Chapter

Diversity of Arbuscular Mycorrhizal Fungi in the Rhizosphere of *Argania spinosa* in Morocco

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Abstract

Despite the importance of arbuscular mycorrhizal fungi (AMF) within forest and agroecosystems, few data are available about how AMF communities are structured in the root zone of the argan tree. Some studies have characterized endomycorrhizal fungi population occurring in rhizosphere soils of argan trees grown in southwest of Morocco, numerous sites in this area harbored unexplored communities. The endomycorrhizae diversity of rhizosphere soils collected from 15 argan forest stands located in Lakhssas, Smimou, Ait Baha, Tamanar, Essaouira, Taroudant (Elkodya), Irherm, Guelmim, Imsouane, Anzi, Tiznit, Taghazoute, Ait Melloul, Bouizakarne, and Oulad Teima have revealed the presence of different AMF communities sharing some species but dissimilar AMF community compositions are noted according to sampling time and site. Additionally, the diverse AMF structures detected such as vesicles, arbuscules and hyphae reflect implicitly the germination of AMF propagules in the rhizospheric area of the Argan tree. The pre-evaluation of AMF in the soil through spores' density can indicate AMF community dynamics, signaling either the adaptability of mycorrhizal symbionts to the local conditions or its decline. In total, 39 morphotypes of endomycorrhizal fungal spores were identified and described, representing seven genera: *Glomus* (15 species), *Scutellospora* (3 species), *Entrophospora* (4 species), *Pacispora* (2 species), *Gigaspora* (4 species), *Acaulospora* (10 species), and *Ambispora* (1 species). The genus *Glomus* has a wide occurrence and had the largest number of species. This chapter gives a great overview of the mycorrhizal status of argan trees in their natural habitats of the main Moroccan argan forests.

Keywords: Morocco, *Argania spinosa*, arbuscular mycorrhizal fungi, diversity

1. Introduction

In their natural environment, plants are part of a rich ecosystem, including numerous and diverse microorganisms in the soil and the arbuscular mycorrhizal fungi (AMF), which represent the main component of the soil microbiota in most agroecosystems. Arbuscular mycorrhizal fungi (AMF) are obligate biotrophs and rely on their autotrophic host to complete their life cycle and produce the next generation of spores [1]. These symbionts colonize the roots of the vast majority of plants, either the roots of 86% of terrestrial plants [2] and most crop plants [3]. By forming an extended, intricate hyphal network, AMF can efficiently absorb mineral nutrients from the soil and deliver them to their host plants in exchange for carbohydrates. They play an important role in soil fertility, the acquisition of mineral nutrients, especially immobile nutrients, such as phosphorus [4, 5]. AMF can also enhance tolerance or resistance to root pathogens [6] or abiotic stresses, such as metal toxicity [7]. Yet another benefit conferred by the mycorrhizal fungi is plant growth increase under water deficit conditions. It does so by aiding drought avoidance, enhancing mineral nutrition, improvement in soil physicochemical and biological properties [8].

AMF protects the plant health against other environmental stresses [9, 10] and improves the soil structure by the formation of stable soil aggregates, building up a macroporous structure of soil that allows penetration of water and air and prevents erosion, which results in promoting root system development [11].

Due to all of these advantageous attributes of AMF related to the extended absorptive root surface and the available soil volume by hyphae mycelium of mycorrhizal fungi, some ecological scientists have advocated their use in the regeneration of tropical forests and the restoration of degraded soil in arid and semi-arid areas. In Morocco, there are many representative areas where potential resources are affected by the grazing pressure, arid climate, and anthropogenic activities, such as the northwest palm grove [12, 13], Thuya [14], and argan forest [15]. Of these latter, the argan-ecosystem, suffers from an increase in the deterioration of its various components and needs rehabilitation and reforestation programs to restore a sustainable natural environment.

The use of AMF is one of the natural processes that gains an increasing interest. Its success depends on the knowledge of the diversity and richness of AMF as probable indicators of adaptation in certain environments and the setting of symbiosis with plants [16]. In this context, the study of the diversity of AMF in argan tree rhizosphere through the isolation, identification, and quantification of the number of spores constitute the key step to the characterization of the native AMF associated with this plant species before using as inoculants with a better chance of adapting to particular soil, climate conditions [17].

Several works have shown that the argan tree benefits from a symbiotic association established between the roots of the plant with mycorrhizal fungi [18–21]. Indeed, in semi-arid and arid seeded areas, soils are deficient in nutrients and subject to long periods of drought, hence the need for such root symbiosis [22]. Describing the diversity of the community of AMF at numerous sites from the same area can be useful tool awarding eventual changes that can occur in the course of years before undertaking preservation strategies of this endemic tree, such as incorporating AMF-based biotechnology to cope with stressful conditions that threaten both the perennity and production of this agroforestry system.

2. Argan stands in southwestern Morocco

Argan tree forest covers an area of 3,976,000 ha, spanning from the city of Safi in northeastern Morocco to the Saharan fringe in the south, where the argan tree

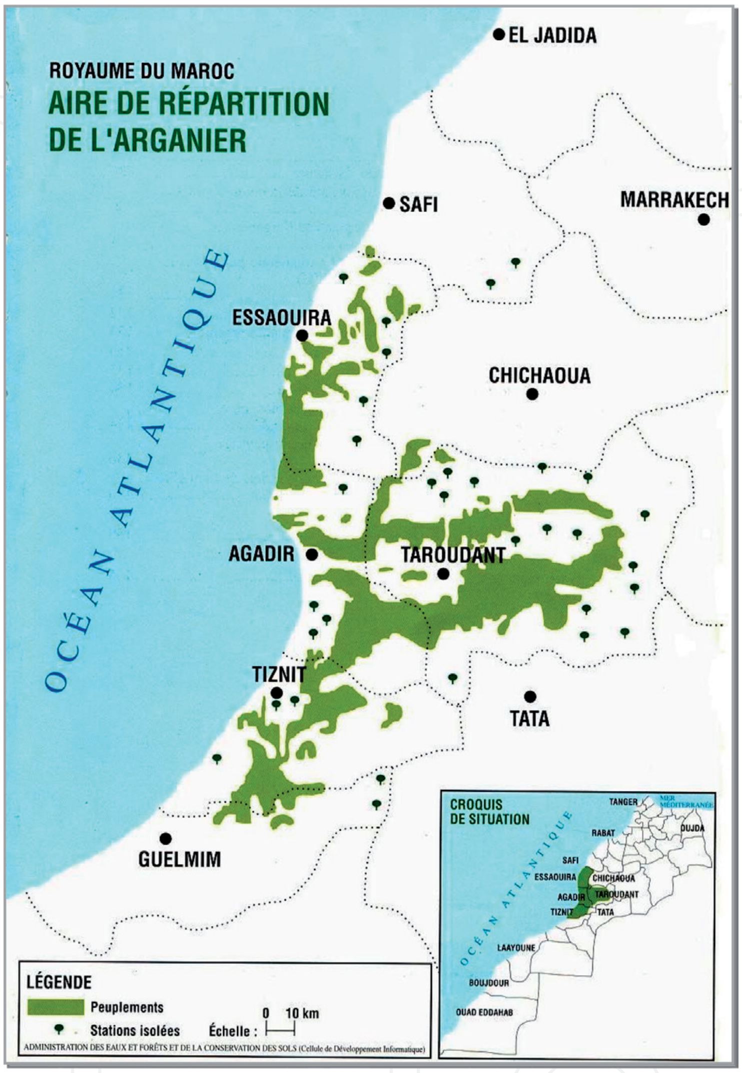

Figure 1.
Distribution area of the argan tree in Morocco [23].

(a) (b)

Figure 2.
Argan tree from Tamanar (a) and Oulad Teima (b) regions.

Figure 3.
Fruits of the argan trees of southwestern Morocco (A) Smimou, (B) Ait Baha, (C) Tiznit, and (D) Bouizakarne.

occupies about 70% of the woodland area [23]. The most important stands extend mainly from the Northeast of Essaouira to the valley of Souss (**Figure 1**).

This locality constitutes the central area of the argan grove and this is because of the state of development and the exceptional vigor that this species presents as shown in 15 sites covering areas of Lakhssas, Smimou, Ait Baha, Tamanar, Essaouira, Taroudant, Irherm, Guelmim, Imsouane, Anzi, Tiznit, Taghazoute, Ait Melloul, Bouizakrane, and Oulad Teima (**Figures 2** and **3**).

3. Physicochemical properties of soil—AMF community

Soil properties are critical in determining the fertility of soils, and some parameters can define the composition and species richness of AMF communities. Hazard *et al.* [24] stated that soil pH has a stronger effect than land use itself on AMF communities in agroecosystems and crops. Alguacil *et al.* [25] suggested that three soil properties related to microbial activity, that is, pH and levels of two micronutrients (Mn and Zn) also determined the distribution of AMF communities in soils. Differences in soil have been found to be key factors in determining AMF community composition [26], and this is particularly relevant in stressed environments. Soil properties have been found to affect the AMF community [27], especially in terms of the availability of nutrients

[28] and variations in pH [29, 30]. Moreover, the structure and dynamic of the AMF community can be influenced by edaphic features, including soil texture and structure, organic matter content, the pH, and macro and micronutrient levels [31, 32]. As pH increases above 7.0 in aqueous solutions, most of the dissolved phosphorus reacts with calcium forming calcium phosphates resulting in a decrease in solubility and availability of phosphate [33, 34]. Indeed, external abiotic factors, such as precipitation or edaphic characteristics, can directly influence the available habitat for a species, which affects an organism's ability to survive in a given location [35]. Furthermore, soil characteristics, such as pH, electrical conductivity, and assimilable phosphorus levels, may also affect the spore number of endomycorrhizal fungi [36].

4. AMF community composition associated with Argan trees

The AM fungi are the important rhizospheric microorganisms whose diversity can be decisive for both plant community structure and ecosystem productivity. Studies on AMF occurrence and distribution have been made by spore extraction from soil and identification based on the morphology of the spores. Thus, the identification of spores has also been widely used to characterize AMF communities in soil [26, 37, 38].

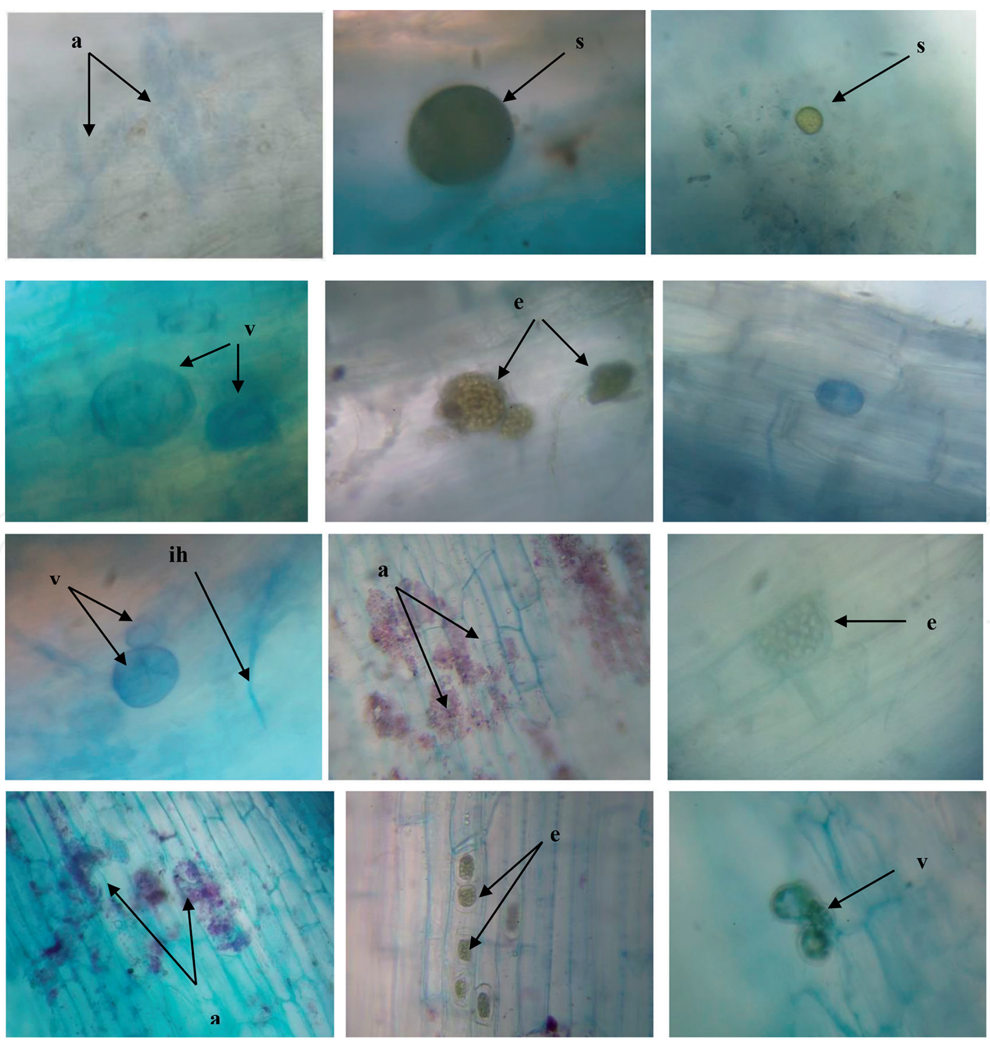

Figure 4.
Different structures of endomycorrhizal fungi colonizing the roots of Argania spinosa. Arbuscules (a); intra hyphae (ih), spores (s); vesicles (v) and endophytes (e). (G. × 400).

4.1 Root colonization with AM fungi

The root colonization by AM fungi relies on the presence of microscopic structures, such as external and internal hyphae, vesicles and arbuscules, as well as endophytes (**Figure 4**).

4.2 AMF spore density

According to Morton *et al.* [39] and Sturmer and Bellei [40], spore density is the common tool for quantifying the AMF population in the soil. The highlighting of the structure mycorrhizal community consists of spores' number enumeration and abondance of each one. The communities of these fungi present in soil can be estimated in terms of the number of species observed and the abundance of each of them in the community. In *Argania spinosa* rhizosphere soil gathers 561 spores/100 g of soil (**Figure 5**) [41].

Oliveira and Oliveira [42] have revealed significant variations in spore density between the soil samples collected in August (dry season) obviously lower than in the sampling performed during the rainy season. Likewise, Khaekhum *et al*. [43] noted a higher number of AMF spores in the rainy season than in the dry season. The changes in spore densities are probably attributable to annual variations in climatic and edaphic conditions, especially as spore density increases in dry climates [44] reflecting adaptability to temperate, dry, and arid ecosystems [45, 46]. It is well known that edaphoclimatic conditions, such as pluvial precipitation can influence AMF spore density [47]. According to Pringle and Bever [48], fungal species sporulate differently on the season. For these authors, the seasonal variations in spore densities probably reflect seasonal differences in spore formation. Smith [49] showed that maximum spore densities are noted in the spring and decline in the summer.

The variation of spore density of AMF is directly related to the plant growth stage [50]. Various medicinal plants have displayed the highest intensity of AMF colonization and spore population in the flowering stage [51]. Hatimi and Tahrouch [52] have demonstrated that mycorrhization is nutrient level-dependent, and the spore production of AMF tends to be significant at the flowering stage and then decreased at the end of the growing season when the physiological cycle of plant roots changed. Indeed, disturbance of semi-arid ecosystems decreased mycorrhizal spore density and nutrient availability.

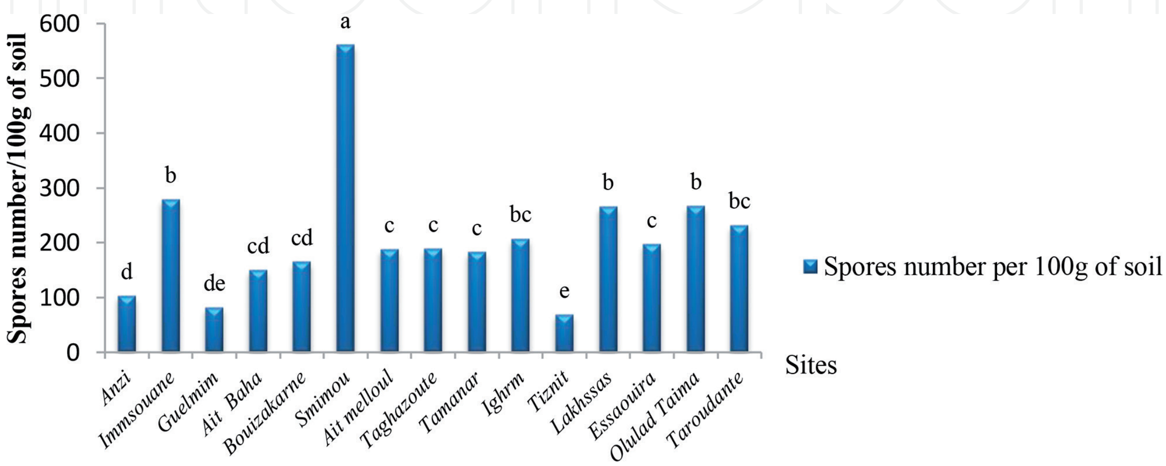

Figure 5.
Average of AMF spore density according to soils of sampled sites from Argania spinosa distribution areas [41].

DOI: http://dx.doi.org/10.5772/intechopen.106162

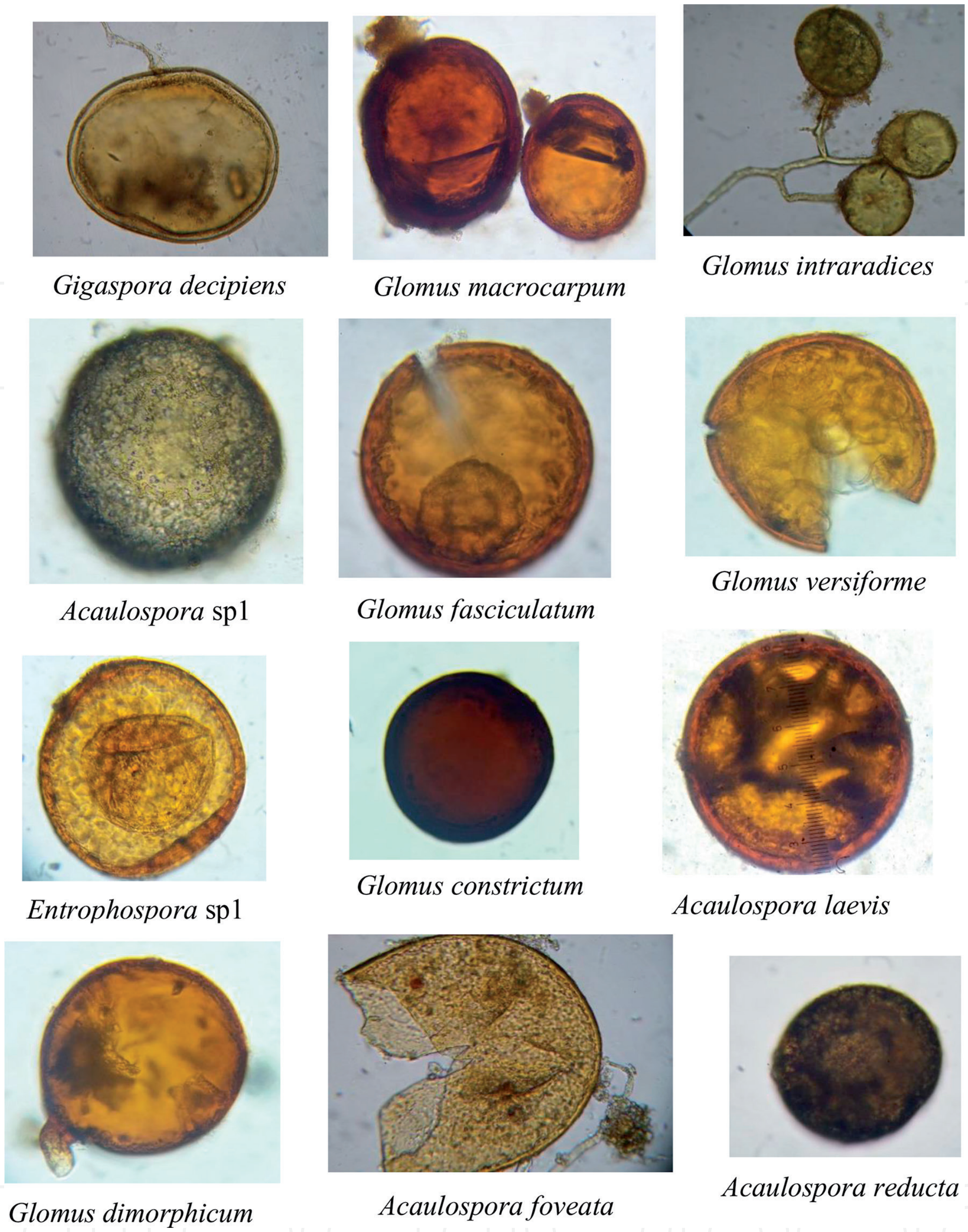

Figure 6.
Some AMF species and morphotypes isolated from the rhizospheric soil of argan tree [41].

4.3 AMF Community and species richness

As all natural plant communities, the argan tree contains arbuscular mycorrhizal fungi at rhizospheric soil level. The total number of AMF morphotypes was 35 in 2016 [53] and 39 in 2021 [41] illustrated in **Figure 6**.

The specific richness of this assembly of community attains 18, 14, and 9 species in some sites (**Figure** 7). Almost the same number of AMF spore morphotypes (31) was found in the rhizosphere of *Ceratonia siliqua* developing in different ecological zones (Afourar, Ksiba Khénifra, Taroudant, and Nador) [54]. El Maati *et al.* [55] detail a low specific richness (nine species) of native AMF communities from *Argania spinosa*, *Acacia gummifera,* and *C. siliqua* in southwest Morocco, 11 morphotypes from the argan tree in northwest Morocco [56]. Several factors can explain these

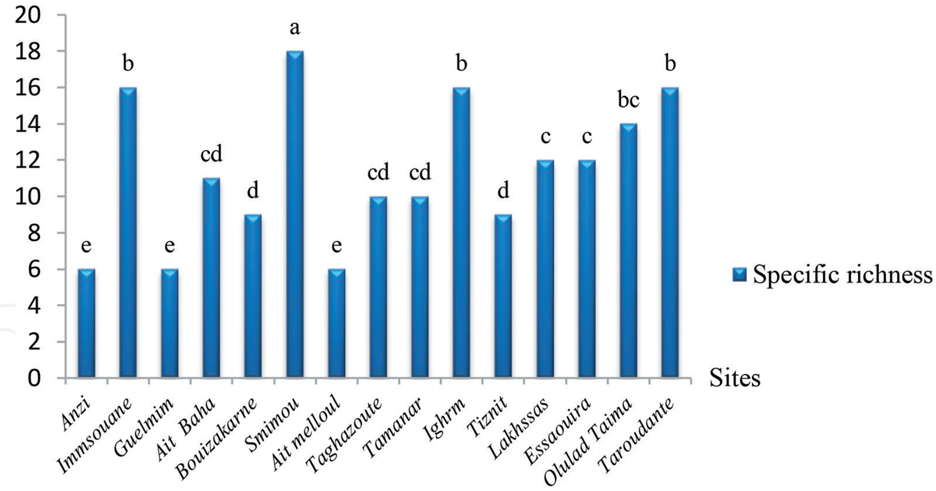

Figure 7.
Specific richness of mycorrhizal species in the rhizosphere of argan tree according to studied sites.

disparities. Relative air humidity and rainfall are significant drivers for AMF spore density, especially for members of the families Acaulosporaceae, Diversisporaceae, and Glomeraceae, which were positively correlated with these abiotic factors [57]. The precipitation and water availability could drive the changes in AMF communities at a regional scale [58]. Spore abundance and species richness can also be influenced by elevation gradients [59, 60] and mycorrhizal fungi pH tolerance [61], plant density [62], and productivity and land-use intensity [63].

Regarding the dominance of genera *Glomus* and *Acaulospora* in the rhizospheric soil of argan tree, it was also cited by El Maati *et al.* [55], in the rhizosphere of diverse plant species [64–69], in soil from different ecosystems, in Senegal [70], in China [71], Burkina Faso [72], Kenya [73], Sudan [74], and in central Europe [75]. The high occurrence of the *Glomus* genus is due to its ability to produce more spores in a shorter time than other genera, such as *Gigaspora* and *Scutellospora,* and its adaptation to drought and soil salinity [76]. In disturbed habitats, the high abundance of Glomeraceae is related to the considerable capacity of some of its most frequently found members, for example, *Rhizophagus irregularis*, to sporulate [77]. *Acaulosporaceae* members may be confined to the harsh environmental conditions of uplands [78] and are dominant in protected areas. In fact, the high anthropic impact may modify the AMF community and cause decreased AMF biodiversity, root colonization, and sporulation [79]. It was emphasized that degraded lands harbor low levels of AMF abundance and diversity [80]. Several studies found that disturbance of semi-arid ecosystems decreased mycorrhizal spore density and root colonization [81]. It was also reported that livestock and human disturbances decreased AMF spore density, root colonization, and nutrient availability [82].

5. Conclusion

Mycorrhizal fungi play a complex role in ecosystem function, so knowledge of their distributional patterns is important, especially in view of the current environmental threats to AMF diversity and plant productivity under climate changes. The present study provides useful information about the composition of the AMF community associated with *Argania spinose* tree within its natural environment where some conditions exert strong pressure leading to the appearance, dominance of AMF type or disappearance of other AMF species, and replaced by others. Thus, we can expect the success of restoration programs if the suited AMF is used for multiplication in soil with plants displaying great mycorrhizal capacity.

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