

Importance of *Picoa* spp. as Desert Truffles Fungi

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Birds truffles; *Picoa* spp. have been subject to few studies. Birds truffles are considered among desert truffles and a valuable food. Further, they were used as medicine in Arabian Gulf countries including Saudi Arabia and several other countries of the world. Recently, many researchers have demonstrated that desert truffles including bird's truffles are source of important nutritional elements. In addition, they have some biological activities such as antibacterial, antioxidant activities, kind of medicinal properties and used in folk medicine. Meanwhile, birds truffles were not investigated for its cultivation, ecology, taxonomy, physiology, edibility, medicinal properties as well as antimicrobial activities. Rare studies on birds truffles could be found in surveyed literatures concerning geographic distribution and molecular studies. These molecular research were achieved to elucidate the ambiguity of the classification of birds truffles; this with the help of the advanced recent techniques in molecular biology. Hence, in this present article, we compile recent data on the importance of *Picoa* spp. as desert truffles fungi. The *Picoa* can play a significant role in biological control agents and provide food for birds. Moreover, the decomposition of fruit-bodies of *Picoa* in the soils can improve the physical, chemical and biological conditions of the soils that will improve their ecological conditions.

Keywords: Desert truffles; *Picoa* spp.; Importance; Saudi Arabia.

Picoa spp. called "Birds' truffles" are considered as desert truffles. They are valuable as food and used as medicine in Arabian Gulf countries including Saudi Arabia and several other countries of the world. Truffles, in general, have been considered for centuries as valuable food due to their high nutritional value¹. As it is well known, desert truffles are a natural source for several chemical components such as proteins, amino acids, vitamins, flavor compounds, sterols, terpenes, fatty acids, minerals and carbohydrates^{2,3,4,5}. Truffles were usually used to make typical food in several societies including the Middle Eastern and North African societies where desert truffles were highly

valued by people of these regions^{6,7}. In addition, desert truffles were widely used in traditional medicine due to their pharmaceutical properties and medicinal value. Different species belonging to the genus *Picoa* have been cited in all countries of the Mediterranean basin including Saudi Arabia and Iran. *Picoa* species is found in a gypsiferous and calcareous gravelly deserts soil where the fruiting bodies appear from January to April in Kuwait⁸, while in Saudi Arabia appear from November to March⁹. These periods are directly related to climatic conditions. During the fruiting season, ascomata of *Picoa* spp. can indirectly noticed by remarking the surface of the soil which appears cracked or convex. The modification of soil surface and the presence of *Helianthemum* spp. confirm that the ascomata of *Picoa* spp. are in the remarked place. Furthermore, the mutual relationship

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between desert truffles and *Helianthemum* spp. had been proved via Isotopes tracer $^{14}\text{CO}_2$ aided research¹⁰. In comparison with desert truffles, birds' truffles have not been sufficiently studied; because few research works concerning *Picoa* spp. highlighted the ecological importance, distribution as well as the taxonomy. In this present article, we primarily compile recent data on the importance of *Picoa* spp. as desert truffles fungi.

Occurrence of desert truffles

The desert truffles grow principally in countries around the Mediterranean basin, they have been reported by many scientists in countries of Southern Europe including Spain and Portugal^{11,12}, France¹³, Italy and France¹⁴, Hungary¹⁵, Turkey¹⁶. Also, they have been reported in North Africa that extends from Mauritania to Egypt^{17,18,19,20,21} as well as in the Middle East^{22,23,24,25} and Qatar²⁶. However, some species of desert truffles were also found in Botswana, South Africa^{7,27,28} and in North America²⁹. Regarding the morphology of desert truffles, several types have been collected in Africa and in the Middle East region and have been evaluated by numerous scientists. Some wild macro-fungi species were reported in Saudi Arabia, Bahrain, and Egypt such as *T. claveryi* and *Tirmania nivea*^{4,5,30,31,32}. Other types of desert truffles, such as *Choiromyces echinulatus*, *T. pfeilii* have also been reported in South Africa³³. Furthermore, various types were found in Tunisia such as *P. juniperi*, *P. lefebvrei* and *Terfezia* sp.³⁴. Moreover, five types of desert truffles were found and identified in different parts of Iran such as *T. claveryi*, *Tir. nivea*, *T. pinoyi*, *P. juniperi* and *P. lefebvrei*³⁵.

Hosts plants of desert truffles

Desert truffles have a mycorrhizal association with numerous annual and perennial xerophytic host plants that belongs to the Cistaceae family. They form mycorrhizae mainly on roots of different species of the genus *Helianthemum* sp.^{10,36}, or *Cistus* sp.³⁶. The type of this association between desert truffles and *Helianthemum* sp. is function to culture conditions³⁶, and function to phosphorus content of culture medium³⁷. In sterile conditions; an ectomycorrhiza was noticed in high phosphorus level of phosphorus, while ectendomycorrhiza it is observed in a medium culture lacking phosphorus, but an endomycorrhiza formed in a medium deficient in level of available phosphorus³⁷.

Interestingly, scientists have successfully obtained an endomycorrhiza between *Helianthemum* spp. with *Terfezia* and *Tirmania* spp.^{38,39}. This specific type of mycorrhizal association; endomycorrhiza firstly called "helianthemoid" which is firstly proposed by Alsheikh⁴⁰. The plasticity of desert truffles to form different mycorrhizal association types have been demonstrated recently by Zitouni-Haouar *et al.*⁴¹ when they inoculated in *in vivo* conditions six *Cistaceae* species with three *Terfezia* species: *T. leptoderma*, *T. boudieri*, and *T. claveryi*. In fact, typical endomycorrhizae was formed in *H. ledifolium*, *H. lippii* and *Fumana procumbens* whereas an ectomycorrhiza was synthesized in *Cistus* species (*C. albidus*, *C. incanus*, *C. salvifolius*) and *Pinus halepensis* (Aleppo pine) in green house conditions.

Ecological importance

Mycorrhizal association between desert truffles and xerophyte plants plays an important ecological role in arid and semi-arid ecosystems. Furthermore, it helps to prevent erosion and combat desertification⁴². On the other hand, desert truffles may constitute an alternative agricultural yield in arid and semi-arid lands and have high price in the market⁴³, they also have a positive effect on sustainability, biodiversity⁴⁴ and a considerable role in eco-tourism in arid and semi-arid regions.

Cultivation and conservation of desert truffles

Cultivation of desert truffles in arid and semi-arid lands was studied by different scholars. But some were focusing their work on cultivation and fruiting of *T. boudieri* Chatin in semi controlled conditions (green house) and *in situ*; this work was composed by inoculating of *H. sessiliflorum* Desf. Pers. by *T. boudieri* using two types of soil; gypsy and sandy soil⁴⁵ and the results of this research are encouraging to turn toward "cultivation" of desert truffles. Cultivation of desert truffles may represent *ex situ* conservation⁴⁶, despite a specific cares should be followed in this activities. Evaluation of soil and environmental characteristics of the plantation site are crucial, especially in semi-arid areas where climate conditions are critical^{47,48}. *Ex situ* conservation of desert truffles can constitute a new branch of ecotourism for local population in Middle East and North Africa. In this scope, Saudi Wildlife Authority which manages several natural reserves takes, every year, special action to organize desert truffles collecting inside the natural

reserve of Harrat Al Harrah in the northern region of Saudi Arabia, in a way to preserve fungal flora and fauna of this reserve⁴⁹.

Few studies have been conducted to characterize the mycorrhizae of desert truffles cultivated with their host plants under semi-controlled conditions in green house. In fact, the first attempt to cultivate desert truffles in the western desert in *in vivo* was performed in Iraq¹⁰. Several *Helianthemum* species such as *H. salicifolium* and *H. ledifolium* have been inoculated by different species of desert truffles in the conditions of green house¹⁰. Actually, they simulated desert condition to cultivate desert truffles and investigate their relationship with *Helianthemum* herbs. Interestingly, Alrawi and co-workers¹⁰ have demonstrated that some critical factors are essential to improve desert truffles production such as soil composition, texture, moisture contents, temperature, as well as the type of water. Moreover, they have tested the effect of irrigation on the growth of desert truffles, surprisingly, irrigation test was succeeded, and all irrigated areas have produced desert truffles. On the other hand, a research field study of an installation of drip irrigation system in wild productive of desert truffles plots near Arar city (KSA) had a positive effect on production. Irrigation in autumn increases, qualitatively and quantitatively, the obtained ascomata of desert truffles⁵⁰. Additionally, the importance of irrigation factor for successful cultivation has been reported by Morte *et al.*,⁵¹. Other researchers⁵², demonstrated that irrigation should be applied twice during the season, one time at the end of the summer especially when rainfall is less than 150 mm and the second time is during the fruiting season in dry period of the year.

***Picoa* spp.**

Focusing on desert truffles include several valuable hypogeous macro-fungi species, few scientists have been interested in discovering and studying new desert truffles species, especially the genus *Picoa* which belong to Ascomycota (Pyronemataceae, Pezizales). Several *Picoa* species have been reported in arid and semi-arid ecosystem especially in Tunisia, Saudi Arabia, and Iran. Table1 presents few examples of *Picoa* species reported in Africa and Middle East.

Actually, *P. juniperi* and *P. lefebvrei* are not, traditionally, the most highly appreciated

desert truffles in Middle East due to their small fruit-bodies. This is the reason that these fungi are not collected in spite of their edibility. A recent field study⁵⁸, showed that drip irrigation of naturally producing plot of *Picoa* spp. in Muayala Natural Reserve near Arar city at the north-east of Saudi Arabia, has to obtained for the first time relatively big ascomata of *Picoa* spp. with a diameter reach to 7.5 cm. In near of this locality, a study revealed for the first time the presence of *P. lefebvrei* in the eastern area of the northern borders province⁹. While in the same region the presence of *Phaeangium lefebvrei* in the northern region of Saudi Arabia had been confirmed⁵⁷.

Classification

Classification of desert truffles including birds' truffles was based on morphological characters such as morphology of ascomata, spore, peridium, sporocarp odor, as well as color of the gleba. Classification of *Phaeangium* was the subject of different opinions. In taxonomical point of view, *P. lefebvrei* was firstly described and grouped in the genus *Phaeangium*; *P. lefebvrei* Pat.⁵⁹. Current name: *P. lefebvrei* (Pat.) Maire⁶⁰. Also, the same name was adopted^{61,62}, other synonym: *T. schweinfurthii* Henn. after Gücin *et al.*⁵⁵, while *Phaeangium* was placed temporarily in Peronymataceae⁶³. Classification based on morphological features is common and used till these days. Spores in *Phaeangium* are ornamented at maturity and have tomentose peridium, whereas *P. juniperi* has smooth spores and no tomentum. *Phaeangium* and its single species, *P. lefebvrei*, are re-described and placed in the family

Table 1. Examples of *Picoa* species reported in Africa and Middle East

Truffles	Countries	References
<i>P. juniperi</i> <i>P. lefebvrei</i>	Tunisia	[³⁴]
<i>P. lefebvrei</i> <i>P. juniperi</i> <i>P. lefebvrei</i>	Turkey	[⁵³] [⁵⁵]
<i>P. lefebvrei</i> <i>Phaeangium lefebvrei</i>	Saudi Arabia	[⁹] [⁵⁷]
<i>P. lefebvrei</i> <i>Picoa</i> spp.	Iran	[⁵⁴] [⁵⁶]

Pyronemataceae, tribe Mycolachneae²². Actually, classification based on morphological characters is a complementary approach but, at the same time, it is difficult and not sufficient to differentiate two close species. This may be attributed to the effect of environmental factors and various ecological habitat conditions on morphological characters⁶⁴.

Recent studies have been carried out to revise the classification of *Picoa* using molecular methods; the obtained results showed that most morphological character used in classifications of *Picoa* were not sufficient to study phylogenetic relationship and don't provide phylogenetic information. Whereas molecular markers especially Internal Transcribed Spacer (ITS), were essentially phylogenetically informative and useful to separate the different lineages in *Picoa*, also in addition, geographical and ecological factors, rather than morphological data, are most useful character for separation of these lineages⁶⁵. Other phylogenetic analyses demonstrate that *P. lefebvrei* belongs to the *Geopora-Tricharina* clade of *Pyronemataceae* family. In fact *P. lefebvrei* was placed in the genus *Picoa* due to its close genetic relationship with *P. juniperi*^{65,66}.

Chemical composition of *Picoa*

Chemical composition and nutritional value of several desert truffles and *Picoa* spp. were studied and evaluated by many reviewers and researchers^{67,68,69,70}. Precisely, other author⁶⁸ studied the composition of desert truffles "birds' truffle" *P. lefebvrei*, they reported that the fruit-bodies of *Picoa* are rich in minerals and contain 23% total protein (% dry weight), 18% total carbohydrates, 1% crude fat and 3% total crude fibers, and a total of 26 amino and 11 fatty acids. This can give us an indication to take care of these neglected desert truffle fungi which can participate in a high quality of human nutrition.

Importance of *Picoa* spp.

Species belonging to *Picoa* spp. are not extremely appreciated by local people in Middle East and Africa, in spite of their nutritional value², antioxidant activity⁷¹ and medicinal properties⁷² but also for their important role in preventing erosion and desertification. It has a good chemical composition which is suitable for human health like other types of desert truffles. In comparison to desert truffles, the *Picoa* spp. does not have tremendous values and economic importance.

The interesting related study is which confirms the importance of birds' truffles; *P. lefebvrei* and *P. juniperi* such as an antibacterial agent against the development or the inhibition of several bacteria; *Escherichia coli*, *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Streptococcus mutans*, *Proteus vulgaris*, *Salmonella typhi*. In parallel, an identical study showed that the same effects were observed against *Candida tropicalis* and also against the dermatophyte *Trichophyton* sp.⁷². The *Picoa* can play significant role as biological control agents, which may reduce the harmful organisms in the soils. It can also provide food for birds, because the fruiting bodies which appear partially on the surface of the soil are eaten by birds^{8,73}. They were sought out by migratory birds and have been used by the Bedouins as bait in bird traps⁷⁴. Interestingly, *P. lefebvrei* were generally used in folk medicine to treat people infectious eye diseases⁷¹. By decomposition of the *Picoa* in the soils, it may improve physical, chemical and biological conditions of the soils that directly or indirectly improve the ecological conditions of the soils and environment.

CONCLUSION

This review study reflects the importance of *Picoa* species as food, as biological control agents. These wild fungi may contribute in biodiversity and assure sustainability. *Picoa*, also can have an important medicinal effect against human pathogenic bacteria and yeasts. Further studies are needed to develop molecular probes for birds' truffles identification, and more researches are also required to study their biodiversity and to understand in a better way the physiology of these fungi in Middle East and north of Africa. In additions, international legislations need to be developed to regulate trading of desert truffles. These multiple actions may advance our scientific knowledge generally on desert truffles in arid and semi-arid ecosystems, and can play as a crucial element to improve natural production including preservation in their habitat. Also, these actions will indirectly help local population to realize the concept of eco-tourism. A special attention need to be focused on developing natural production, and why not to move to the "production" via controlled mycorrhization of annual or perennial associative

desert plants, to meet the forte need for protecting and preserving arid or semi-arid region.

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