuscular mycorrhizal fungi (MACs) as biocontrol agents has been described in the case of various root infections (Fiorilli *et al.,* 2011; Castellanos-Morales *et al.,* 2012). In this sense, an endomycorrhizal inoculum has shown great efficacy against *Fusarium solani*, the pathogenic agent responsible for root rot in chickpea plants (El Hazzat *et al.,* 2019). Mycorrhization of chickpea plants reduced infection of chickpea plants by *F. solani* and increased activity in the soil of the plant rhizosphere, sporulation of endomycorrhizal fungi was noted.

To achieve this objective, it is necessary to select certain endomycorrhizal species having both a high infectious power and a good adaptation to the different climatic and edaphic conditions of cereal cultivation.

Acknowledgments

"The Authors would like to acknowledge the support through the R and D Initiative-Appel à projets autour des phosphates APPHOS-sponsored by OCP (OCP Foundation, R and D OCP, Mohammed VI Polytechnic University, National Center of Scientific and technical Research CNRST, Ministry of Higher Education, Scientific Research and Professional Training of Morocco MESRSFC) under the project entitled *Sélection et utilisation des Trichoderma spp. pour l'amélioration de l'efficacité des phosphates et la lutte contre la pourriture racinaire du blé au Maroc * project ID *AGR-DOI-1/2017*.

References

Alaoui, S.B. (2003). Conduite technique de l'orge. Production de fourrage à partir de céréales cultivées seules ou mélangées avec les légumineuses. Techniques de production des principales cultures fourragères en Bour et en irrigué. Session de formation au profit des techniciens et ingénieurs de l'ORMVA des Doukkala. Décembre 2003.

Anderson, T.H. and K.H. Domsch (1993).The metabolic quotient for CO_2 (q CO_2) as a specific activity parameter to assess the effects of environmental conditions such as pH, on the microbial biomass of forest soils. *Soil Biology & Biochemistry.*, **25:** 393-395.

An Na Yang, Lin Lu Chen Xi Wu and Ming Mei Xia (2011). Arbuscular mycorrhizal fungi associated with Huangshan Magnolia cylindrica). *Journal of Medicinal Plants Research.*, **5(18):** 4542-4548.

Bâ, M., Y. Dalpé and T. Guissou (1996). Les Glomales d'*Acacia holosericea* et d'*Acacia mangium*. *Bois et forêts des tropiques.*, **250:** 6-14.

Brundrett, M.C. (1991). Mycorrhizas in natural ecosystems. In: Macfayden A., Begon M., Fitter, A.H. (Eds.), Advances in Ecological Research, vol. 21. Academic Press Ltd., London, 171-213.

Ben Khaled, L., G. Asunéion, M. El-Ouarraqi and O. Abdallah (2003). Réponses physiologiques et biochimiques du trèfle (*Trifolium alexandrinum* L.) à la double association Mycorhizes- Rhizobium sous une contrainte saline. Agronomie, *EDP Sciences.,* **23:** 571-580.

Campagnac, E., A. Lounes - Hadj Sahraoui, D. Debiane, J. Fontaine, F. Laruelle, G. Gar9on, A. Verdin , R. Durand, P. Shirali and A. Grandmougin-Ferjani (2010). Arbuscular mycorrhiza partially protect chicory roots against oxidative stress induced by two fungicides, fenpropimorph and fenhexamid. *Mycorrhiza.,* **20:** 167-178.

Campos-Soriano, J. García-Martínez and B. San Segundo (2012). The arbuscular mycorrhizal symbiosis promotes the systemic induction of regulatory defense-related genes in rice leaves and confers resistance to pathogen infection. *Molecular plant pathology.,* **10:** 1364-3703.

Castellanos-Morales, V., R. Cárdenas-Navarro, J.M. García-Garrido, A. Illana, J.A. Ocampo, S. Steinkellner and H. Vierheilig (2012). Bioprotection against *Gaeumannomyces graminis* in barleya comparison between arbuscular mycorrhizal fungi. *Plant Soil Environ.,* **58:** 256-261.

Cimen, I., B. Turgay and V. Pirinç (2010). Effect of solarization

and vesicular arbus cular mychorrizal on weed density and yield of lettuce (*Lactuca sativa* L.) in autumn season. *African Journal of Biotechnology.*, **9:** 3520-3526.

Cruz, C., H. Egsgaard, C. Trujillo, P. Ambus, N. Requena, M.A. Martins-Loucao and I. Jakobsen (2007). Enzymatic evidence for the key role of arginine in nitrogen translocation by arbuscular mycorrhizal fungi. *Plant Physiology.*, **144:** 782-792.

Dalpé, Y., F.A. De-Souza and S. Declerck (2005). Life Cycle of *Glomus* Species in Monoxenic Culture. Dans: Biology of arbuscular mycorrhizal fungi under in vitro culture. Eds: Declerck, S, Fortin JA, Strullu, DG, Springer-Verlag, Germany. 49-71.

Dalpé, Y. (1989). Inventaire et répartition de la flore endomycorhizienne de dunes et de rivages maritimes du Québec du Nouveau-Brunswick et de la nouvelle. *Ecosse Rev. Ecol. Syst*., **116:** 219-236.

Dalpé, Y., R.L. Granger and V. Purlan (1986). Abondance relative et diversité des Endogonacées dans un sol de verger du Quebec. *Can. J. Bot*., **64:** 912-917.

Debiane, D., G. Garçon, A. Verdin, J. Fontaine, R. Durand, A. Grandmougin-Ferjani, P. Shirali and A. Lounes-Hadj Sahraoui (2008). *In vitro* evaluation of the oxidative stress and genotoxic potentials of anthracene on mycorrhizal chicory roots. *Environmental and experimental botany.*, **64:** 120-127.

Debiane, D., G. Garçon, A. Verdin, J. Fontaine, R. Durand, P. Shirali, A. Grandmougin-Ferjani and A. Lounes-Hadj Sahraoui (2009). Mycorrhization alleviates benzo [a] pyrene-induced oxidative stress in an *in vitro* chicory root model. *Phytochemistry.,* **70:** 1421-1427.

Derkowska, E., L. Sas-Paszt, B. Sumorok, E. Szwonek and S. Gluszek (2008). The influence of mycorrhization and organic mulches on mycorrhizal frequency in apple and strawberry roots. *Journal of Fruit and Ornamental Plant Research.*, **16:** 227-242.

Diop, T.A., M. Gueye, B.I. Dreyfus, C. Plenchette and D.G. Strullu (1994). Indigenous arbuscular mycorrhizal fungi associated with *Acacia albida* Del. in different areas of Senegal. *Applied and Environment Microbiology.*, **60:** 3433-3436.

Ezawa, T., M. Hayatsu and M. Saito (2005). A new hypothesis on the strategy for acquisition of phosphorus in arbuscular mycorrhiza: upregulation of secreted acid phosphatase gene in the host plant. *Molecular Plant Microbe Interaction*., **18:** 1046-1053.

FAO STAT (2014). Retrieved April 21, 2017, from http://www.fao.org/faostat/fr/#data/qc.

Fernández, F., J.M. Dell'Amico, M.V. Angoa and I.E. De-la Providencia (2011). Use of a liquid inoculum of the arbuscular mycorrhizal fungi Glomus hoi in rice plants cultivated in a saline Gleysol: A new alternative to inoculate. *Journal of Plant Breeding and Crop Science.,* **3:** 24-33.

Fiorilli, V., M. Catoni, D. Francia, F. Cardinale, L. Lanfranco (2011). The arbuscular mycorrhizal symbiosis reduces disease severity in tomato plants infected by *Botrytis cinerea*. *Journal of Plant Pathology.,* **93:** 237-242.

Gallou, A., H.P.L. Mosquera, S. Cranenbrouck, J.P. Suárez and S. Declerck (2011). Mycorrhiza induced resistance in potato plantlets challenged by *Phytophthora infestans*. *Physiological and Molecular Plant Pathology.,* **76:** 20-26.

Gao, X., T.W. Kuyper, C.Z.F. Zhang and E. Hoffland (2006). Mycorrhizal responsiveness of aerobic rice genotypes is negatively correlated with their zinc uptake when non mycorhizal. *Plant Soil.*, **290:** 283-291.

Garbaye, J. (2013). La symbiose mycorhizienne, Quae, 280.

Gemma, J.N., R.E. Koske and M. Carreiro (1989). Seasonal variation in spore abundance and dormancy of *Gigaspora gigantea* and in Mycorrhizal inoculum potential of a dune soil. *Mycologia.*, **80:** 211-216.

Gerdemann, J.W. and T.H. Nicholson (1963). Spores for mycorrhizal endogone species extracted from soil by wet sieving and decanting. *Trans. Br. Mycol. Soc*., **46:** 235-244.

Gianinazzi, S., A. Gollotte, M.N. Binet, D. Tuinen, D. Redecker and D. Wipf (2010). Agroecology: the key role of arbuscular mycorrhizas in ecosystem services. *Mycorrhiza.,* **20:** 519-530.

Govindarajulu, M., P.E. Pfeffer, H. Jin, J. Abubaker, D.D. Douds, J.W. Allen, H. Heike Bücking, P.J. Lammers and Y. Shachar-Hill (2005). Nitrogen transfer in the arbuscular mycorrhizal symbiosis. *Nature.,* **435:** 819-823.

Hamza, N. (2014). Application des mycorhizes arbusculaires en culture maraîchère cas de la pastèque (*Citrullus lanatus*).Université Ferhat Abbas Sétif 1, 83.

Hatim, A. and S. Tahrouch (2007). Caractérisations chimique, botanique et microbiologique du sol des dunes littorales du Souss-Massa. *Biomatec Echo*., **2(5):** 85-97.

Hirrel, M.C. and J.W. Gerdemann (1980). Improved growth of onion and *bell pepper* in saline soils by two vesicular-arbuscular mycorrhizal fungi, *Soil Sci. Soc. Am. J*., **44:** 654-655.

Houngnandan, P., R.G. Yemadje, A. Kane, P. Boeckx and O. Van Cleemput (2009). Les Glomales indigènes de la forêt Claire à *Isoberlinia doka* (Craib et Stapf) à Wari-Maro au centre du Bénin. *Tropicultura.*, **27(2):** 83-87.

Jerbi, M., S. Labidi, F. Laruelle, B. Tisserant, A. Lounès Hadj Sahraoui and F. Ben Jeddi (2018). Variation de la biomasse naturelle des champignons mycorhiziens arbusculaires dans la rhizosphère des principales poacées en Tunisie septentrionale. 5émes Journées Francophones des Mycorhizes. Du 27 au 29 Juin 2018. Dunkerque- France.

Johnson, N.C., D.R. Zak, D. Tilman and F.L. Pfleger (1991). Dynamics of vesicular-arbuscular mycorrhizae during old-field succession. *Oecologia.*, **86:** 349-358.

Khaosaad, T., J.M. Garcia-Garrido, S. Steinkellner and H. Vierheilig (2007). Take-all disease is systemically reduced in roots of mycorrhizal barley plants. *Soil Biology and Biochemistry.,* **39:** 727-734.

Koske, R.E. (1987). Distribution of VA mycorrhizal fungi along a latitudinal temperature gradient. *Mycologia*., **79:** 55-68.

Köske, R.E. and J.N. Gemma (1989). A Modified Procedure for Staining Root to Detect VAM. *Mycological Research*., **92:** 486-505.

Kormanik, P.P. and A.C. Mc-Graw (1982). Quantification of vesicular- arbuscular mycorrhizae in plant roots. In

Methods and principles of Mycchorizal Research, N.C. editor, APS Press, 37.

Kothari, S.K., H. Marschner and E. George (1990). Effect of VA mycorrhizal fungi and rhizosphere microorganisms on root and shoot morphology, growth and water relations in maize, *New Phytol*., **116:** 303-311.

Laminou Manzo, O., D. Ibrahim, B. Campanella and R. Paul (2009). Effets de l'inoculation mycorhizienne du substrat sur la croissance et la résistance au stress hydrique de cinq espèces fixatrices de dunes : *Acacia raddiana* Savi ; *Acacia nilotica* (L.) Willd. Ex Del. var. adansonii ; *Acacia senegal* (L.) Willd ; *Prosopis chilensis* Stunz. and *Bauhinia rufescens* Lam. *Geo-Eco-Trop*., **33:** 115-124.

Li, Y., Z. Liu, H. Hou, H. Lei, X. Zhu, X. Li, X. He and C. Tian (2013). Arbuscular mycorrhizal fungi-enhance resistance against Phytophthora sojae infection on soybean leaves is mediated by a network involving hydrogen peroxide, jasmonic acid and the metabolism of carbon and nitrogen. *Acta Physiol Plant.,* **35:** 3465-3475.

Maffei, G., L. Miozzi, V. Fiorilli, M. Novero, L. Lanfranco and G.P. Accotto (2014). The arbuscular mycorrhizal symbiosis attenuates symptom severity and reduces virus concentration in tomato infected by Tomato yellow leaf curl Sardinia virus (TYLCSV). *Mycorrhiza.,* **24:** 179-186.

Miransari, M. (2010). Contribution of arbuscular mycorrhizal symbiosis to plant growth under different types of soil stress. *Plant Biology.,* **12:** 563-569.

El-Hazzat, N., A. Ouazzani Touhami, M. Chliyeh, A. Errifi, K. Selmaoui, R. Benkirane and A. Douira (2019). Effect of a composite endomycorrhizal inoculum on the manifestation of chickpea wilt, caused by *Fusarium Solani. Plant Cell Biotechnology and Molecular Biology.,* **20(11&12):** 486-500.

Ngonkeu, M.E.L., D. Nwaga, S. Adamou, R. Fokom, N.S. Tchameni, N.A. Onguene, W.L. Nana, C. Chaintreuil, C. The, A. Amougou, L. Moulin, Y. Prin, M. Lebrun and B. Dreyfus (2013). Diversité des champignons mycorhiziens arbusculaires du Cameroun.

Philips, J.M. and D.S. Hayman (1970). Improved procedures for clearing root and staining parasitic and vesicular-arbuscular mycorrhizal fungi for rapid assessment of infection. *Trans. Br. Mycol. Soc*., **55:** 158-161.

Pozo, M.J., S.C. Jung, A. Martínez-Medina, J.A. López-Ráez, C. Azcón-Aguilar and J.M. Barea (2013). Root allies: Arbuscular mycorrhizal fungi help plants to cope with biotic stresses. In: Aroca R. eds. Progress in symbiotic endophytes, Springer 289-307.

Rajeshkannan, V., C.S. Sumathi and S. Manian (2009). Arbuscular mycorrhizal fungi colonization in upland rice as influenced by agrochemical application. *Rice Science.*, **16:** 307-313.

Raimam, M.P., U. Albino, M.F. Cruz, G.M. Lovato, T. Gaulart, C.M. Bernardi, M. Miyauchi, M.A. Nogueira and G. Andrado (2007). Interaction among free living N fixing bacteria isolated from *Droseravilliosa* var. *villosa* and AM fungi (*Glomus clarum*) in rice (*Oryza sativa*). *Applied Soil Ecology.*, **35:** 25-34.

Rayan, M.H., G.A. Chilvers and D.C. Dumaresq (1994). Colonisation of wheat by VA- mycorrhizal was found to be higer on farm managed in an organic manner than on a convenionnal neighbor, *Plant and Soil.,* **160:** 33-40.

Redhead, J.F. (1977). Endotropic mycorrhizas in Nigeria: species of the endogonaceae and their distibution. *Trans. Br. Mycol. Soc*., **69:** 275-280.

Ruiz-Lozano, J.M. and R. Azcon (1995). Hyphal contribution to water uptake in mycorrhizal plants as affected by the fungal species and water status, *Physiol. Plant*., **95:** 472-478.

Sellal, Z., A. Ouazzani Touhami, N. Mouden, M. El-Ouarraqi, K. Selmaoui, J.L. Dahmani, R. Benkirane, Ch. El-Modafar and A. Douira (2017). Effect of an Endomycorrhizal Inoculum on the Growth of Argan Tree. *International Journal of Environment, Agriculture and Biotechnology (IJEAB).,* **2(2):** Mar-Apr- 2017 ISSN: 2456-1878.

Smith, S.E. and D.J. Read (1997). Mycorrhizal symbiosis, 2nd Edition. London, Academic Press.

Smith, S. and D. Read (2008). Mineral nutrition, toxic element accumulation and water relations of arbuscular mycorrhize al plants. In: Smith, S. and Read. D. Mycorrhizal Symbiosis. 3rd. 145-18. Academic Press, London.

Smith, T.F. (1980). The effect of saison and crop relation with abundance of spores of vesicular arbuscular (VA) mycorrhizal endophytes. *Plant and soil.*, **57:** 475-479.

Qostal, S., S. Kribel, M. Chliyeh, K. Selmaoui, A. Ouazzani Touhami, S. Serghat, R. Benkirane and A. Douira (2019a). Comparative pathogenesis of 7 *Fusarium* spp. Species and bipolaris sorokiniana obtained from necrotic lesions of wheat roots and barley plants (North-Western Morocco). *Plant cell biotechnology and molecular biology.,* **20(5&6):** 261-274.

Qostal, S., S. Kribel, M. Chliyeh, K. Selmaoui, A. Ouazzani Touhami, S. Serghat, R. Benkirane and A. Douira (2019b). *Curvularia spicifera,* a parasite of the fungal complex of root rot of wheat and barley in Morocco. *Plant cell biotechnology and molecular biology.,* **20(9&10):** 354-365.

Tellal, M. (2008). Contribution à l'étude de la symbiose Casuarina-microrganismes et son importance sur la production de plants en pépinière et la fertilité du sol. Thèse de Doctorat. Université Ibn Tofail, Fac. des Sciences, Kénitra, Maroc, 135.

Tobar, R., R. Azcon and J.M. Barea (1994). The improvement of plant N acquisition from an ammonium-treated, drought-stressed soil by the fungal symbiont in arbuscular mycorrhizae, *Mycorrhiza.,* **4:** 105-108.

Walker, C., C.W. Mize and H.S. Mc Nabb (1982). Populations of endogonaceous fungi at two localities in central Iowa. *Can. J. Bot*., **60:** 2518-2529.

Wehner, J., P.M. Antunes, J.R. Powell, J. Mazukatow and M.C. Rillig (2010). Plant pathogen protection by arbuscular mycorrhizas: *a role for fungal diversity Pedologia.,* **53:** 197-201.

Zhang, X.H., Y.G. Zhu, B.D. Chen, A.J. Lin, S.E. Smith and F.A. Smith (2005). Arbuscular Mycorrhizal fungi contribute to resistance of upland rice to combined metal contamination of soil. *Journal of Plant Nutrition.*, **28:** 2065-2077.