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MYCORRHIZAL STATUS OF WHEAT (*TRITICUM AESTIVUM* AND *TRITICUM DURUM*) CULTIVATED IN NORTH WEST OF MOROCCO

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Abstract

This study describes the mycorrhizal status of wheat plants growing in six localities in northwest Morocco. Microscopic analyzes of the roots of wheat plants (hard and soft) revealed the presence of endomycorrhizal structures in all root samples. The frequency and intensity of mycorrhization reached 100% and 19.8% respectively. The highest arbuscular and vesicle contents are 16.04% and 6.42% respectively. The density of spores in the rhizosphere of durum wheat and common wheat varied between 25 spores / 100g of soil (Ouazzane BT site) and 84 spores / 100g of soil (Megren BD site). The identification of isolated spores made it possible to note the presence of one hundred and six (106) morphotypes belonging to fourteen (14) genera (*Acaulospora, Claroideoglomus, Cetraspora, Dentiscutata, Diversispora, Entrophospora, Funneliformis, Glomus, Gigaspora, Pacispora, Paraglomus, Racocetra, Rhizophagus, Scutellospora*) and seven families (*Glomaceae, Acaulosporaceae, Claroideoglomeraceae, Gigasporaceae, Pacisporaceae, Paraglomaceae* and *Diversisporaceae*) and three orders (Glomerales, Diversisporales and Paraglomerales). The spores belonging to the *Glomus* and *Acaulospora* genera are the most abundant.

Key words : Morocco, Soft wheat, Durum wheat, Rhizosphere, Arbuscular mycorrhizal Fungi (AMF).

Introduction

Wheat occupies a strategic place in the agriculture of many countries of the world. It ranks second in the world for cereals with 30% of world production, ahead of rice 19% and behind corn 41% (Source : USDA, campaign 2017/ 2018).

In Morocco, the cultivation of wheat occupies a very important place in the socio-economic context. Wheat occupies an area of 3 100 ha, with 1 100 ha of durum wheat and 2 000 ha of common wheat and production is estimated at around 73 421 tons with 24 320 tons of durum wheat and 49 101 tons of common wheat (MAPMDREF, 2018). The three historic production regions, dubbed the granaries of Morocco, Doukkala, Chaouia and El Haouz, ensure more than 45% of production (MAPM, 2014/ 2015). However, Morocco is unable to achieve self-sufficiency in wheat production, and therefore remains among the largest importers of wheat in the world (USDA, 2015).

For efficient, sustainable and environmentally-friendly agriculture, scientists advocate healthy ecological practices such as the use of bio-resources; cases of mycorrhizal fungi; these AMFs are microorganisms that live in compulsory symbiosis with more than 200 000 cultivated and uncultivated plant species (Oehl and Sieverding, 2004; Smith and Read, 2008). Symbiotic fungi are considered as a 'key' microbial group in the functioning of terrestrial ecosystems, in particular for their ability to promote the development of plants in degraded areas (Smith and Read, 2008). They promote the growth of plants on soils contaminated with heavy metals (Leyval, 2005). Within this group, arbuscular mycorrhizal fungi (AMF) are very vital for the absorption of phosphorus (P) by the plant, mainly in environments where assimilable phosphorus is often limiting (Matos *et al.,* 1999). They facilitate the mineral nutrition of plants (Fortin *et al.,* 2008) and water (Grümberg *et al.,* 2010) and participate

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in the tolerance of plants to biotic (Whipps, 2004) and abiotics (Tao and Zhiwei, 2005) stress.

In Morocco, many works have made it possible to identify the endomycorrhizal species present in the rhizosphere of different cultivated plant species, for example chickpeas (El Hazzat *et al.,* 2018), sugar cane (Selmaoui *et al.,* 2017), saffron (El Aymani *et al.,* 2019), citrus (Artib *et al .,*2017), the leek (Hibilik *et al.,*2019) and the argan tree (Sellal *et al.,*2019). This work has shown that this diversity of arbuscular mycorrhizal fungi depends on the type of culture and the mycotrophic plant species. Such information is important for a given crop, particularly in a process of promoting AMFs to promote the growth and protection of cultivated plant species (Chliyeh *et al.,* 2014; El Hazzat *et al.,* 2019 ; El Aymani *et al.,*2019). In the case of wheat cultivation in Morocco, this information is lacking and no study has been conducted, to our knowledge, on the CMA associated with the cultivation of Wheat. Thus, the present study aims to determine the mycorrhizal status of *Triticum aestivum* and *Triticum durum* in Morocco, by studying the parameters of mycorrhization: the frequency and intensity of mycorrhization, the arbuscular and vesicular contents and the diversity of the spore spectrum.

Materials and Methods

Samplings

Surveys were conducted in different localities of North-western Morocco, two paths were followed: 1/ Kénitra, Sidi Yahia, Sidi Slimane, Sidi Kacem and Had Kourt and 2/ Kénitra, Souk Larbaa, Larache, Belksiri and Ouazzane. Six stations containing plots of durum wheat and common wheat were chosen in these localities. In each of the stations and for each type of cereal (durum wheat, common wheat), a total of 100 whole plants with a clod of rhizospheric soil was sampled diagonally from each plot of 2 to 3 hectare. The collected plants are placed in white plastic bags bearing the indications relating to their origin (place and date of collection) and brought back to the laboratory.

Root mycorrhization 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), 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 x100 and x400 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 :

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

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:

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

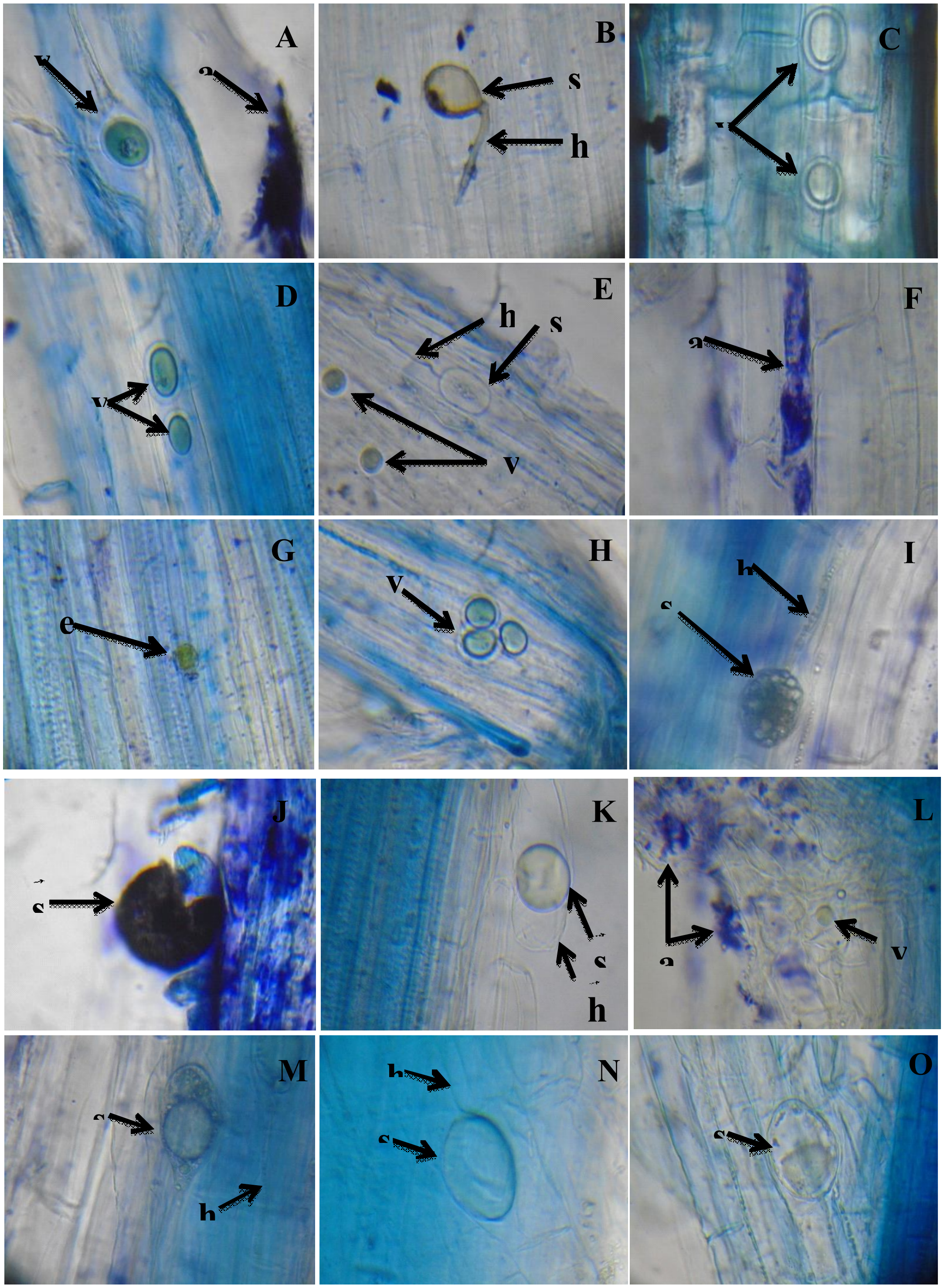

Fig. 1: Different structures of arbuscular mycorrhizae observed in the roots of wheat. Arbuscule (a); endophyte; hypha (h); Spore (h); vesicle (v); (G. × 400).

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%.

Mycorrhizal frequency %

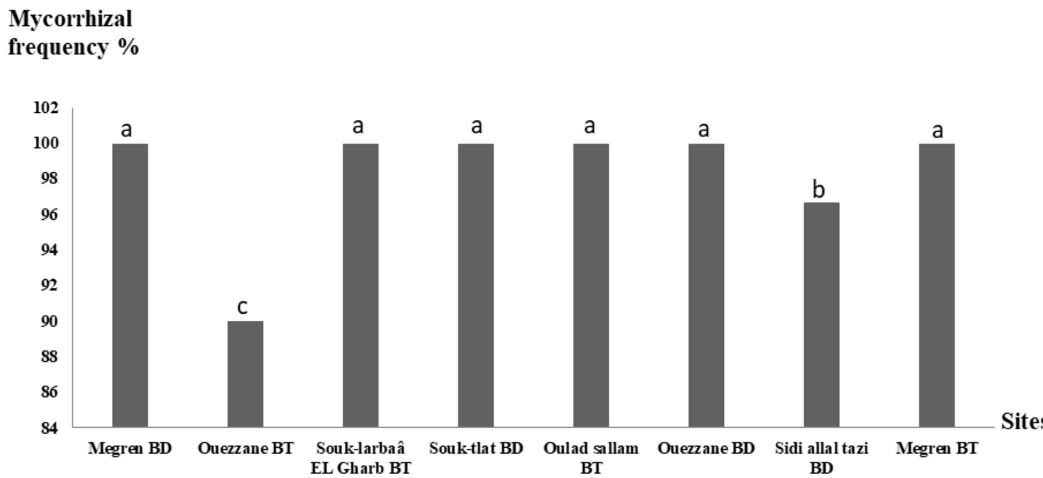

Fig. 2: Mycorrhizal Frequency of wheat roots (hard and soft) developed in the sites studied.

Mycorrhizal intensity %

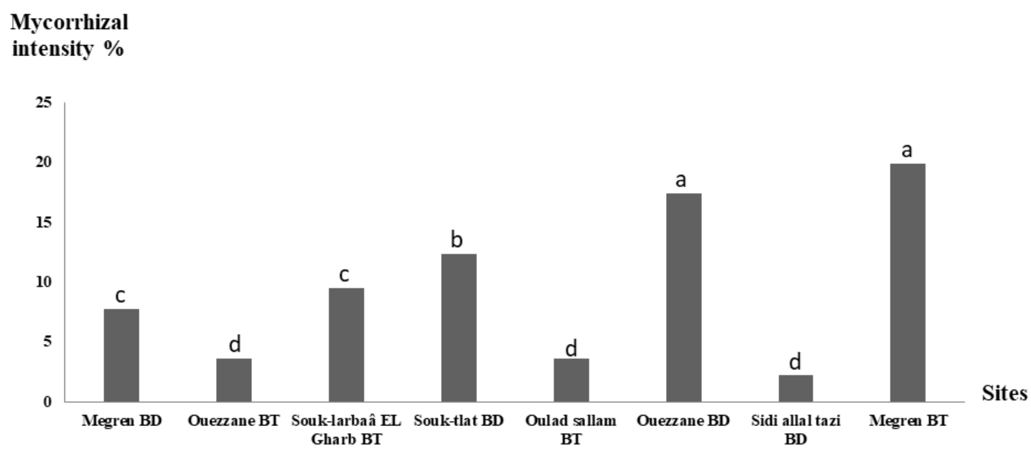

Fig. 3: Mycorrhizal Intensity (M) of wheat roots (hard and soft) developed in the studied sites.

Arbuscular content %

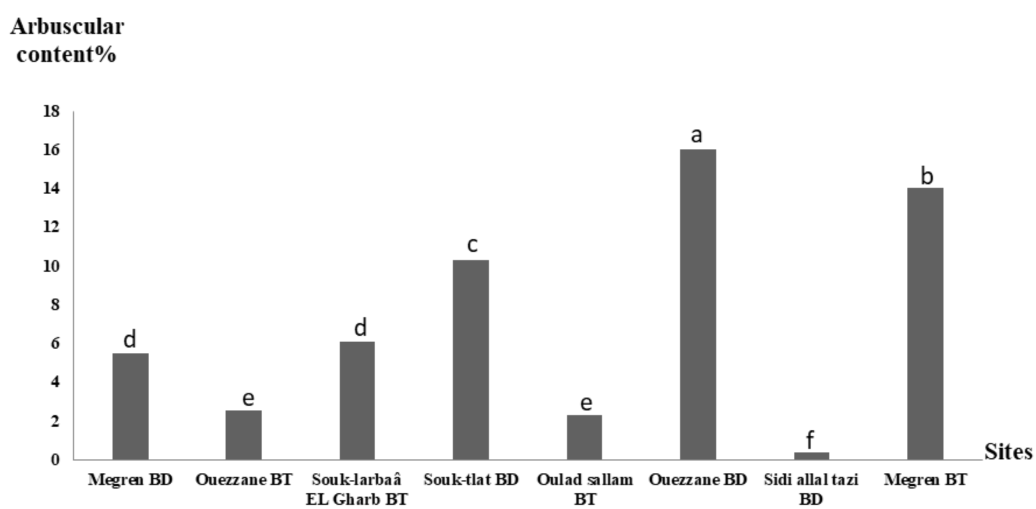

Fig. 4: Arbuscular contents of the roots of durum and soft wheat in the studied sites.

Vesicular content

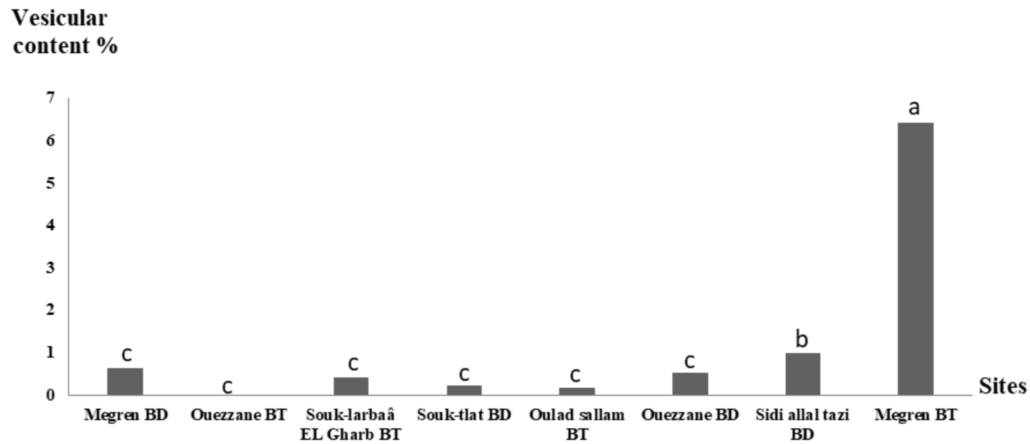

Fig. 5: Vesicle contents in wheat roots (hard and soft) in the studied sites.

Density of spores

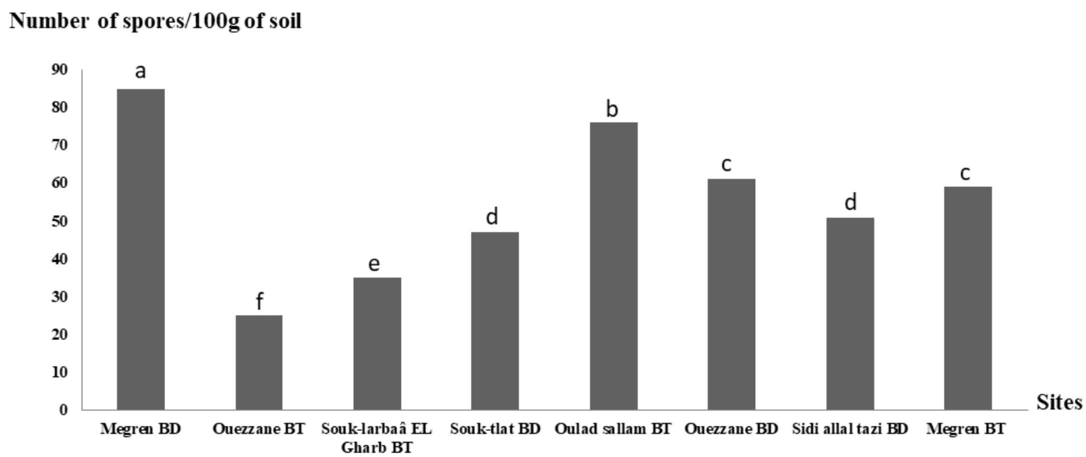

Fig. 6: Density of spores (number of spores / 100g of soil) of AM fungi in the rhizosphere of wheat plants (hard and soft) in the studied sites.

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 ìm). This operation is repeated twice. The content retained by the 200, 80 and 50 µm sieves is distributed into two tubes and 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.

Results

The observation of the fragments of the roots of soft and hard wheat, prepared according to the technique of Philips and Hayman (1970) and stained with cresyl blue, made it possible to highlight the presence of mycorrhizal structures. In the fragments of the roots of this species, the vesicles are regular, sometimes irregular (Fig. 1, A, C, D, E, H, L), and the arbuscules are present in the cells of the roots of wheat (Fig. 1, A, F, L). Spores have been

Table 1: Species of arbuscular mycorrhizal fungi (AMF) in the rhizosphere of wheat plants (hard and soft) of the studied sites.

Mycorrhizal species	Number of spores per 100g of soil							
	Megren (BD)	Ouezzane (BT)	Souk-Larbaâ EL Gharb (BT)	Souk-Tlat (BD)	Oulad Sallam (BT)	Ouazzane (BD)	Sidi Allal tazi (BD)	Megren (BT)
A.alpina	1	-	-	-	-	-	-	-
A.bireticulata	-	-	-	-	1	-	-	-
A. cavemata	1	-	-	-	-	-	-	-
A.colombiana	1	-	-	-	-	-	-	-
A.colossica	2	-	-	-	-	-	-	-
A.capsicula	-	-	-	1	-	-	-	-
A.delicata	-	-	-	-	-	-	1	-
A. denticulata	-	-	-	-	-	1	-	-
A.dilatata	-	-	-	1	-	1	1	1
A.excavata	1	1	-	2	-	-	3	-
A.foveata	1	-	-	-	-	-	-	1
A. gedanensis	3	-	-	1	1	-	-	3
A.kentinensis	1	-	-	-	-	-	-	-
A.lacunosa	1	-	-	-	1	-	-	-
A.leavis	-	-	-	-	2	2	3	1
A. mellea	-	1	-	-	-	-	-	-
A.rehmii	-	2	-	-	-	-	-	-
A.scrobiculata	-	-	-	-	-	-	1	-
A. spinosa	3	-	-	1	-	-	-	1
Acaulospora sp.1	1	-	-	-	-	-	-	-
Acaulospora sp.2	1	-	-	-	-	-	-	-
Acaulospora sp.3	1	-	-	-	-	-	-	-
Acaulospora sp.4	-	-	-	-	-	1	-	-
Acaulospora sp.5	1	-	-	-	-	-	-	-
Acaulospora sp.6	1	-	-	-	-	-	-	-
Acaulospora sp.7	-	-	-	-	1	-	-	-
Acaulospora sp.8	-	-	-	-	1	-	-	-
C.gilmorei	1	-	-	-	-	-	-	-
Cl. claroideum	-	-	-	-	1	-	-	-
Cl. etunicatum	2	-	-	-	-	1	1	7
Cl. lamellosum	-	-	-	2	-	-	-	-
D. heterogama	1	-	-	-	-	-	-	-
D. nigra	1	-	-	-	-	-	-	-
D. epigaea	-	-	-	1	-	-	-	-
Di. globifera	-	-	-	-	2	-	-	-
Diversispora sp	1	-	-	-	-	-	-	-
E.infrequens	-	-	-	1	-	-	-	-
F.badium	-	-	-	-	-	-	3	4
F.constrictum	2	-	-	-	-	-	1	-
F.geosporum	1	-	-	1	-	-	2	-
F.mosseae	2	-	-	1	-	-	-	-
F .vesiculiferum	1	-	-	-	-	-	-	-
F. verruculosum	-	-	1	-	-	-	-	-
G.aggregatum	-	-	-	2	-	-	-	-

Table 1 contd....

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Mycorrhizal species	Number of spores per 100g of soil							
	Megren (BD)	Ouezzane (BT)	Souk-Larbaâ EL Gharb (BT)	Souk-Tlat (BD)	Oulad Sallam (BT)	Ouazzane (BD)	Sidi Allal tazi (BD)	Megren (BT)
G.albidum	-	-	-	-	1	-	-	-
G.ambisporum	-	-	-	-	-	1	-	-
G.caesaris	-	3	-	-	-	-	-	-
G.deserticola	2	3	1	3	-	-	2	-
G.formasum	-	-	-	1	-	-	-	-
G.glomerulatum	4	-	-	-	-	-	-	3
G. macrocarpum	7	4	2	4	4	8	3	3
G. margarita	-	-	1	-	1	1	-	-
G.microcarpum	-	-	-	-	3	3	3	1
G. minutum	-	-	-	1	1	-	-	-
G. microaggregatum	-	-	-	-	-	-	-	1
G. multicaule	-	1	-	-	-	-	-	-
G.pansihalos	-	-	-	-	-	-	-	1
G.rubiforme	-	-	-	-	1	-	-	-
G.versiforme	8	3	12	11	25	21	13	13
Glomus sp.1	1	-	-	-	-	-	-	-
Glomus sp.2	1	-	-	-	-	-	-	-
Glomus sp.3	1	-	-	-	-	-	-	-
Glomus sp.4	-	1	-	-	-	-	-	-
Glomus sp.5	-	-	1	-	-	-	-	-
Glomus sp.6	-	-	-	-	1	-	-	-
Glomus sp.7	-	-	-	-	-	1	-	-
Glomus sp.8	-	-	-	-	-	-	1	-
Glomus sp.9	-	-	-	-	-	-	1	-
Glomus sp.10	-	-	-	-	-	-	1	-
Glomus sp.11	-	-	-	-	-	-	-	1
Glomus sp.12	-	-	-	-	-	-	-	1
Glomus sp.13	-	-	-	-	-	-	-	1
Glomus sp.14	1	-	-	-	-	-	-	-
Glomus sp.15	1	-	-	-	-	-	-	-
Glomus sp.16	1	-	-	-	-	-	-	-
Glomus sp.17	1	-	-	-	-	-	-	-
Glomus sp.18	-	1	-	-	-	-	-	-
Glomus sp.19	-	-	1	-	-	-	-	-
Glomus sp.20	-	-	1	-	-	-	-	-
Glomus sp.21	-	-	1	-	-	-	-	-
Glomus sp.22	-	-	1	-	-	-	-	-
Glomus sp.23	-	-	-	1	-	-	-	-
Glomus sp.24	-	-	-	1	-	-	-	-
Glomus sp.25	-	-	-	1	-	-	-	-
Glomus sp.26	-	-	-	-	1	-	-	-
Glomus sp.27	-	-	-	-	-	-	1	-
Gi.gigantia	-	-	-	-	-	1	-	-

Table 1 contd....

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Mycorrhizal species	Number of spores per 100g of soil							
	Megren (BD)	Ouezzane (BT)	Souk-Larbaâ EL Gharb (BT)	Souk-Tlat (BD)	Oulad Sallam (BT)	Ouazzane (BD)	Sidi Allal tazi (BD)	Megren (BT)
Gigaspora sp.1	1	-	-	-	-	-	-	-
Gigaspora sp.2	-	-	-	-	1	-	-	-
Gigaspora sp.3	-	-	-	-	1	-	-	-
Gigaspora sp.4	-	-	-	-	-	-	1	-
Gigaspora sp.5	-	-	-	-	-	-	-	1
Gigaspora sp.6	-	-	-	-	-	1	-	-
Gigaspora sp.7	-	-	-	-	-	1	-	-
Pacispora sp.1	1	-	-	-	-	-	-	-
Pacispora sp.2	-	-	1	-	-	-	-	-
Paraglomus sp	1	-	-	-	-	-	-	-
R. castanea	-	-	-	-	-	2	-	1
R.fulgida	-	1	-	-	-	-	-	-
R.minuta	-	-	-	1	-	-	-	-
R.persica	-	-	-	-	-	-	1	-
Rh.clarus	1	-	-	-	4	4	1	2
Rh.fasciculatus	2	-	-	-	1	-	2	-
Rh.intraradices	2	-	1	1	2	3	-	2
S.calospora	1	-	-	-	1	-	-	-
Scutellospora.sp	1	-	-	-	-	-	-	-
Total	85	25	35	47	76	61	51	59

SW: Soft wheat; **DW:** Durum wheat; **A :** *Acaulospora* ; **Cl :** *Claroideoglomus ;* **C :** *Cetraspora;* **D :** *Dentiscutata ;* **Di :** *Diversispora* ; **E :** *Entrophospora ;* **F :** *Funneliformis* ; **G :** *Glomus ;* **Gi :** *Gigaspora;* **R :** *Racocetra ;* **Rh :** *Rhizophagus ;* **S :** *Scutellospora.*

observed at the roots (Fig. 1, B, E, I, J, K, N, S) as well as endophytes (Fig. 1 G).

The mycorrhizal frequency of wheat roots (hard and soft) varies from one locality to another (Fig. 2). It is 100% at the Megren (durum wheat), Souk Tlat EL Gharb (soft wheat) and Ouazzane (durum wheat) sites, 96.6% at Sidi Allal Tazi durum wheat and 90% at the Ouazzane site (common wheat).

The intensity of wheat root mycorrhization (Fig. 3) is higher (19.85%) at the Megren site (soft wheat) and low (2.19%) at the Sidi Allal Tazi sites (wheat dur) and Ouazzane (soft wheat (M = 3.6%) and Oulad sallam soft wheat (M = 3.5%). In addition, the arbuscular contents are higher at the site of Ouazzane hard wheat (16.04%) and Megren soft wheat (14.04%) (Fig. 4). On the other hand, these contents are low at the site of Oulad sallam, case of common wheat (2.3%). The vesicle contents are very low in all the sites, in the Megren site (common wheat) the content is around 6.4%.

As far as the estimation of the density of spores in the rhizosphere of wheat plants (hard and soft) developed in the sites studied (Fig. 5) is concerned, we can it point out that varies from one site to another. The highest number of spores was observed in the roots of durum wheat plants from the Megren site 84 spores / 100 g of soil. This number is relatively low in the roots of common wheat plants from the Ouezzane and Souk-larbaâ EL Gharb sites, 25 and 35 spores / 100g of soil respectively.

Preliminary and provisional identifications have made it possible to note that the isolated spores belong to 106 morphotypes belonging to 14 genera: *Glomus* (43 species), *Acaulospora* (27 species), *Gigaspora* (8 species), *Funneliformis* (6 species), *Racocetra* (4 species), *Claroideoglomus* (3 species), *Diversispora* (3 species), *Rhizophagus* (3 species), *Dentiscutata* (2 species), *Pacispora* (2 species), *Scutellospora* (2 species), *Cetraspora* (one species), *Entrophospora* (one species), and *Paraglomus* (one species). These morphotypes are also divided into 3 orders (Glomales, Diversisporales and Paraglomerale) and 7 families (Glomaceae, Acaulosporaceae, Claroideoglomeraceae, Gigasporaceae, Pacisporaceae, Paraglomaceae and Diversisporaceae).

Table 2: Identification of mycorrhizal fungi isolated from the rhizosphere of wheat plants (hard and soft) growing in the study sites.

S.N.	Name	Form	Color	Spore surface	Spore size (µm)	Length of the hypha
1	*D. heterogama*	Globular	Brown	Granular	66.6	33.3
2	*D. glomerulatum*	Globular	Black yellow	Smooth	99.9	-
3	*A. spinosa*	Globular	Yellow	Granular	199.8	-
4	*A.lacunosa*	Oval	Dark yellow	Granular	66.6	-
5	*Acaulospora* sp.1	Globular	White	Smooth	149.85	73.26
6	*A. alpina*	Oval	White	Granular	149.85	99.9
7	*F. mosseae*	Globular	Dark yellow	Smooth	166.5	-
8	*G.versiforme*	Globular	Black	Granular	99.9	69.93
9	*A. gedanensis*	Globular	Ellipsoid	Granular	83.25	-
10	*D. nigra*	Globular	Black	Smooth	99.9	-
11	*Glomus* sp.1	Globular	White green	Granular	109.89	-
12	*F .vesiculiferum*	Globular	Black red	Granular	66.6	-
13	*G. deserticola*	Globular	Black red	Smooth	66.6	-
14	*A. spinosa*	Globular	Yellow	Granular	156.51	-
15	*G. macrocarpum*	Globular	Dark Brown	Smooth	39.96	33.3
16	*A.colossica*	Oval	Yellow	Granular	133.2	-
17	*Rh.fasciculatum*	Oval	Orange	Smooth	49.95	-
18	*Glomus* sp.2	Oval	Dark Brown	Smooth	73.26	-
19	*Glomus* sp.3	Oval	Yellow	Granular	116.55	33.3
20	*A.kentinensis*	Oval	White	Granular	93.24	-
21	*A. excavata*	Oval	Dark yellow	Granular	123.21	-
22	*D.nigra*	Globular	Black	Smooth	76.59	-
23	*F.constrictum*	Globular	Dark yellow	Smooth	219.78	-
24	*A.foveata*	Globular	Yellow	Smooth	199.8	-
25	*C.gilmorei*	Ellipsoid	White	Granular	66.6	33.3
26	*Paraglomus* sp.	Ellipsoid	White	Smooth	149.85	-
27	*Rh.intraradices*	Ellipsoid	Clear brown	Smooth	116.55	-
28	*Diversispora* sp.	Ellipsoid	White	Granular	66.6	36.63
29	*A. cavemata*	Ellipsoid	Grey	Granular	109.89	33.3
30	*Cl.etunicatum*	Oval	Clear brown	Smooth	183.15	116.55
31	*S. calospora*	Globular	Orange	Smooth	166.5	-
32	*Acaulospora* sp.2	Globular	Brown	Granular	66.6	-
33	*Gigaspora* sp.1	Globular	Dark brown	Smooth	159.84	49.95
34	*A.colombiana*	Oval	Clear yellow	Granular	76.59	-
35	*F. geosporum*	Globular	Dark brown	Smooth	66.6	-
36	*Pacispora* sp.1	Globular	Green	Granular	83.25	-
37	*R.clarus*	Globular	Dark green	Smooth	223.11	-
38	*G.caesaris*	Globular	Brown	Granular	233.1	-
39	*R.fulgida*	Globular	Clear yellow	Granular	123.21	-
40	*A.rehmii*	Globular	Dark brown	Granular	139.86	-
41	*A. mellea*	Oval	Hyaline	Granular	166.5	-
42	*Acaulospora* sp.3	Oval	Black yellow	Granular	59.94	-
43	*Glomus* sp.4	Globular	Dark brown	Granular	83.25	-
44	*G. multicol*	Globular	Green	Granular	116.55	33.3

Table 2 contd....

Table 2 contd....

S.N.	Name	Form	Color	Spore surface	Spore size (µm)	Length of the hypha
45	*Glomus* sp.5	Ellipsoid	Dark brown	Smooth	86.58	-
46	*G. margarita*	Globular	Brown	Granular	166.5	-
47	*F.verruculosum*	Oval	Black	Smooth	39.96	33.3
48	*Pacispora* sp.2	Ellipsoid	Yellow	Granular	116.55	-
49	*E.infrequens*	Oval	Black yellow	Granular	83.25	-
50	*A.excavata*	Globular	Brown	Granular	99.9	-
51	*A.capsicula*	Oval	Brown yellow	Smooth	76.59	-
52	*D.epigieaum*	Globular	Yellow	Granular	99.9	-
53	*Cl.lamellosum*	Globular	Clear yellow	Granular	116.55	-
54	*G.formasum*	Globular	Dark brown	Smooth	59.94	-
55	*A.gedanensis*	Globular	Yellow	Granular	133.2	-
56	*G. minutum*	Globular	Hyaline	Granular	116.55	-
57	*A.dilatata*	Globular	Yellow	Granular	106.56	-
58	*G. aggregatum*	Oval	Dark yellow	Granular	66.6	-
59	*R. minuta*	Oval	Hyaline	Granular	66.6	33.3
60	*Gigaspora* sp.2	Oval	Yellow	Granular	133.2	-
61	*Glomus* sp.6	Oval	Dark brown	Smooth	66.6	-
62	*G.microcarpum*	Oval	Dark yellow	Granular	56.61	-
63	*A.leavis*	Globular	white	Granular	66.6	-
64	*A.bireticulata*	Globular	Brown	Granular	59.94	-
65	*Di.globifera*	Globular	Brown	Granular	119.88	-
66	*G.rubiforme*	Oval	Brown yellow	Smooth	206.46	133.2
67	*Cl.claroideum*	Globular	Grey	Granular	99.9	99.9
68	*G.albidum*	Globular	Dark yellow	Granular	49.95	33.3
69	*G.deserticola*	Oval	Brown	Granular	156.51	-
70	*F.badium*	Globular	Brown yellow	Granular	199.8	-
71	*R. castanea*	Globular	Dark Brown	Granular	169.83	-
72	*A. denticulata*	Globular	Brown	Granular	99.9	-
73	*Acaulospora* sp.4	Oval	white	Granular	83.25	-
74	*Gi.gigantia*	Oval	Yellow	Granular	199.8	-
75	*G.ambisporum*	Oval	Black yellow	Smooth	109.89	66.6
76	*A.delicata*	Globular	White	Granular	66.6	99.9
77	*Gigaspora* sp.3	Oval	Brown	Granular	159.84	59.94
78	*Gigaspora* sp.4	Globular	White Brown	Granular	66.6	-
79	*Glomus* sp.7	Globular	Black yellow	Granular	116.55	-
80	*A. scrobiculata*	Globular	White	Granular	39.96	-
81	*Glomus* sp.8	Oval	Dark Brown	Granular	79.92	16.65
82	*Glomus* sp.9	Globular	Brown	Granular	116.55	-
83	*Glomus* sp.10	Oval	Brown	Granular	46.62	-
84	*E.infrequens*	Oval	Brown	Granular	83.25	49.95
85	*Gigaspora* sp.5	Oval	Yellow	Granular	136.53	-
86	*Glomus* sp.11	Globular	Yellow	Granular	89.91	-
87	*G.microaggregatum*	Globular	Brown	Granular	46.62	-
88	*G. pansihalos*	Oval	Brown white	Granular	36.63	23.31
89	*Glomus* sp.12	Oval	Green	Granular	166.5	-

Table 2 contd....

Table 2 contd....

S.N.	Name	Form	Color	Spore surface	Spore size (µm)	Length of the hypha
90	*Glomus* sp.13	Globular	Green yellow	Granular	113.22	-
91	*Scutellospora.*sp	Globular	Dark Brown	Granular	33.3	-
92	*Acaulospora* sp.5	Oval	White	Granular	69.93	-
93	*Acaulospora* sp.6	Globular	Hyaline	Granular	153.18	-
94	*Acaulospora* sp.7	Globular	Yellow	Granular	143.19	-
95	*Acaulospora* sp.8	Globular	Yellow	Granular	103.23	-
96	*P.scintillans*	Globular	White	Granular	99.9	33.3
97	*Glomus* sp.14	Globular	Black	Smooth	123.21	-
98	*Glomus* sp.15	Oval	Black yellow	Smooth	133.2	-
99	*Glomus* sp.16	Globular	Black yellow	Granular	66.6	143.19
100	*Glomus* sp.17	Oval	Yellow	Granular	49.95	-
101	*Glomus* sp.18	Globular	Black yellow	Granular	99.9	-
102	*Gigaspora* sp.6	Globular	Brown	Granular	133.2	-
103	*A. excavata*	Globular	Brown	Granular	73.26	-
104	*Glomus* sp.19	Globular	Black	Smooth	46.62	-
105	*Glomus* sp.20	Oval	Black	Granular	76.59	-
106	*Glomus* sp.21	Globular	Black Brown	Smooth	133.2	-
107	*Glomus* sp.22	Globular	Black yellow	Granular	73.26	-
108	*Glomus* sp.23	Globular	Black	Smooth	93.24	-
109	*Glomus* sp.24	Oval	White	Granular	66.6	39.96
110	*Glomus* sp.25	Globular	Yellow	Granular	83.25	-
111	*Gigaspora* sp.7	Oval	Brown	Granular	66.6	-
112	*D.glomerulatum*	Globular	Yellow	Granular	69.93	-
113	*Rh.intraradices*	Oval	White Brown	Granular	159.84	-
114	*G.versiforme*	Globular	Hyaline	Granular	69.93	66.6
115	*A. foveata*	Ellipsoid	Dark yellow	Smooth	133.2	146.52
116	*Glomus* sp.26	Globular	Yellow	Granular	79.92	-
117	*Glomus* sp.27	Oval	Black yellow	Granular	66.6	56.61

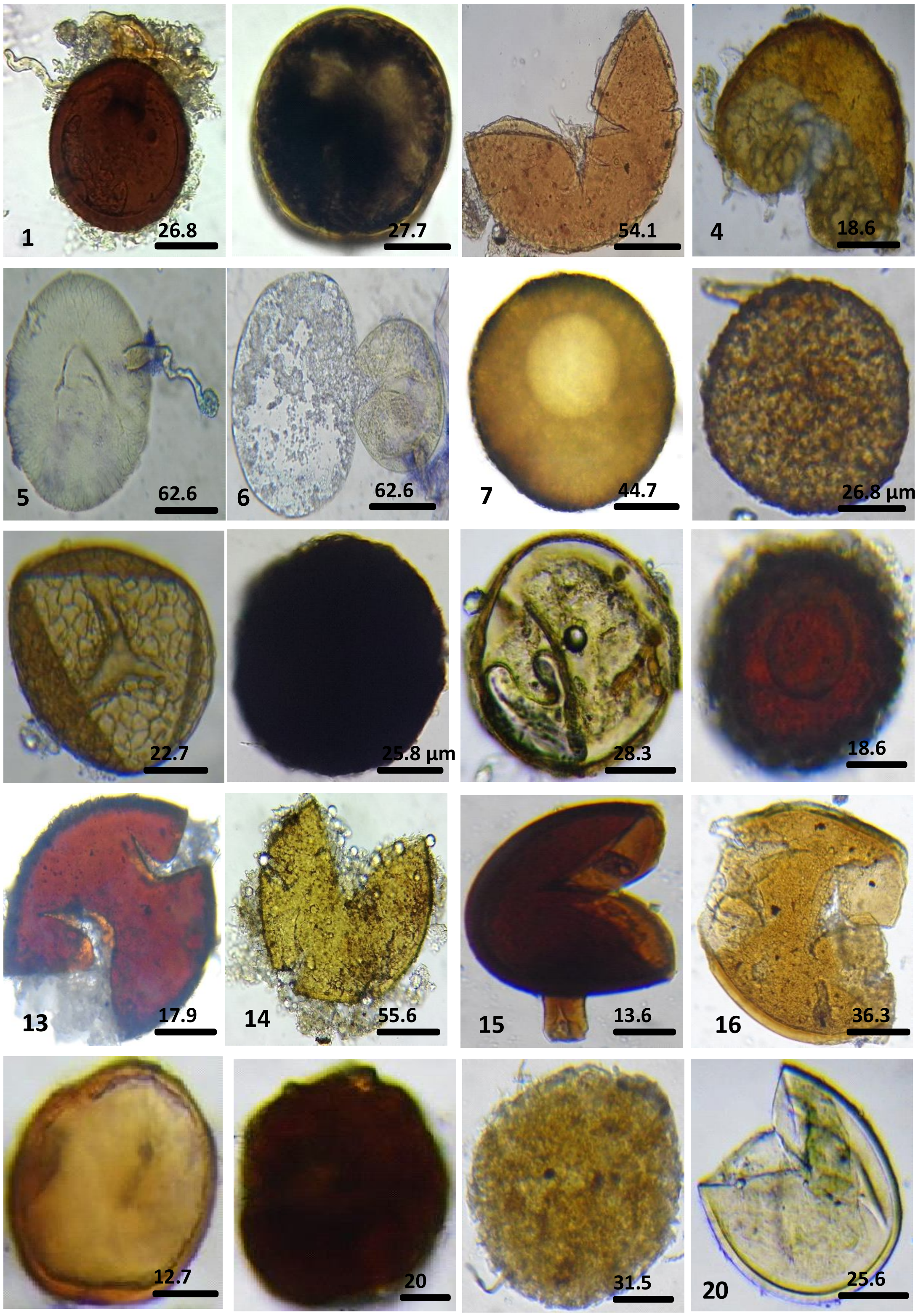
A : *Acaulospora* ; **Cl :** *Claroideoglomus ;* **C :** *Cetraspora ;* **D :** *Dentiscutata ;* **Di :** *Diversispora* ;
E : *Entrophospora ;* **F :** *Funneliformis* ; **G :** *Glomus ;* **Gi :** *Gigaspora;* **R :** *Racocetra ;* **Rh :** *Rhizophagus ;* **S :** *Scutellospora.*

Discussion

The roots of wheat plants (hard and soft) from all the studied sites showed endomycorrhizal structures (arbuscules, vesicles, spores, hyphae). The arbuscular contents of the roots are relatively higher than those of the vesicles. Wheat in general is considered a mycotrophic species and forms a symbiotic association with endomycorrhizal arbuscular fungi (AMF) (Trouvelot *et al.,* 1982).

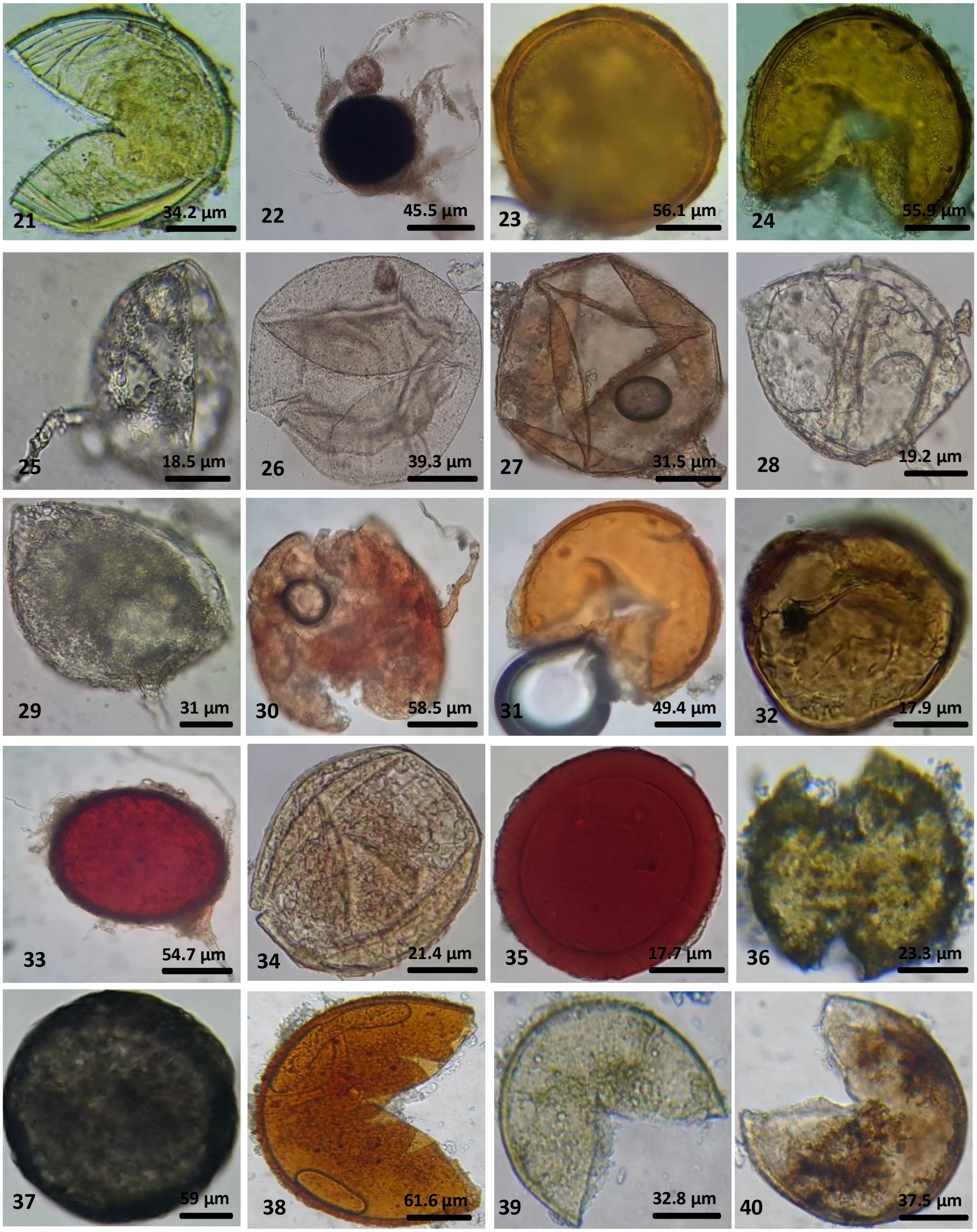
The intensity of mycorrhization, the content of arbuscules and vesicles of the roots vary from one site to another, this variation can be explained by the difference in the physico-chemical properties of the substrates of the sites (Mahesh and Selvaraj, 2008). The highest intensity of root mycorrhization was noted in the roots of common wheat plants at the Megren site (19.85%), the Ouezzane site (17.4) and the Souk-Larbaâ El site. Gharb BT (12.3) and the lowest were observed in the roots of common wheat (2.19%) and durum wheat (3.6%) plants, respectively from the Sidi Allal Tazi and Ouazzane BT.

The frequencies of mycorrhization are high in the roots of common wheat plants growing in the Megren site (100%) and Ouazzane BT (90%). However, the rhizosphere of plants at the Ouazzane site is less rich in spores of endomycorrhizal fungi (25 spores / 100g of soil). On the other hand, it seems that there is a positive relationship between the frequencies of mycorrhization (100%) and the number of spores observed in the durum wheat plants (Megren site) and soft wheat plants (Oulad Sellam site), respectively around 84 and 76 spores per



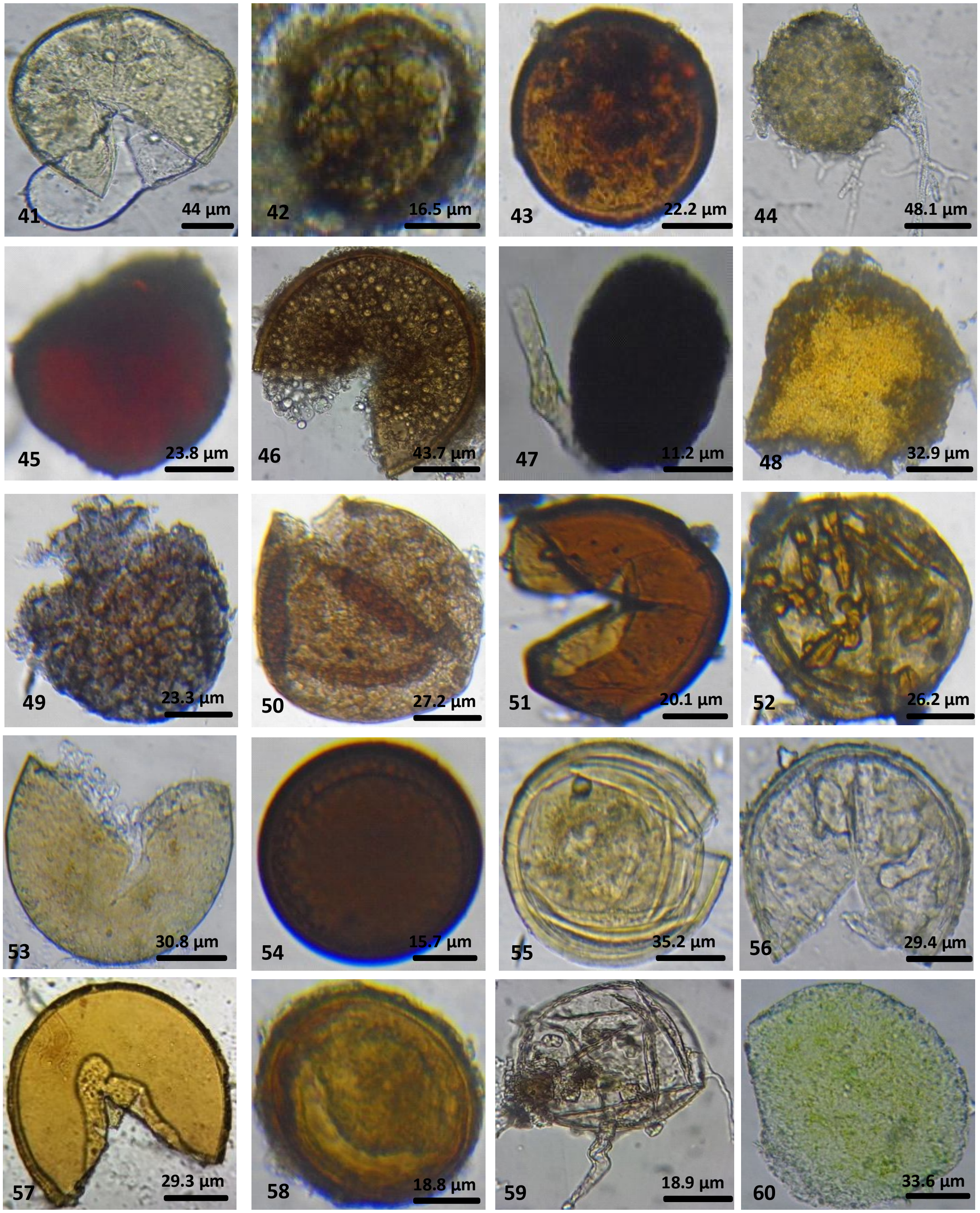
100g of soil.

Analysis of spore communities of endomycorrhizal fungi encountered in the rhizosphere of wheat plants shows a variation in spore density from one site to another. This observed variation can be attributed to the spore formation process and the degradation of their germination (Smith, 1980), at sampling season (Gemma *et al.,* 1999), soil and climatic variations (Koske, 1987; Johnson*et al.,* 1991) and soil microorganisms (Dalpé., 1989). according Jasper *et al.* (1991), the weak relationship between the formation of endomycorrhizae and the quantity of spores isolated is due to the fact that



certain propagules are dormant. However, according to these authors, the number of spores increases regularly from July, reaches a maximum value in October (rainy season), decreases in winter and reaches its minimum in summer (March and May).

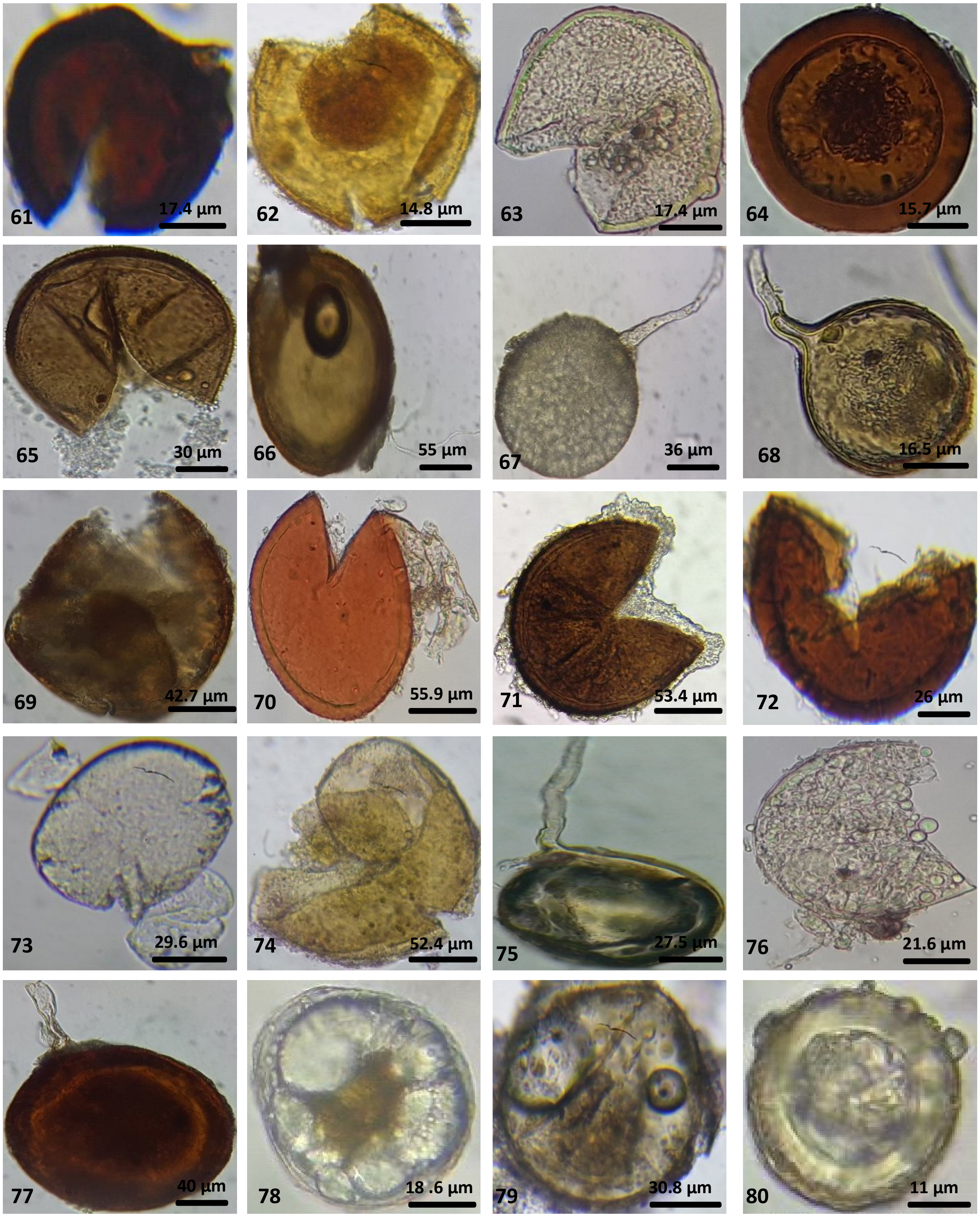
The spore densities observed in the rhizosphere of the studied wheat (25 to 64 spores per 100 g of soil) are lower than those observed by Ghazala *et al.,* (2007). They revealed that the densities of spores in the soybean rhizosphere vary between 250 and 715 spores per 100g of soil. Weissenhorn (1994) noted 150 to 200 spores per 100g of dry soil taken from agricultural soils polluted by atmospheric deposition; Sieverding (1991) counted 120 spores per 100g of soil under cassava monoculture, 132



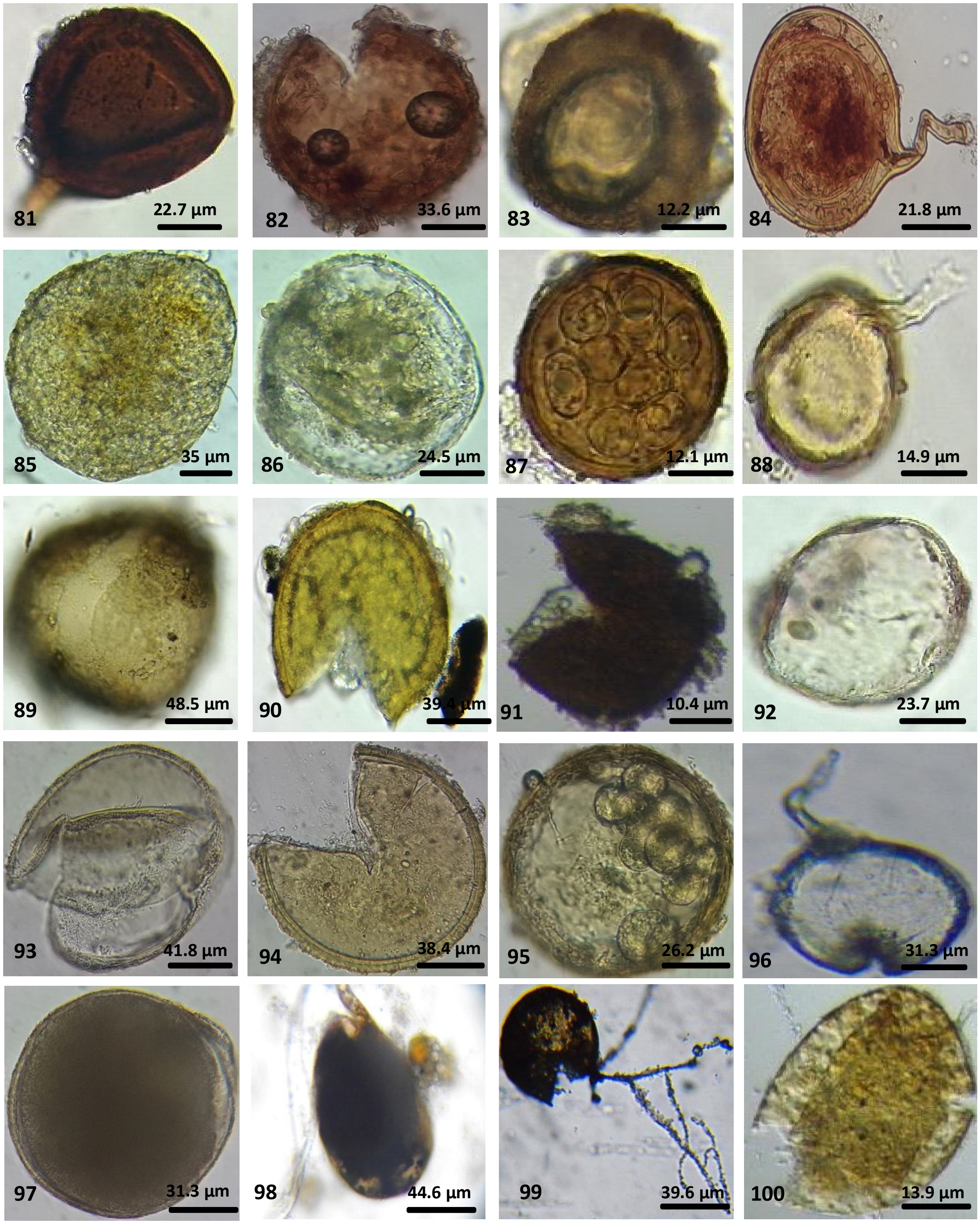
under rotational cultivation and 360 in savannah.

The endomycorrhizal fungi associated with wheat roots are very varied. Preliminary identifications, based solely on the morphological criteria of the spores, made it possible to note one hundred and six 106 morphotypes distributed in fourteen genera: *Acaulospora* (27 species), *Claroideoglomus* (3 species), *Cetraspora* (one species), *Dentiscutata* (2 species), *Diversispora* (3 species), *Entrophospora* (one species), *Funneliformis* (6 species), *Glomus* (43 species), *Gigaspora* (8 species), *Pacispora* (2 species), *Paraglomus* (one species), *Racocetra* (4 species), *Rhizophagus* (3 species) and *Scutellospora* (2 species).

The study showed that the genus Glomus is the most dominant species in the rhizosphere of wheat plants, the dominance varies from site to site, followed by the genera



Acaulospora, Gigaspora, Funneliformis, Racocetra, Claroideoglomus, Diversispora, Rhizophagus, Dentiscutata, Pacispora, Scutellospora, Cetraspora, Entrophospora, and *Paraglomus*. The dominance of species of the *Glomus* genus has also been noted in the rhizosphere of wheat plants in Iran (Daei *et al.,* 2009). In Morocco, the representatives of the *Glomus* genus are those who dominate in the rhizosphere of different plant species: olive tree (Kachkouch *et al.,* 2012, 2014), oleaster (Sghir *et al.,*2013), date palm (Bouamri *et al.,* 2006; Sghir *et al.,* 2014), carob tree (El Asri *et al.,* 2014, Talbi *et al.,* 2015), poplar (Talbi *et al.,* 2014), sea rush (Talbi *et al.,* 2014), European tea-tree (Box thorn) (Touati *et al.,* 2013).



Conclusion

It emerges from this study that the rhizosphere of wheat plants growing in different sites in northwest Morocco presents abundance and diversification of AMFs. This diversity of endomycorrhizal fungi associated with wheat roots can be used for the production of endomycorrhizal inocula based on these fungi in order to promote the growth of cereal species and their protection against fungal diseases.

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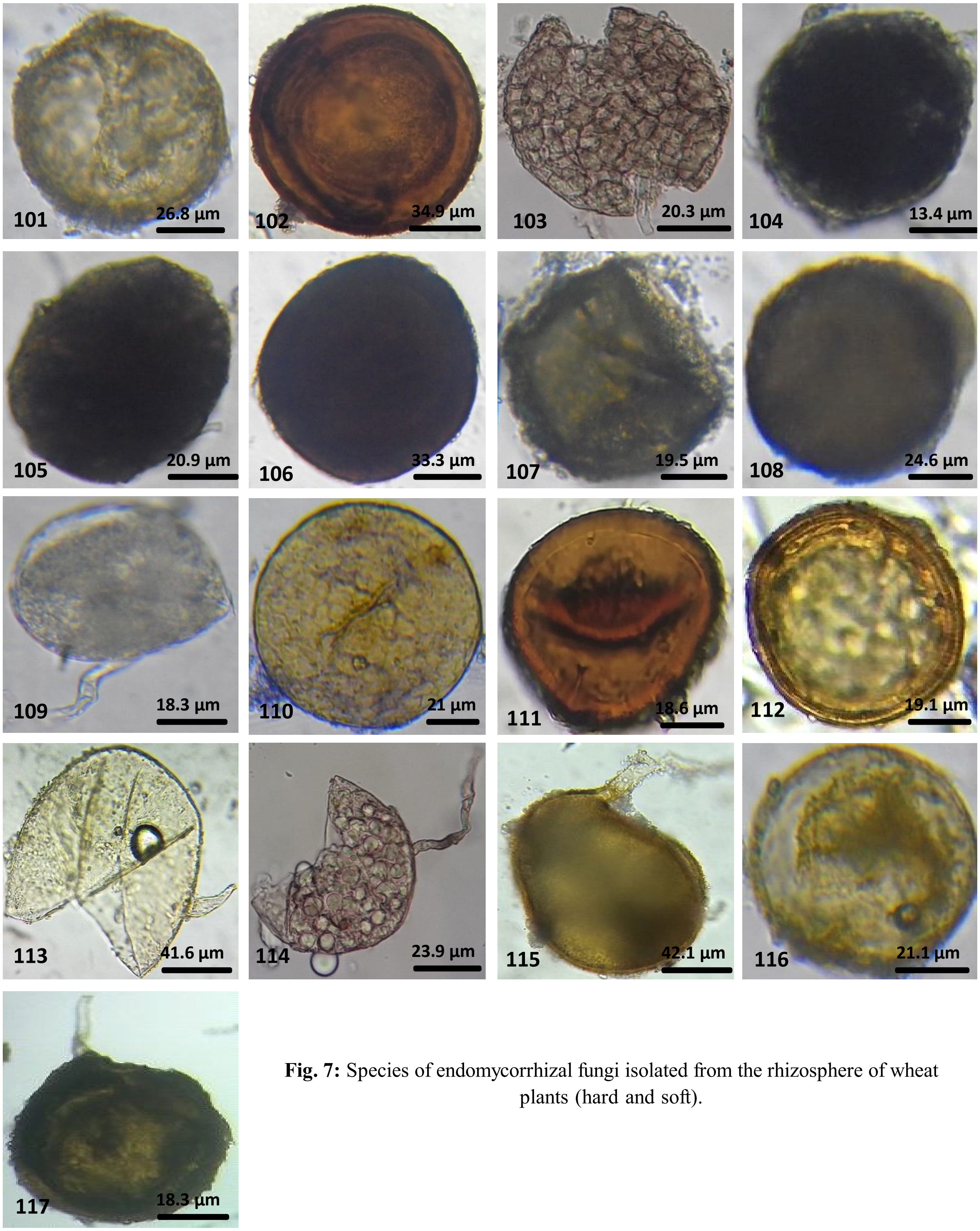

Fig. 7: Species of endomycorrhizal fungi isolated from the rhizosphere of wheat plants (hard and soft).

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