

Species Diversity of Hypogeous Ascomycetes in Israel

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We conducted a species diversity study of the hypogeous Ascomycetes of Israel. The hypogeous Ascomycetes in Israel include members of the families Pyrenomataceae, Pezizaceae, and Tuberales, which are represented by seven species: *Hydnocystis piligera*, *Terfezia arenaria*, *T. claveryi*, *T. oligosperma*, *Tirmania africana*, *Tuber asa*, and *T. nitidum*; only *T. asa* is new to Israeli mycobiota. Synonymy, locations, collection data, general distribution, distribution in Israel, descriptions, a key to identification, illustrations, and taxonomic remarks are provided.

KEYWORDS : Ascomycetes, Distribution, Hypogeous, Mediterranean, Mycorrhiza

The hypogeous Ascomycetes represent one of the most interesting and complicated systematic groups of Ascomycetes. The species diversity of this group in Israel is poorly known compared to many other fungal groups, and only a few surveys on this subject have been published. The most notable ones include the elaborations by Rayss [1, 2] and Binyamini [3-5]. However, none of these researchers provided a critical species diversity study or a taxonomic analysis of the hypogeous Ascomycetes in Israel.

Hypogeous fungi colonize a variety of forests and semi-arid ecosystems in the Mediterranean region. Most of these fungi frequently establish mutualistic associations with vascular plants via specialized nutrient-gathering organs called mycorrhizas [6]. Many hypogeous fungi occurring in semi-arid and arid desert ecosystems of the Mediterranean Basin belong to the genera *Hydnocystis*, *Terfezia*, *Tirmania*, and *Tuber*. Most are endemic not only to Israel but also to the Mediterranean region and establish mycorrhizal symbioses with members of the Cistaceae, mainly with *Helianthemum* species.

According to classical mycology, most species have been described based on their morphological features such as ascospore and peridium morphology, gleba color, odor and other organoleptic characteristics. However, these fungi are difficult to identify at the species level. The use of morphological features is problematic for the systematics of hypogeous Ascomycetes because of the reduced set of morphological characteristics and homoplasy. Ascocarp features are homoplastic as a result of the parallel evolution of independent lineages of epigeous/hypogeous fruit bodies during the evolutionary history of the Peziza-

les [7]. This accounts for the early artificial classification of hypogeous fungi in the order Tuberales. Tuberales includes several hypogeous families with similar morphology that originated by parallel or convergent evolution [8]. Realizing that the Tuberales artificially grouped many Pezizales, Trappe [7] transferred some of families from Tuberales to Pezizales and amended some families in Pezizales to include related hypogeous fungi. He also amended the Pezizaceae Fries *sensu* Korf to accommodate several related hypogeous taxa lacking forcible spore discharge, such as *Tirmania*. In addition, Trappe [7] included *Terfezia* in the Terfeziaceae and *Picoa* in the Balsamiaceae, based on a comparative morphological study.

The increasing amount of molecular phylogenetic data now available has led to a continued revision of the hypogeous Ascomycetes [8-12]. O'Donnell *et al.* [8] provided support for the occurrence of independent lines of epigeous/hypogeous fruit body evolution in the Pezizales, which has affected classification of the desert truffles. Moreover, an 18S rDNA sequence analysis has revealed a close relationship between *Terfezia* and the Pezizaceae [13, 14].

Subgeneric relationships within the Pezizales have been subjected to molecular analysis [14-17]. However, other than studies of the genus *Tuber* [16], no recent work has addressed subgeneric relationships within the hypogeous genera. Many hypogeous Ascomycetes have a rich synonymy, i.e., some species have, at times, been placed in different genera, families, or orders by different authors, and species names have been changed as well. New interpretations based on molecular phylogenetic analyses are leading to the assignment of species to different genera based on generic relationships rather than structural relationships. Therefore, the names accepted in this study have

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been used currently by many mycologists but are subject to change with new interpretations.

After searching the literature, we found that six species of hypogeous Ascomycetes are known in Israel. During the investigation, one new species from the genus *Tuber* was added to Israel's mycobiota. At present, the hypogeous Ascomycetes in Israel are represented by seven species.

Materials and Methods

This investigation was based on the 2002 and 2007 growing seasons and on published literature devoted to Ascomycetes of Israel. The collected specimens were preserved at the Institute of Evolution, University of Haifa (HAI,

Israel) herbarium. The microscopic characteristics were observed with a Carl Zeiss-amplival microscope (Carl Zeiss, Jena, Germany), and photomicrographs were taken with a Sony camera (Sony, Tokyo, Japan). Fungal material was mounted on a microscope slide and examined in water using a light/dark field microscope with or without phase contrast at a magnification of up to $\times 1,000$. Micromorphological characteristics of our specimens were observed using Melzer's reagent. For statistical calculations, 30–40 ascospores, asci, excipular hyphae, and paraphyses were measured for each preparation.

The habitat and general distribution of hypogeous Ascomycetes species are given according to Saccardo [18], Burdsall [19], Dennis [20], Binyamini [3-5], and Montecchi and Sarasini [21]. All synonyms were adopted from the Index Fungorum online database (<http://www.index-fungorum.org/>) and were revised by the authors, and the most significant were chosen. The distribution of species is provided, using the natural regions of Israel, according to Feinbrun-Dothan and Danin [22] (Fig. 1).

Results and Discussion

Pyronemataceae Corda

Genus *Hydnocystis* Tulasne & C. Tulasne, Parl. Giorn. Bot. Ital. 2(1): 59 (1844).

Type species. *Hydnocystis piligera* Tul. & Tul., Parl. Giorn. Bot. Ital. I 1(2): 59 (1844).

Hydnocystis piligera Tul. & Tul., Parl. Giorn. Bot. Ital. I 1(2): 59 (1844) (Fig. 2)

Icon. Tulasne & Tulasne, Fung. Hypo. t. 13, fig. II, 1–11, 1851; Burdsall, Mycologia 60(3), 505: fig. 22–25, 1968; Binyamini, Nova Hedvigia XXXII, 18: fig. 1, 19: 7a, b, c, d, 1980; Montecchi & Sarasini, Fungi Ipogei D'Europa, p. 183, 2000.

Ascocarps: 1.0–2.5 cm in diam, hypogeous, globose to subglobose, flattened, lobed with basal pore, sessile, hollow, brownish to yellow-brown, felted with short fine hairs, sometimes attached to plant debris. Gleba: cream or straw colored, fleshy but firm. Odor: strong and unpleasant. Outer excipulum: composed of *Textura angularis* about 300 μm thick, cells 10–25 μm broad, pigmented yellowish cream. Excipular hairs in young specimens 50 μm up to 150 μm long, 5–8 μm broad, thick-walled, septate, hyaline or yellowish brown, apex obtuse, bulbous at the base. Inner excipulum: composed of *Textura angularis* about 200 μm thick, subhymenium with *Textura intricata* 20–30 μm thick, thin-walled, hymenium about 200–500 μm thick. Asci: cylindrical to subclavate, 180–350 \times 20–45 μm , tapering gradually to the base, 8-spored, uniseriate, rarely bi-seriate. Ascospores: globose, 22–28 (~31) μm , hyaline or yellowish, smooth, thin-walled, with-

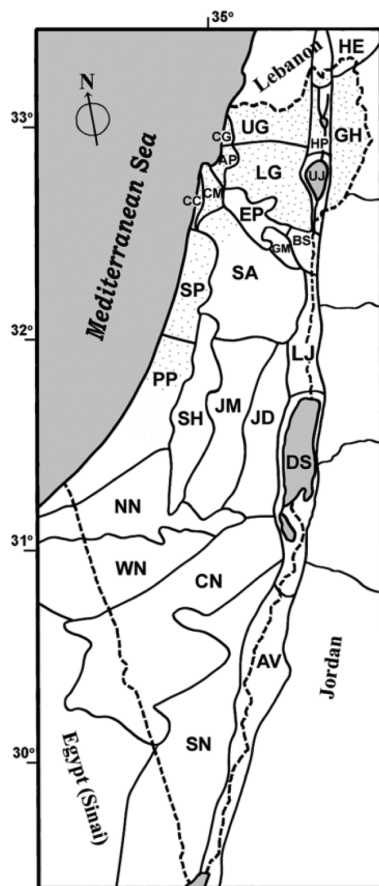


Fig. 1. Accepted abbreviations of nature regions of Israel: AP, Akko Plain; AV, Arava Valley; BS, Beit Shean Valley; CC, Carmel Coast; CG, Coast Galilee; CM, Carmel Mount; CN, Central Negev; DS, Dead Sea area; EP, Esdraelon (Yizre'el) Plain; GH, Golan Heights; GM, Gilboa Mount; HE, Hermon Mount; HP, Hula Plain; JD, Judean Desert; JM, Judean Mts.; LG, Lower Galilee; LJ, Lower Jordan Valley; NN, Northern Negev; PP, Philistean Plain; SA, Samaria; SH, Shefela; SN, South Negev; SP, Sharon Plain; UG, Upper Galilee; WN, Western Negev.

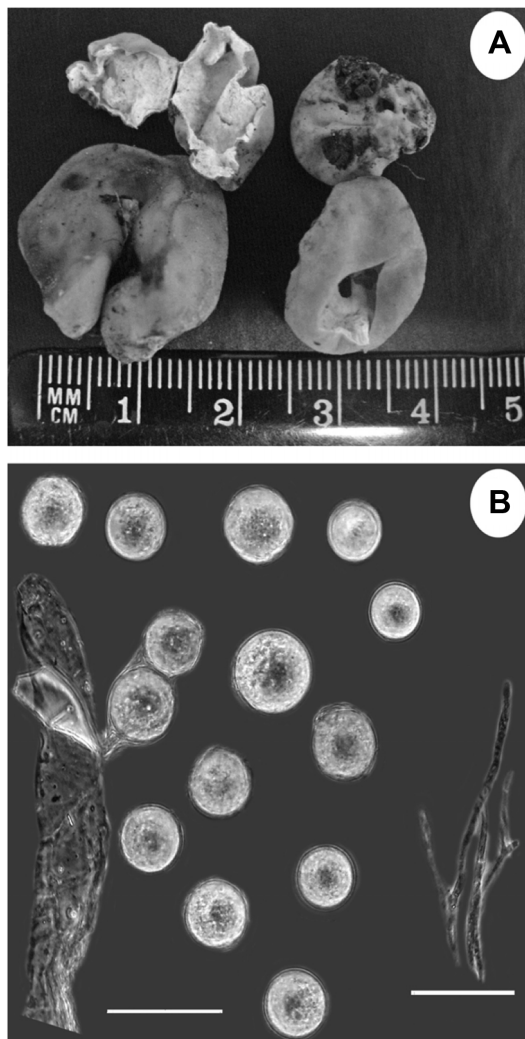


Fig. 2. *Hydnocystis piligera* Tul. & Tul. (HAI-D-035): A, Ascocarps and ascocarp in cross-section; B, Part of ascus, ascospores and paraphyses (scale bars = 50 µm).

out oil drops. Paraphyses: 1~3 µm broad, septate, hyaline or slightly yellowish, thin-walled.

Habitat & Distribution in Israel. Fruiting in December, in mixed *Pinus* and *Quercus* wood, at or near the soil surface. UG: Hiram Wood, Desember 8, 1976, leg. by students, det. N. Binyamini (Fig. 3) [3].

Material examined. SA: Reihan forest, on the ground, under *Pinus* sp., February 19, 2007, leg. Y.Ur, det. G. Bar-seghyan (HAI-D-035) (Fig. 3).

Habitat & General distribution. Mycorrhizal species. In the Mediterranean shrub environments, in sandy forest soil, associated with *Cupressus*, *Pinus*, *Cistus*, and *Pistacia*. Asia: China, Israel. Europe: Austria, Belgium, France, Germany, Italy, the Netherlands, Russia, Spain, and Switzerland.

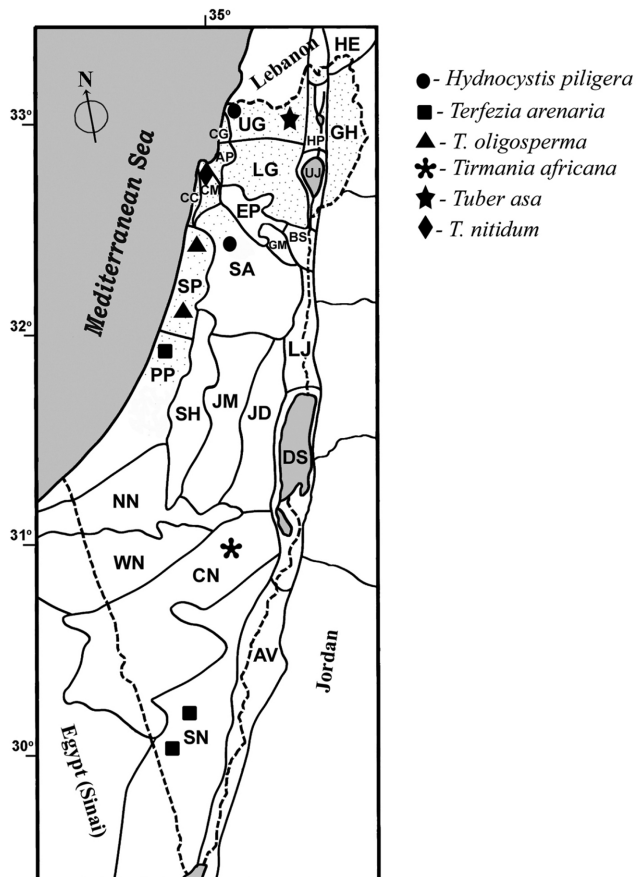


Fig. 3. Distribution of hypogeous Ascomycetes representatives in Israel. AP, Akko Plain; AV, Arava Valley; BS, Beit Shean Valley; CC, Carmel Coast; CG, Coast Galilee; CM, Carmel Mount; CN, Central Negev; DS, Dead Sea area; EP, Esdraelon (Yizre'el) Plain; GH, Golan Heights; GM, Gilboa Mount; HE, Hermon Mount; HP, Hula Plain; JD, Judean Desert; JM, Judean Mts.; LG, Lower Galilee; LJ, Lower Jordan Valley; NN, Northern Negev; PP, Philistean Plain; SA, Samaria; SH, Shefela; SN, South Negev; SP, Sharon Plain; UG, Upper Galilee; UJ, Upper Jordan Valley; WN, Western Negev.

Note. *H. piligera* is a rare species for Israeli and Asian mycobiota. This species is strongly characterized by its epithecium structural elements and spherical ascospores [21].

Pezizaceae Dumort.

Genus *Terfezia* (Tul. & C. Tul.) Tul. & C. Tul. Fungi Hypog.: 172 (1851).

Type species. *Terfezia arenaria* (Moris) Trappe, Trans. Br. Mycol. Soc. 57(1): 90 (1971).

KEY TO THE SPECIES KNOWN IN ISRAEL

- 1A. Ascospores globose.....2
- 1B. Ascospores subglobose to ovoid
.....*Terfezia oligosperma* Tul. & C. Tul.

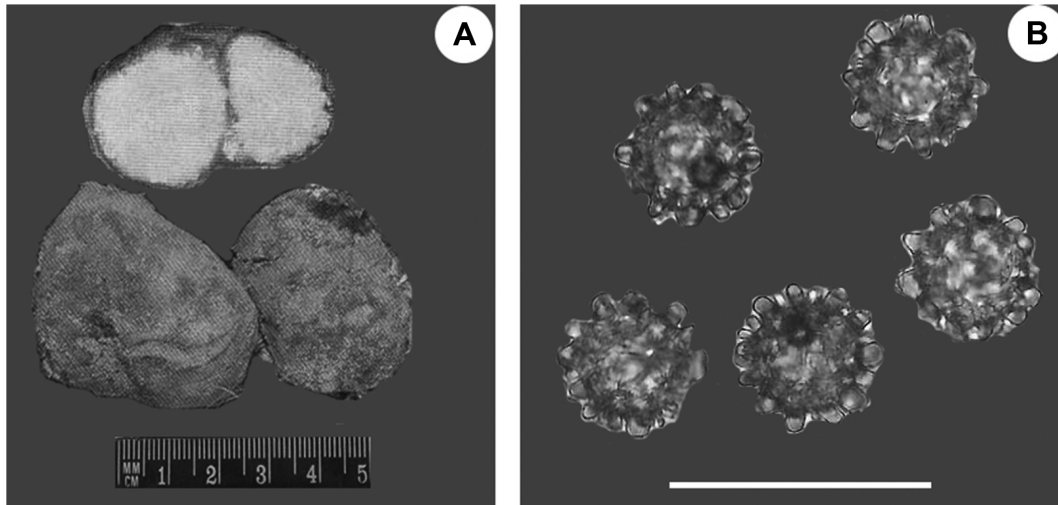


Fig. 4. *Terfezia arenaria* (Moris) Trappe (HAI-D-091): A, Ascocarps and ascocarp in cross-section; B, Warted ascospores (scale bar = 50 µm).

- 2A. Brownish color, coarsely warted at maturity, without any mark of reticulum
 *Terfezia arenaria* (Moris) Trappe
- 2B. Ascospores white-yellowish to yellow, completely reticulate at maturity, with low thickness meshes
 *Terfezia claveryi* Chatin

***Terfezia arenaria* (Moris) Trappe, Trans. Br. Mycol. Soc. 57(1): 90 (1971) (Fig. 4)**

= *Tuber arenaria* Moris, Brit. Sp. Ang. Lich. 3: 222 (1829).

= *Terfezia leonis* (Tul. & C. Tul.) Tul., Expl. Sci. Alg., Bot., Atlas 1: 432 (1895).

Icon. Binyamini, Nova Hedvigia XXXII, 18: fig. 2, 20: 9a,b, 1980 (as *Terfezia leonis*); Montecchi & Sarasini, Fungi Ipogei D'Europa, p. 183, 2000.

Ascocarps: subglobose, 4~10 cm in diam, tuberiform, with short basal mycelial tuft, whitish at first, then ochraceous, becoming brown with age. Peridium: often cracked, surface glabrous and smooth, consisting primarily of large isodiametric cells of (8~) 15~25 × 15~40 (~45) µm, slightly brownish, walls of cells thin and delicate. Gleba: fleshy, compact and elastic, initially white or flesh-colored, then greenish or reddish becoming brown, with evident sterile veins, 1~2 mm broad, irregularly delimiting fertile areas. Odor weak, fruity, taste mild. Asci: subglobose, sometimes ovoid, randomly arranged in a hyphal tissue, 72~81 × 82~97 µm, usually with 4~6 spores at maturity, hyaline, thin-walled, sessile or substipitate, ascospores loosely arranged within ascus. Ascospores: globose, coarsely warted at maturity, (16~) 20~25 × 22~22.5 (~25) µm broad (including warts), Q = 0.9~1.1, hyaline when young and slightly brownish at maturity, walls 1~1.5 µm broad, warts truncate-tipped, 1.5~2 µm broad.

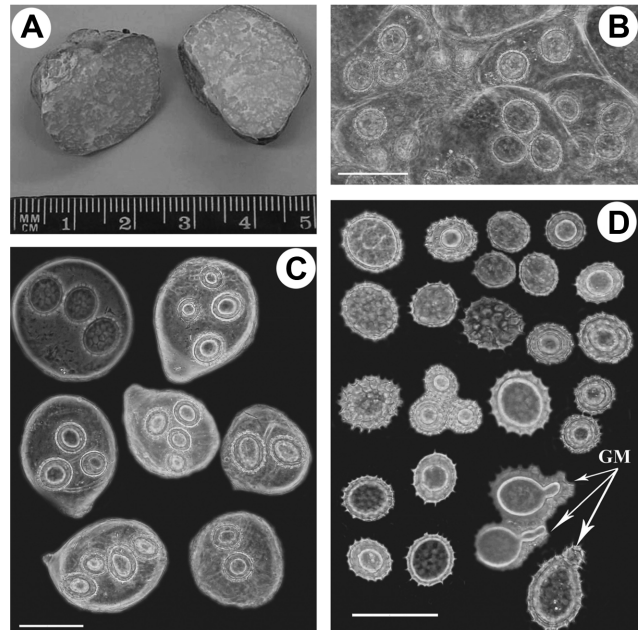


Fig. 5. *Tuber asa* Tulasne & C. Tulasne (HAI-D-033): A, Cross-section of ascocarp; B, Hymenium (asci, spores); C, Asci with 2~4 ascospores; D, Ascospores with ornamentation (GM, germination of ascospores) (scale bars = 50 µm).

Habitat & Distribution in Israel. SN: in Negev sand dunes, fruiting from March to May, in depths of 5~20 cm, very close to *Helianthemum sessiliflorum* roots, February 28, 1973, leg. K. Avshalom, det. N. Binyamini; March 19, 1974, leg. Zeelim, det. N. Binyamini (Fig. 3) [3].

Material examined. PP: Ashdod, in sand, very close to *H. sessiliflorum* roots, January 15, 2002, leg. & det. SP. Wasser (HAI-D-091) (Fig. 3).

Habitat & General distribution. Mycorrhizal fungi. Linked mainly to the coastal and sandy soil of Mediterranean areas, but also to the semi-desert inland areas. Africa: Morocco. Asia: Israel, China, Turkey, United Arab Emirates. Europe: Italy, Spain, Sweden. North: America: USA.

Note. This is a rare species for Israeli mycobiota. This species was found for the first time and described in Israel by Rayss [2]. After Binyamini [3], a detailed discussion and a comparison with species described by Tulasne and Tulasne [23] and Bataille [24] as *T. leonis* was conducted. The name *T. leonis*, under which this species is commonly known, has to be rejected as an illegitimate name, according to Trappe and all other modern authors.

***Terfezia claveryi* Chatin, La Truffe: 74 (1892)**

Icon. Montecchi & Sarasini, *Fungi Ipogei D'Europa*, p. 222–223, 2000.

Ascocarps: 10 cm in diam, subglobose-compressed or pyriform, lobate, with short, sterile base, surface gibbous, ochraceous to reddish brown, stained blackish brown with maturity. Peridium: rather thick, 0.8–1.2 mm, whitish, becoming brown when cut, constituted of filamentous hyphae, 8–12 μm in diam, parallel to the surface. Gleba: fleshy, compact, at first whitish or flesh colored, then yellowish-reddish, subdivided by paler veins. Odor: reminiscent of pepper. Asci: globose, 8-spored, randomly arranged in the hyphal tissue, 50–90 \times 50–75 μm . Ascospores: globose, confusedly disposed in the ascus, whitish-yellowish to yellow, then immature nearly smooth-asperulate, when completely mature reticulate, with low thickness meshes, about 2 μm high, irregular, 16–23 μm in diam, including ornamentations.

Habitat & General distribution. Mycorrhizal species. Linked mainly to the desert lands of the South Mediterranean basin and the Middle East, in sandy soils covered with *Helianthemum* species, especially *H. aegyptiacum*. Asia: Iraq, Israel, Kuwait, Syria. Europe: Spain. North America: USA.

Note. This is a very rare species for Israeli mycobiota. *Terfezia claveryi* was found in Israel for the first time by Rayss [1]; the location of the sample collection or the herbarium as well as other important information was not mentioned. This species has since been properly characterized by its ascospore ornamentation and habitat.

***Terfezia oligosperma* Tul. & C. Tul., *Fungi Hypog.*: 176 (1851)**

= *Delastreopsis oligosperma* (Tul. & C.Tul.) Mattir., *Bolm. Soc. Broterisna*, Coimbra (1905).

= *Tuber oligospermum* (Tul. & C. Tul.) Trappe, Myco-

taxon 9(1): 336 (1979).

Icon. Binyamini, *Nova Hedvigia* XXXII, 18: fig. 3, 19: 8, 1980; Montecchi & Sarasini, *Fungi Ipogei D'Europa*, p. 300, 2000 (as *Tuber oligospermum*).

Ascocarps: 3–4 cm in diam, irregularly globose, slightly folded, light clay color, peridium about 0.5 mm thick. Peridium: consisting of interwoven hyphae 3–8 μm broad, hyaline. Gleba: dirty white, then brown to dark brown, fleshy, solid, marbled with white irregular veins. Glebal fertile pocket separated by sterile undifferentiated veins, the hyphal hyaline, thin-walled 4–7 μm broad. Asci: subglobose or ovoid, 60–120 \times 50–75 μm broad, shortly stalked, thin-walled, hyaline, spores loosely arranged within, 1–4 spored, mostly 1–2 spored at maturity. Ascospores: globose ornamented with spines and alveolate polygonal cells, 30–47 μm broad (including spines), hyaline or yellowish when young, brown at maturity, walls 1–1.5 μm thick, spines 2.5–3.5 μm long.

Habitat & Distribution in Israel. Fruiting from January to April, in wood of *Pinus halepensis* at a depth of 3–5 cm or at the surface of soil at maturity, in groups of 3–8. The outward sign of the presence of these fungi is the appearance of cracks in a slight elevation of the soil. SP: Tel Aviv, Ramat Gan Park, March 22, 1977, January 24, 1979, leg. B. Shemen, det. N. Binyamini (Fig. 3) [3].

Habitat & General distribution. Mycorrhizal species. Not a very common species, generally growing in deciduous woods, preferably with a Mediterranean climate, typical on sandy coast-lines, where it grows in autumn and also in spring in warmer locations. Asia: Israel. Europe: France.

Note. This fungi was described for the first time in Israel by Reichert [25] under the name *Delastriopsis oligosperma*. Mycorrhizal fungi, mostly endemic to arid and semi-arid areas of the Mediterranean Region, are associated with *Helianthemum* species [26].

Genus *Tirmania* Chatin, *Truffe*, Edn 2: 80 (1892)

Type species. *Tirmania africana* Chatin, *Truffe*, Edn 2: 80 (1892).

***Tirmania africana* Chatin, *Truffe*, Edn 2: 80 (1892)**

Icon. Binyamini, *Nova Hedvigia* XXXII, 18: fig. 4, 20: fig. 10 a, b, c, 1980.

Ascocarps: subglobose often flattened, potato-shaped, sessile or sometimes shortly stalked, reaching 6–12 cm in diam, and whitish to white cream, smooth. Peridium: 1.5–2 mm thick. Gleba: white fleshy, solid, faintly marbled with a few wide veins 2–5 mm broad. Odor: slightly spermatoc when young and weak at maturity. Asci: ovoid

or broadly clavate 50~80 × 40~50 μm, usually with 6~8 spores at maturity, thin-walled, shortly stalked hyaline, ascospores loosely arranged within. Ascospores: oval, 15~19 × 12~13.5 μm broad, Q = 1.2~1.4 smooth, hyaline, thin-walled, 0.5~1 μm thick, sometimes with oil drop. Peridium consisting of prosenchymatic hyphae 5~7 μm broad, walls of cells thin. Glebal fertile pockets by sterile undifferentiated veins consisting of hyphae 7~11 μm broad, thin-walled, but sometimes inflated up to 18 μm.

Habitat & Distribution in Israel. CN: fruiting from March to May in Negev sand dunes at a depth of 10~20 cm close to *H. sessiliflorum* roots. Two additional plants close to the ascocarps are *Artemisia monosperma* and *Plantago albicans*, February 28, 1973, leg. K. Avshalom, det. N. Binyamini (Fig. 3) [3].

Habitat & General distribution. Mycorrhizal fungi. In deserts with the development of various *Helianthemum* species. Africa: Algeria, Morocco. Asia: Israel.

Note. This is a rare species for Israeli mycobiota. This species was found for the first time and briefly described in Israel by Rayss [2]. According to Montecchi and Sarasini [21], *Tirmania africana* is in synonymy with *T. nivea* and its current name is *T. africana*, according to the Index Fungorum online database. This species can be confused morphologically with *T. pinoi* but the smooth surface and ellipsoid spores of *T. africana* make it easy to distinguish from *T. pinoi*.

Tuberaceae Dumort.

Genus *Tuber* P. Micheli ex F.H. Wigg., Prim. Fl. Holsat. (Kiliae) (1780).

Type species. *Tuber aestivum* Vittad., Monogr. Tuberac. (Milano): 38 (1831).

Key to the species known in Israel

- 1A.** Ascospores globose, subglobose to ellipsoid, with brown ornamentation and alveolate reticulum
.....*Tuber asa* Tulasne & C. Tulasne
- 1B.** Ascospores ellipsoid to fusiform, light brown, covered with numerous slender spines
.....*Tuber nitidum* Vittad.

***Tuber asa* Tulasne & C. Tulasne, Fungi hypogaei. Hist. et Monog. Des Champ. Hypogés: 222. (1851) (Fig. 5)**

Icon. Montecchi & Sarasini, Fungi Ipogei D'Europa, p. 257, 2000.

Ascocarps: 15~25 cm in diam, irregularly tuberous, gibbose, glabrous, dirty yellowish to dark olive, with smooth surface. Peridium: whitish to cream, thick with interwoven hyphae. Odor: intense and pleasant. Gleba: light gray-

brown to beige, marbled with narrow off-white anastomosed veins. Asci: ovoid-ellipsoid to subglobose, 70~78 × 50~65 μm, thin-walled, hyaline, sessile or with a short stem, reaction with Meltzer's reagent negative, asci non-amyloid, 2~4 spored. Ascospores: globose, ellipsoid-subglobose, 21~44 × 18~35 μm (not including ornamentation), Q = 1.1~1.2, with brown ornamentation an alveolate reticulum, ascospore walls 1.8~3.2 μm thick. Paraphyses: absent.

Material examined. Israel, UG: Goren Park, in sandy soil close to *Cistus incanus* roots, at a depth of 10~15 cm, April 7, 2007, leg. Z. Shafranov & R. Kuznetsov, det. G. Barseghyan (HAI-D-033) (Fig. 3).

Habitat & General distribution. Mycorrhizal species. Not a very common species, generally found in dry and sandy soils of coast-lines with a Mediterranean climate, in desert areas, with the sole presence of various species of *Cistus*, *Tuberaria*, *Helianthemum*, and *Ephedra*. Asia: Israel. Europe: Italy, Spain.

Note. This is a new species for Israeli mycobiota that can be confused with similar species, such as *T. oligospermum*, but this species does not have a pleasant odor, and all ascospores are spherical. *T. puberulum* have very similar odor, but ascospores are smaller and usually have ovoid or spheric forms.

***Tuber nitidum* Vittad., Monograph: 48 (1831)**

= *Tuber rufum* f. *nitidum* (Vittad.) Montecchi & Lazzari, Atlante Fotografico di Funghi Ipogei (Trento):197 (1993).

Icon. Montecchi & Sarasini, Fungi Ipogei D'Europa, p. 317, 2000 (as *Tuber rufum* f. *nitidum*).

Ascocarps: 1~2 cm in diam, globose to subglobose, slightly compressed, hard. Peridium: smooth or slightly papillate, yellowish-brown to grayish-orange, shining. Gleba: white, becoming grayish with reddish tinge, veins few, remain white. Odor: light, unpleasant and acid when mature. Asci: ellipsoid, pyriform, stalked, 40~70 × 14~18 μm, 1~5-spored, but mostly 3~4-spored. Ascospores: ellipsoid to fusiform, 20~27 × 14~18 μm, Q = 1.4~1.5, light brown, covered with numerous slender spines.

Habitat & Distribution in Israel. CM: rare, in open places on the northern side of Mt. Carmel, March 26, 1987, leg and det. N. Binyamini (Fig. 3) [5].

Habitat & General distribution. Mycorrhizal species. This species is associated with both coniferous and deciduous trees, widely spread in all environments. Asia: Israel. Europe: Austria, Italy, Poland, Spain, Switzerland.

Note. This is a very rare species for Israeli mycobiota. According to Hawker [27], this species is very close to

Tuber rufum but differs in color. The hymenium does not have a red tinge, and the spore spines are more slender and more densely crowded [5]. According to Montecchi and Sarasini [21], the differential characteristics of this "form" are limited to the fairly regular fruit bodies' form and light colors on a smooth and bright surface, even during late maturity. Due to these characteristics, this entity could be mistaken for a species in the so-called *T. puberulum* group, but the aculeate and none reticulate-alveolate spores, or in the case of immature ascospores, the peridium structure of the interwoven hyphae eliminate any doubt.

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References

1. Rayss T. Nouvelle contribution à l'étude de la mycoflore de Palestine (Deuxieme partie). Palest J Bot 1940;1:313-55.
2. Rayss T. On the hypogeous fungi of Israel. Mada 1956;6:9-13.
3. Binyamini N. Addenda to the Hypogeous Mycoflora of Israel. Nova Hedwigia 1980;32:9-20.
4. Binyamini N. Larger fungi of Israel: Ascomycotina, Basidiomycotina (Aphylophorales, Auriculariales, Tremellales and Gasteromycetes). Tel Aviv: Ramot Publishing Co.; 1984.
5. Binyamini N. Rare and interesting records of the higher fungal flora of Israel. IV. Opera Bot 1989;100:23-7.
6. Trappe JM. Use of truffles and false-truffles around the world. In: Bencivenga M, Granetti B, editors. Acti del II Congresso Internazionale sul Tartufo. Spoleto: Comunità Montana dei Monti Martani e del Serrano; 1992. p. 19-30.
7. Trappe JM. The orders, families, and genera of hypogeous Ascomycotina (truffles and their relatives). Mycotaxon 1979;9: 297-340.
8. O'Donnell K, Cigelnik E, Weber NS, Trappe JM. Phylogenetic relationships among ascomycetous truffles and the true and false morels inferred from 18S and 28S ribosomal DNA sequence analysis. Mycologia 1997;89:48-65.
9. Gargas A, Taylor JW. Phylogeny of Discomycetes and early radiations of the apothecial Ascomycotina inferred from SSU rDNA sequence data. Exp Mycol 1995;19:7-15.
10. Spatafora JW. Ascomal evolution among filamentous ascomycetes: evidence from molecular data. Can J Bot 1995; 73:S811-5.
11. Landvik S, Egger KN, Schumacher T. Towards a subordinal classification of the Pezizales (Ascomycota): phylogenetic analyses of SSU rDNA sequences. Nord J Bot 1997;17:403-18.
12. Harrington FA, Pfister DH, Potter D, Donoghue MJ. Phylogenetic studies within the Pezizales. I. 18S rRNA sequence data and classification. Mycologia 1999;91:41-50.
13. Percudani R, Trevisi A, Zambonelli A, Ottonello S. Molecular phylogeny of truffles (Pezizales: Terfeziaceae, Tuberales) derived from nuclear rDNA sequence analysis. Mol Phylogenet Evol 1999;13:169-80.
14. Norman JE, Egger KN. Molecular phylogenetic analysis of *Peziza* and related genera. Mycologia 1999;91:820-9.
15. Harrington FA, Potter D. Phylogenetic relationships within *Sarcoscypha* based upon nucleotide sequences of the internal transcribed spacer of nuclear ribosomal DNA. Mycologia 1997;89:258-67.
16. Roux C, Séjalon-Delmas N, Martins M, Parguey-Leduc A, Dargent R, Bécard G. Phylogenetic relationships between European and Chinese truffles based on parsimony and distance analysis of ITS sequences. FEMS Microbiol Lett 1999;180: 147-55.
17. Norman JE, Egger KN. Phylogeny of the genus *Plicaria* and its relationship to *Peziza* inferred from ribosomal DNA sequence analysis. Mycologia 1996;88:986-95.
18. Saccardo PA. Sylloge fungorum omnium hucusque cognitorum. Ann Arbor: Edwards Brothers, Inc.; 1882-1931; T. 1-25; 1902: 16; 1906: 18; 1913: 22; 1931: 25.
19. Burdsall HH Jr. A revision of the genus *Hydnocystis* (Tuberales) and of the hypogeous species of *Geopora* (Pezizales). Mycologia 1968;60:496-525.
20. Dennis RW. British ascomycetes. 2nd ed. Vaduz: Gantner AR & Verlag KG; 1981.
21. Montecchi A, Sarasini M. Funghi ipogei d'Europa. Trento: AMB Fondazione Centro Studi Micologici; 2000.
22. Feinbrun-Dothan N, Danin A. Analytical flora of Eretz-Israel. 2nd ed. Jerusalem: CANA Publishing House; 1998.
23. Tulasne LR, Tulasne C. Fungi hypogaei. Histoire et monographie des champignons hypogés. Paris: Friedrich Klincksieck; 1851.
24. Bataille MF. Flore analytique et descriptive des tubéroïdées de l'Europe et de l'Afrique du Nord. Bull Soc Mycol Fr 1921;37:155-207.
25. Reichert I. Studies on mushrooms and other fungi of the forests of Palestine. Palest J Bot 1944;4:193-204.
26. Díez J, Manjón JL, Hawker LE. British hypogeous fungi. Philos Trans R Soc Lond B 1954;237:429-546.
27. Hawker LE. British hypogeous fungi. Philos Trans R Soc Lond B 1954;237:429-546.