

Genus *Golovinomyces* (Erysiphales) in Israel: species composition, host range, and distribution

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Abstract. A critical revision of all available, previously collected specimens of *Golovinomyces* in Israel including the respective literature data was made. In addition, the authors also collected extensive herbarium materials. As a result, species composition of ten species from the genus *Golovinomyces* was established. Three of the species, namely, *G. cynoglossi*, *G. echinopis*, and *G. verbasci*, were recorded for the first time for Israel. Also, incorrect identification of *Neoerysiphe cumminsiana* as *Erysiphe cichoracearum* on *Filago eriocephala*, *Hedypnois cretica*, *Lagoseris sancta*, *Phagnalon rupestre*, *Picris amalecitana*, *P. galilaea*, *Rhagadiolus stellatus*, *Senecio vernalis*, *Thrinicia tuberosa*, and *Tolpis virgata* was revealed.

Key words: Erysiphales, *Golovinomyces*, *Neoerysiphe*, species composition, Israel

Introduction

The genus *Golovinomyces* (U. Braun) Heluta was separated (Heluta, 1988) from the genus *Erysiphe* R. Hedw. ex DC. because of the anamorphic states of *Euoidium* or *Ooidium* s.str. type (conidia in chains). Later, on the basis of molecular data and conidial surface features for five *Golovinomyces* species a new genus, *Neoerysiphe* U. Braun, was proposed (Braun 1999). According to molecular phylogenetic analysis data (Mori *et al.* 2000) both genera, *Golovinomyces* and *Neoerysiphe*, together with *Arthrocladiella* Vassilkov form a separate clade. In view of this data it was proposed to move these three genera to the newly established tribe Golovinomyceteae (Braun & Takamatsu 2000). *Golovinomyces* is the largest genus in this tribe, consisting of about 30 species that are frequently distributed throughout the world (Kirk *et al.* 2001).

The host range of *Golovinomyces* species is mainly restricted to herbaceous plants from almost 60 families. The

largest among families are Asteraceae, Boraginaceae, Scrophulariaceae, etc. The authors would like to draw special attention to the Asteraceae family, comprising 1535 genera and about 23 000 species (Bremer 1994). Approximately 1300 of these species are host plants for representatives of the *Golovinomyces* genus. *Golovinomyces cichoracearum* is parasitizing more than 1 000 host species of Asteraceae, and this probably compound species includes numerous specialized biotypes or even separate species. To resolve this taxonomic problem, several molecular phylogenetic analyses of this genus have been reported (Zeller & Levy 1995; Saenz & Taylor 1999; Matsuda & Takamatsu 2003). However, till now the evidence is not clear, and further studies are necessary.

In Israel, the study on the genus *Golovinomyces* was mostly associated with diseases of cultivated plants caused by powdery mildew fungi (Chorin 1946; Duvdevani *et al.* 1946; Palti 1953, 1961, 1975; Ashri 1961, 1971; Minz *et al.* 1961; Palti *et al.* 1974; Eshed 1975; Wahl *et al.* 1979). Field

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investigations in wild vegetation were mostly fragmentary. Therefore, not enough data was available to establish species composition and a range of host plants for *Golovinomyces* species in this country. In addition, many previously collected specimens were incorrectly identified and stored in the Jerusalem Hebrew University Herbarium as *Erysiphe cichoracearum*. In view of this conclusion, studies on species composition of the *Golovinomyces* genus in Israel, with special attention to morphological features, are very important; thus, a revision of all available data is necessary.

Materials and Methods

The current study is based on literature data, previous collections, and results of the authors' field studies. Examined herbarium specimens were provided by the Hebrew University of Jerusalem Herbarium (HUJ) or collected by the authors from 2002 to 2006 during vegetation periods. Examined herbarium specimens were provided by the Hebrew University of Jerusalem Herbarium (HUJ) or collected by authors from 2002 to 2006 during vegetation periods. Species distribution is recorded according to nature regions (Fig. 1) of Israel (Feinbrun-Dothan & Danin 1998). Morphological features of *Golovinomyces* species were examined using light/dark-field (Carl Zeiss Axiostar 1122-100, Germany) and scanning electron microscopes (JSM-35C and Jeol JSM-6060LA, Japan).

Results and Discussion

Examination of collections obtained from extensive field investigations and HUJ Herbarium specimens, and analysis of the literature data reveal that *Golovinomyces* in Israel is represented by ten species. Three of them were not previously recorded here according to literature data: *G. cynoglossi* (Wallr.) Heluta on *Cynoglossum creticum* Miller; *G. echinopis* (U. Braun) Heluta on *Echinops gaillardotii* Boiss.; *G. verbasci* (Jacq.) Heluta on *Verbascum agrimoniifolium* (C. Koch) Huber-Morath subsp. *syriacum* and *V. sinuatum* L. Numerous additional localities of *Golovinomyces* species were found in Israel as well as new host plants, e.g., *Calendula palaestina* Boiss., *Chrysanthemum coronarium* L., *Conyza bonariensis* (L.) Cronquist, *Lactuca tuberosa* Jacq. for *G. cichoracearum* (DC.) Heluta; *Carduus getulus* Pomel, *Onopordon* sp. for *G. depressus* (Wallr.) Heluta; *Datura innoxia* Miller for *G. orontii* (Castagne) Heluta; *Plantago lanceolata* L. for *G. sordidus* (L. Junell) Heluta.

Review of the HUJ Herbarium collection has uncovered incorrect identification of powdery mildew fungus on *Filago eriocephala* Guss., *Hedypnois cretica* (L.) Dum.-Courset, *Lagoseris sancta* (L.) K. Maly, *Phagnalon rupestre* (L.) DC., *Picris amalecitanica* (Boiss.) Eig, *P. galilaea* (Boiss.) Eig, *Rhagadiolus stellatus* DC., *Senecio vernalis* Waldst. et Kit., *Thrinicia tuberosa* (L.) DC., *Tolpis virgata* (Desf.) Bertol. as

Erysiphe cichoracearum DC. (= *G. cichoracearum*). Detailed microscopy has showed that the examined specimens belonged to the genus *Neoerysiphe* – *N. cumminsiana* (U. Braun) U. Braun (Voytyuk *et al.* 2006). Two samples collected on *Senecio cruentus* (Mass.) DC. and *S. vulgaris* L., reported by Amano (1986) as *E. cichoracearum*, are probably *N. cumminsiana* as well. However, their identities could not be verified as the original collections are missing.

The following descriptions, illustrations, and distribution maps of all *Golovinomyces* species known from Israel are generally based on the collections examined and cited previously.

Golovinomyces biocellatus (Ehrenb.) Heluta, Ukrainian Bot. J. 45(5): 62 (1988).

Mycelium on leaves, effuse, evanescent to subpersistent. Hyphae septate, 3–8 µm wide. Appressoria nipple-shaped. **Anamorph** *Oidium* s. str. **Conidiophores** erect, 130–190 µm, foot-cells straight, cylindrical, (30–) 37–70 (–75) × 11–14 µm, followed by 1–3 shorter cells. **Conidia** in chains, ellipsoid-ovoid to doliiform, after drying cylindrical-ellipsoid to vase-like, 25–35 × (10–) 13–20 µm (dry material), 30–40 × 17–25 µm (fresh material). **Chasmothecia** not observed.

Distribution in Israel (Fig. 2):

On *Mentha piperita* L.: CM: Haifa, University of Haifa, Dormitories, 25 Apr 2005, S.O. Voytyuk; UG: Zefat, 20 May 2005, private house, S.O. Voytyuk; Israel (Amano 1986).

General distribution: Europe (Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Greece, Hungary, Italy, Norway, Poland, Russia (European part), Spain, Sweden, Switzerland, Ukraine, Yugoslavia), Asia (Afghanistan, China, India, Iran, Iraq, Israel, Japan, Kazakhstan, Korea, Russia (Far East, Siberia), Turkey), North Africa, North America (Canada, USA), Pacific basin countries, and Australia.

Golovinomyces cichoracearum (DC.) Heluta, Ukrainian Bot. J. 45(5): 62 (1988). (Fig. 3)

Mycelium white or grayish, well developed on stems, leaves, effuse or in patches, evanescent to persistent. Hyphae 3–9 µm wide. Appressoria nipple-shaped or lobed. **Anamorph** *Oidium* s. str. **Conidiophores** erect, 150–200 µm (fresh material), foot-cells straight, cylindrical, (35–) 40–120 × 11–14 µm, followed by 1–3 shorter cells. **Conidia** in chains, ellipsoid, ellipsoid-ovoid, after drying cylindrical-ellipsoid to doliiform-cylindrical, 25–40 × (11–) 13–20 µm (dry material), 31–40 × 15–25 (–30) µm (fresh material), germ tubes simple, tips unlobed. **Chasmothecia** scattered or in large groups, hemispheric, somewhat depressed in the lower part, (60–) 80–180 (–200) µm diam. Peridium cells irregularly shaped, 7–15 (–25) µm diam. Appendages usually in the lower part of the ascocarp, often develop in the upper half, numerous, very variable in length (0.25–) 1.5–2 times as long as the chasmothecia diam, rare, short or rudimentary, 2–10 µm wide, septate, colorless to dark brown, twisting, 3–10 µm wide, thin-walled, mycelium-like, septate, hyaline. **Asci** numerous, 6–25, thin-walled, stalked, 40–67 (–80) × 20–35

Fig. 1. 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; UJ – Upper Jordan Valley; WN – Western Negev

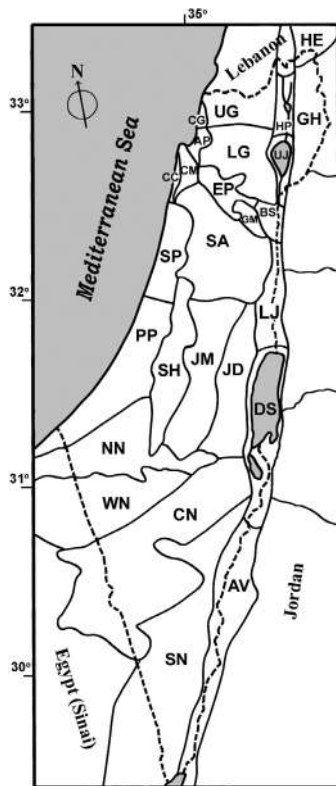


Fig. 2. Distribution of *G. biocellatus* in Israel

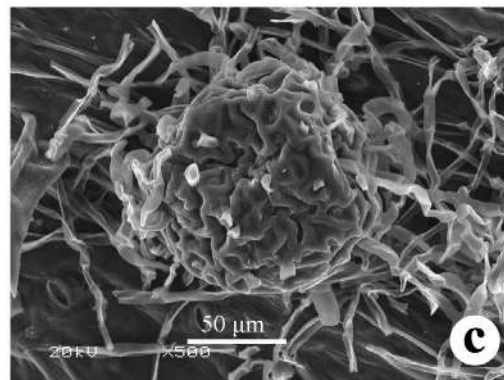
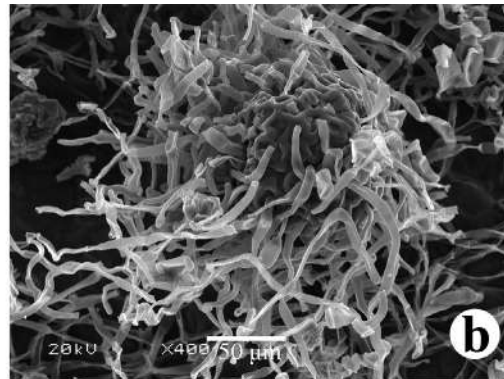
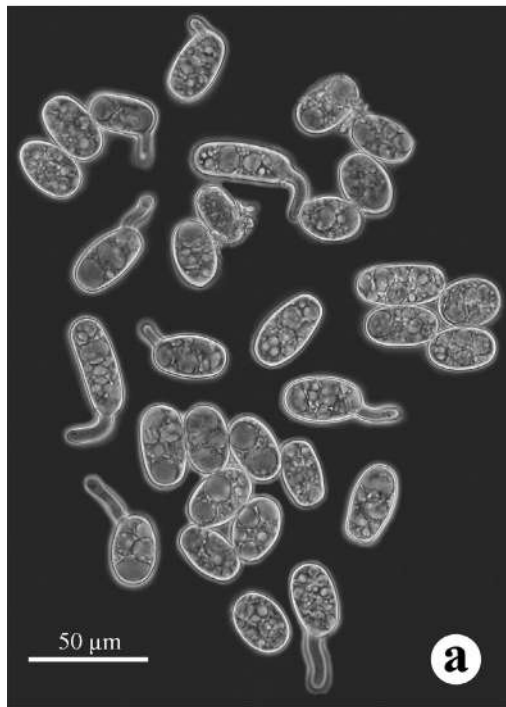
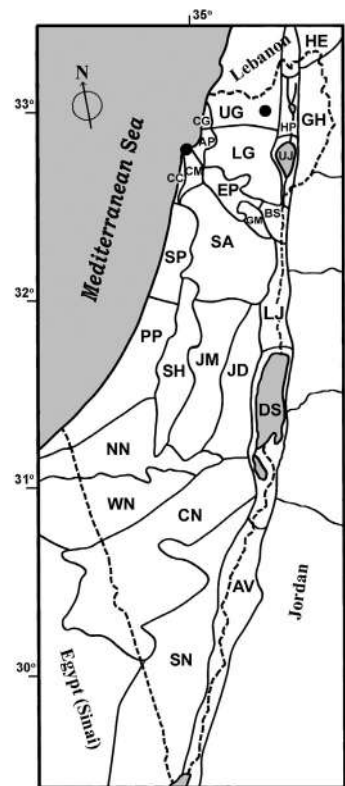


Fig. 3. *Golovinomyces cichoracearum*: a – conidia with germ tubes (fresh material) on *Cichorium pumilum*; b-c – chasmothecia on *Urospermum picroides* under SEM. Scale bars = 50 μm

(–50) μm . **Ascospores** usually 2, occasionally 3, very rarely 4, ellipsoid-ovoid, 18–25 \times 12–20 μm .

Distribution in Israel (Fig. 4):

On *Aetheorbiza bulbosa* (L.) Cass.: Israel (Amano 1986).

On *Aster subulatus* Michaux (*A. amellus* L.): JM: Jerusalem, 5 Jan 1943, J. Rymald (HUJ 5413; Rayss 1947); Israel (Amano 1986).

On *Aster* sp.: Israel (Amano 1986).

On *Bellis perennis* L.: Israel (Amano 1986).

On *Calendula palaestina* Boiss.: CM: near Bet Oren, Nahal Oren, “Evolution Canyon-1”, 32°49' N, 35°46' E, 5 May 2004, S.O. Voytyuk (anamorph).

On *Chondrilla juncea* L.: Israel (Amano 1986) (anamorph).

On *Chrysanthemum coronarium* L.: CC: near 'Atlit, 31°24' N, 34°52' E, 27 Apr 2004, S.O. Voytyuk; CM: near Haifa, 31°24' N, 34°52' E, 16 May 2004, S.O. Voytyuk; near Bet Oren, Nahal Oren, “Evolution Canyon-1”, 32°49' N, 35°46' E, 5 May & 26 May 2004, S.O. Voytyuk; GH: Nahal Gamla, near Nature Reserve, 32°54' N, 35°46' E, 18 May 2004, S.O. Voytyuk; HP: Amirim, 32°56' N, 35°26' E, 24 May 2004, S.O. Voytyuk.

On *Cichorium pumilum* Jacq.: CC: Ma'yan Zevi (kibbutz), 2 May 1947, T. Rayss (HUJ 7578); CM: near Bet Oren, Nahal Oren, “Evolution Canyon-1”, 32°49' N, 35°46' E, 20 Apr 2004, S.O. Voytyuk; GH: Yehudiyya, 32°56' N, 35°41' E, 17 May 2004, S.O. Voytyuk; JM: Qiryat 'Anavim, 10 May 1938, T. Rayss (Rayss 1940); Israel (Amano 1986) (anamorph); PP: Lod (= Lydda) (near Rehovot), 18 Jun 1954, T. Rayss (HUJ 301/11 104S); UG: the road from Rosh-Pinna to Zefat, 32°57' N, 35°32' E, 24 May 2004, S.O. Voytyuk.

On *Conyza bonariensis* (L.) Cronquist: GH: Yehudiyya, 32°56' N, 35°41' E, 17 May 2004, S.O. Voytyuk; PP: near Ashqelon, along the road, 31°46' N, 34°40' E, 19 Apr 2004, S.O. Voytyuk.

On *Filago eriocephala* Guss. (*F. germanica* (L.) Huds.): JM: Jerusalem, 15 May 1939, J. Stettner (HUJ 655; Rayss 1940); Israel (Amano 1986).

On *Gerbera jamesonii* Bolus: Israel (Amano 1986).

On *Gerbera* sp.: Israel (Amano 1986).

On *Helianthus annuus* L.: AV: near Hazeva (Tahanat Yair, experimental station), 23 Feb 2005, S. Dobrynin & L. Dobrynin; Israel (Amano 1986).

On *Helianthus* sp.: Israel (Palti 1972b, b; Amano 1986).

On *Inula viscosa* (L.) Ait.: CC: near 'Atlit, 31°24' N, 34°52' E, 27 Apr 2004, S.O. Voytyuk; CM: Haifa, 11 Mar 2002, V.P. Heluta (anamorph); GH: Nahal Gamla, near Nature Reserve, 32°54' N, 35°46' E, 18 May 2004, S.O. Voytyuk; Yehudiyya, 32°56' N, 35°41' E, 17 May 2004, S.O. Voytyuk; Israel (Amano 1986).

On *Lactuca sativa* L.: Israel (Amano 1986).

On *L. serriola* L. (*L. scariola*): CC: 'Atlit, 10 Apr 2002, A. Beharav (anamorph); HP: Rosh-Pinna, 10 Jun 1937, T. Rayss (HUJ 5397); JM: Jerusalem, 15 May 1940, T. Rayss (Rayss 1940); Qiryat 'Anavim (near Abu Ghosh village), 19 May 1937, T. Rayss (HUJ 659; Rayss 1940); Israel (Amano 1986).

On *L. tuberosa* Jacq.: CM: Haifa, University of Haifa, National Park, 31°24' N, 34°52' E, 25 Apr 2004, S.O. Voytyuk; UG: the road from Rosh-Pinna to Zefat, 32°56' N, 35°30' E, 24 May 2004, S.O. Voytyuk.

On *Liatris spicata* (L.) Willd.: Israel (Amano 1986).

On *Scorzonera subintergra* (Boiss.) Thiébaud (*S. jaquiniana*): Israel (Amano 1986) (anamorph).

On *Sonchus nymanni* Tineo et Guss: Israel (Amano 1986).

On *S. oleraceus* L.: CM: Aharonson's Farm, near 'Atlit, 32°49' N, 35°46' E, 10 Mar 2004, S.O. Voytyuk; Haifa, 29 Mar 1936, T. Rayss (HUJ 681;

Rayss 1940), 13 Mar & 15 Mar 2002, V.P. Heluta (anamorph), 12 Mar 2002, E. Nevo; JM: Jerusalem, 21 Jun 1954, T. Rayss (HUJ 301/11 103S); Jerusalem, 27 May 1953, T. Rayss (HUJ 301/12 108S); Moza (5 km west of Jerusalem), 18 Feb 1938, T. Rayss (HUJ 666; Rayss 1940); Negev: 'En Hawwa (15 km southeast of 'Avedat), 13 Mar 1945, T. Rayss (HUJ 6843); SA: Nabi Rubin (10 km south of Jenin), 23 Apr 1951, T. Rayss (HUJ 301/10 101S); UJ: Geva' (kibbutz), 24 Mar 1942, T. Rayss (HUJ 5152); Nahalal (7 km southeast of Qiryat Tiv'on), 29 Mar 1942, T. Rayss (HUJ 4703); 'En Harod, 4 Feb 1955, T. Rayss (HUJ 301/11 106S); Israel (Wahl *et al.* 1979; Amano 1986).

On *S. tenerrimus* L.: CN: Sede Boqer (kibbutz), 30°52' N, 34°47' E, 25 Apr 2004, S.O. Voytyuk (anamorph); Makhatesh Ha Gadol, 30°57' N, 35°00' E, 25 Apr 2004, S.O. Voytyuk (anamorph); Yerucham, artificial forest near artificially impounded body, 30°59' N, 34°53' E, 25 Apr 2004, S.O. Voytyuk (anamorph); Israel (Amano 1986) (anamorph).

On *Sonchus* sp.: Israel (Amano 1986).

On *Tragopogon buphthalmoides* (DC.) Boiss.: Israel (Amano 1986) (anamorph).

On *T. coelestriacus* Boiss. (*T. longirostris* Bischoff): Israel (Amano 1986) (anamorph).

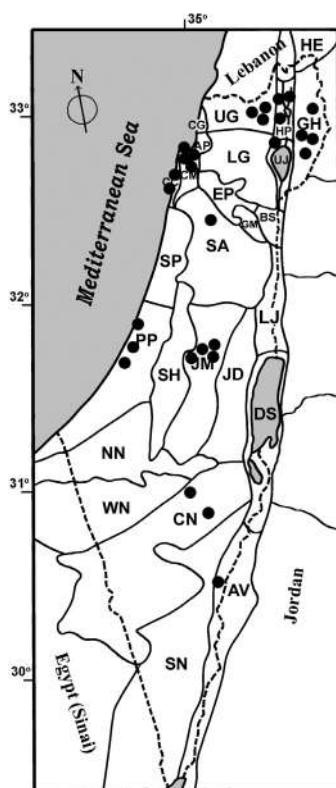
On *Urospermum picroides* (L.) Schmidt: CC: Atlit, Coast Sea, 32°42' N, 34°56' E, 5 Apr 2004, S.O. Voytyuk (anamorph); CM: Haifa, 23 Apr 1943, T. Rayss (HUJ 301/16 92S); Haifa, University of Haifa, National Park, 31°24' N, 34°52' E, 26 Apr 2004, S.O. Voytyuk; Muchraka, 17 Mar 2004, S.O. Voytyuk; near Bet Oren, Nahal Oren, “Evolution Canyon-1”, 32°49' N, 35°46' E, 15 Apr 2002, T. Pavliček, 22 Mar 2004, S.O. Voytyuk; Zikhron Ya'aqov (near railway station), 3 May 1947, T. Rayss (HUJ 7563); CN: Yerucham, artificial forest near artificially impounded body, 30°59' N, 34°53' E, 25 Apr 2004, S.O. Voytyuk; GH: Qidmat-Zevi, 33°01' N, 35°41' E, 5 May 2004, S.O. Voytyuk; HP: Rosh-Pinna, 29 Apr 1937, T. Rayss (HUJ 661); JM: Jerusalem, 17 May 1940, T. Rayss (HUJ 656); Jerusalem, 17 May 1940, T. Rayss (Rayss 1940); Jerusalem, 21 May 1949, T. Rayss (HUJ 301/10 98S); Jerusalem, Bet HaKerem, 16 May 1940, T. Rayss (HUJ 7307); Qiryat 'Anavim (near Abu Ghosh village), 19 May 1938, T. Rayss (HUJ 662); Qiryat 'Anavim, 19 May 1938, T. Rayss (Rayss 1940); between Ramallah and Gezer, 9 Apr 1951, Rayss, T. (HUJ 301/9 95S); LG: the forest near Alloné Abba (near Qirat Tiv'on), 18 Apr 2004, S.O. Voytyuk; Mi'ilya (near Ma'alot), 33°00' N, 35°08' E, 23 Apr & 25 May 2004, S.O. Voytyuk; NN: near Lahav, Keren Kayemeth Leisrael (Forest in memory of the late Master Friedensreich Hundert), 31°24' N, 34°52' E, 21 Mar 2004, S.O. Voytyuk; PP: Tel-Aviv, 16 May 1950, T. Rayss (HUJ 301/10 99S), 19 May 1951, T. Rayss (HUJ 301/13 112S); Tel-Aviv-Yafo, the old City, 32°06' N, 34°48' E, 13 May 2004, S.O. Voytyuk; UG: Mazzuva (kibbutz) (1 km southeast of Hanita junction), 3 May 1947, T. Rayss (HUJ 7566); near Rosh-Pinna, 29 Apr 1937, T. Rayss (Rayss 1940); Zefat, 32°57' N, 35°31' E, 24 May 2004, S.O. Voytyuk; UJ: Qiryat-Tiv'on, Ramez St., 12 May 2004, S.O. Voytyuk.

On *Zinnia elegans* Jacq.: JM: Jerusalem, Botanical Garden, 25 Jul 2004, S.O. Voytyuk; Israel (Amano 1986).

On *Zinnia* sp.: Israel (Amano 1986) (anamorph).

General distribution: Europe (Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Hungary, Italy, the Netherlands, Norway, Poland, Russia (European part), Spain, Sweden, Switzerland, Ukraine, Yugoslavia), Asia (India, Iran, Iraq, Israel, Japan, Jordan, Kazakhstan, Korea, Lebanon, Mongolia, Nepal, Pakistan, Russia (Far East, Siberia), Saudi Arabia, Turkey, Yemen), Africa (Egypt, Ethiopia,

Fig. 4. Distribution of *G. cichoracearum* in Israel



Libya, Malawi, Mauritania, Morocco, Niger, Tanzania), America (Argentina, Bolivia, Brazil, Canada, Chili, Ecuador, Guatemala, Mexico, Panama, Peru, USA, Venezuela), Pacific basin countries, and Australia.

Notes: Widespread species in Israel. Development of fungus observed during the year but mostly as anamorph. Teleomorph was found only on *Cichorium pumilum*, *Sonchus oleraceus*, and *Urospermum picroides*.

Golovinomyces cynoglossi (Wallr.) Heluta, Ukrainian Bot. J. 45(5): 62 (1988).

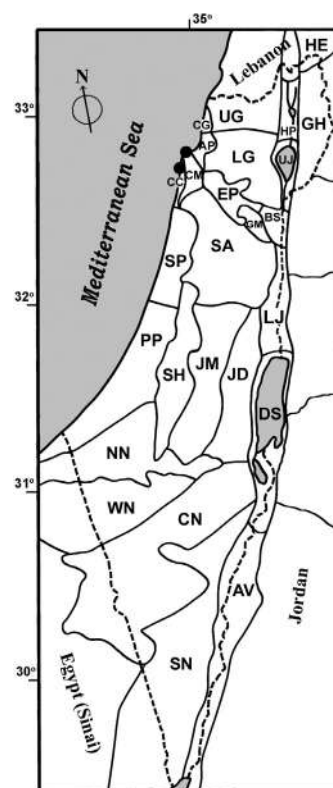
Mycelium on stems, leaves, effuse or in patches, evanescent to subsistent. Hyphae septate, 3-8 μm wide. Appressoria nipple-shaped. **Anamorph** *Oidium* s. str. **Conidiophores** erect, 100-160 μm (fresh material), foot-cells straight, cylindrical, (35-) 37-90 \times 11-14 μm . **Conidia** in chains, ellipsoid, after drying ellipsoid-ovoid to barrel-shaped, 20-35 \times (10-) 13-20 μm (dry material), 28-40 \times 17-25 μm (fresh material). **Chasmothecia** not observed.

Distribution in Israel (Fig. 5):

On *Cynoglossum creticum* Miller: CC: 'Atlit, 32°42' N, 34°56' E, 21 & 28 Apr 2004, S.O. Voytyuk; CM: Canyon between Haifa and 'Atlit (road to the Mediterranean Sea from University of Haifa), 31°24' N, 34°52' E, 26 Apr & 27 May 2004, S.O. Voytyuk.

General distribution: Europe (Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Greece, Hungary, Iceland, Poland, Portugal, Romania, Russia (European part), Spain (Balearic Is.), Sweden, Switzerland, Ukraine, Yugoslavia), Asia (Afghanistan, India, Iran, Israel, Japan, Kazakhstan, Korea, Mongolia, Pakistan, Russia (Far East, Siberia), Turkey), Africa (Canary Is., South Africa), North America (Alaska, Canada, USA), and South America (Bolivia).

Fig. 5. Distribution of *G. cynoglossi* in Israel



Golovinomyces depressus (Wallr.) Heluta, Ukrainian Bot. J. 45(5): 62 (1988). (Fig. 6)

Mycelium white or grayish, net-like or powdered, well developed on stems and leaves of host plant. Hyphae 2-9 μm wide. Appressoria nipple-shaped. **Anamorph** *Oidium* s. str. **Conidiophores** erect, 70-200 μm (fresh material), foot-cells straight, cylindrical, 40-100 (-130) \times 11-14 μm increase from base to top. **Conidia** in chains, doliiform, ellipsoid-ovoid to lemon-shaped, 25-40 \times (10-) 15-25 μm (dry material), 35-60 \times 17-35 μm (fresh material). **Chasmothecia** scattered or in large groups, hemispheric (depressed in the upper part), 80-170 μm diam. Peridium cells irregularly shaped, 3-15 (-25) μm diam. Appendages in the lower part of the ascocarp, often develop in the upper half, numerous, 0.5-3 times as long as the chasmothecia diam or shorter than the chasmothecium diam, 2-10 μm wide, thin-walled, smooth, mycelium-like, septate, hyaline, later faintly colored to dark brown. **Asci** numerous, 4-16 (-25), thin-walled, stalked, 40-67 (80) \times 20-35 (40) μm , 2-, sometimes 3-4-spored. **Ascospores** ellipsoid-ovoid, large, 20-35 \times 14-20 μm .

Distribution in Israel (Fig. 7):

On *Carduus argentatus* L. (*C. pycnocephalus* Jacq.): CM: Bet Oren, 3 May 1947, T. Rayss (HUJ 7564, Rayss 1947); Haifa, 28 Mar 1936, T. Rayss (HUJ 680); Haifa, 28 Apr 1938, T. Rayss (Rayss 1940); GH: Afiq, 32°47' N, 35°42' E, 3 May 2004, S.O. Voytyuk; JM: Jerusalem, 30 Apr 1951, T. Rayss (HUJ 301/10 102S); Jerusalem, 26 May 1945, T. Rayss (HUJ 7702, Rayss 1947); Israel (Amano 1986).

On *C. getulus* Pomel: CN: Sede Boqer (kibbutz), 30°52' N, 34°47' E, 25 Apr 2004, S.O. Voytyuk (anamorph); Yerucham, artificial forest

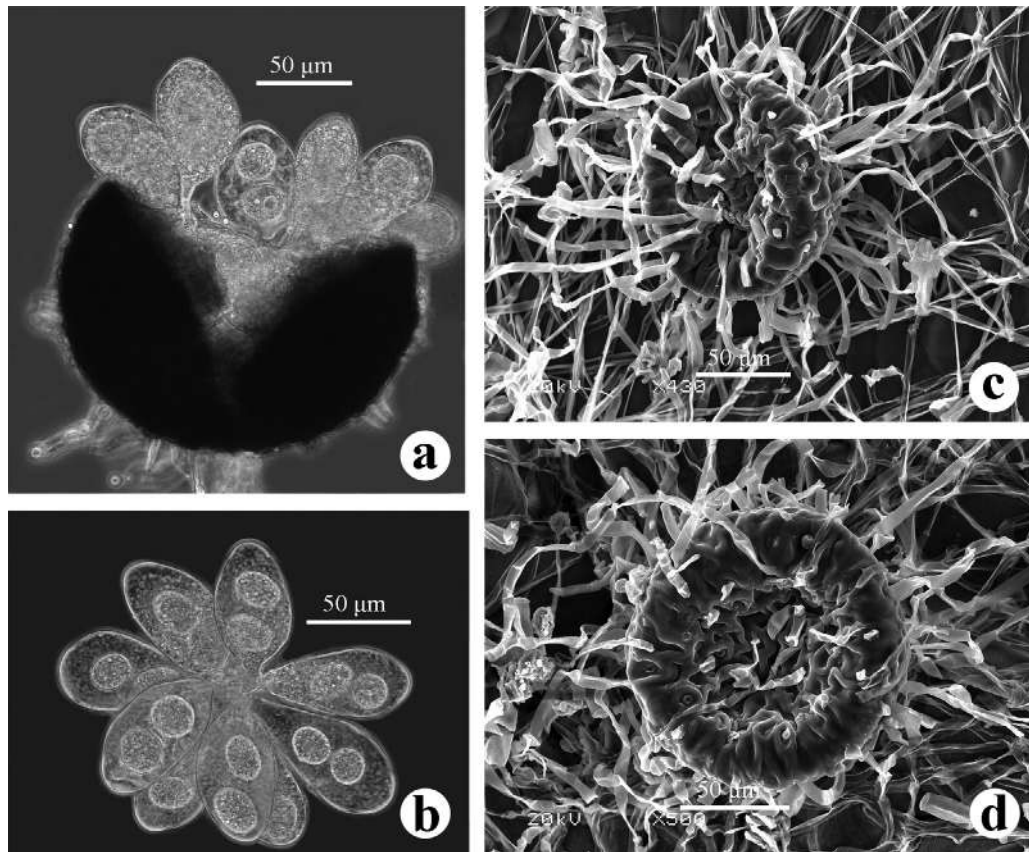


Fig. 6. *Golovinomyces depressus* on *Carduus argentatus*: a – chasmothecium with asci; b – asci; c-d – chasmothecia under SEM. Scale bars = 50 µm

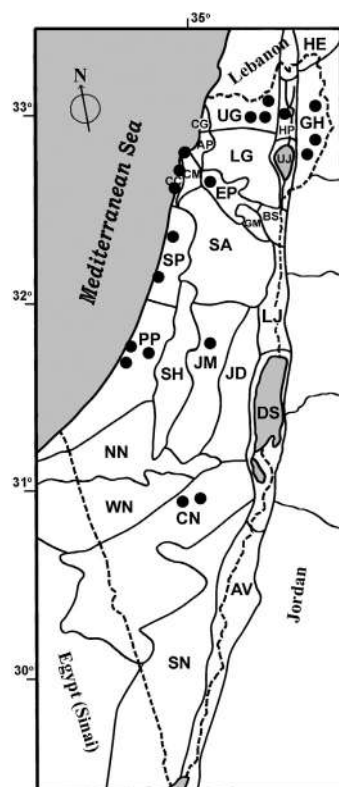


Fig. 7. Distribution of *G. depressus* in Israel

near artificially impounded body, 30°59' N, 34°53' E, 25 Apr 2004, S.O. Voytyuk.

On *Carthamus alexandrinus* (Benth. et Hook.) Asch.: Israel (Amano 1986).

On *C. flavescens* Willd.: Israel (Amano 1986).

On *C. glaucus* Bieb.: Israel (Amano 1986).

On *C. oxyacantha* Bieb.: Israel (Amano 1986).

On *C. persicus* Willd. (*C. palestinus*): Israel (Amano 1986).

On *C. tinctorius* L.: Israel (Rayss 1947; Kenneth *et al.* 1975; Amano 1986).

On *C. turkestanicus* Popov: Israel (Amano 1986).

On *Centaurea cyanoides* Berggren et Wahlenb.: CM: Nahal Oren (4), 32°49' N, 35°46' E, 20 Apr 2004, S.O. Voytyuk; EP: 'En Harod, 15 Apr 1941, T. Rayss (HUJ 653; Rayss 1947); SP: Binyamina (7 km south of Zikhron Ya'aqov) 13 Apr 1941, T. Rayss (HUJ 654; Rayss 1947); Israel (Amano 1986).

On *C. hyalolepis* Boiss.: CM: near Bet Oren, Nahal Oren, "Evolution Canyon-1", 32°49' N, 35°46' E, 5 May 2004, S.O. Voytyuk (anamorph).

On *Cynara syriaca* Boiss. (*C. scolymus* L.): Israel (Amano 1986) (anamorph).

On *Notobasis syriaca* (L.) Cass. (*Cirsium syriacum* (L.) Gaertn.): CM: near Haifa, 31°24' N, 34°52' E, 16 May 2004, S.O. Voytyuk; JM: Jerusalem, Bet HaKerem, 16 May 1940, T. Rayss (HUJ 7254); PP: Bet Dagan (near Tel-Aviv), 15 May 1946, T. Rayss (Rayss 1947); Israel (Amano 1986).

On *Onopordon* sp.: UG: Dalton, 14 Mar 2002, V.P. Heluta.

**Species according to Feinbrun-Dothan & Danin (1998) is absent. Occurrence of this plant in Israel is questionable.

On *Silybum marianum* (L.) Gaertner: CC: 'Atlit, Coast Sea, 32°42' N, 34°56' E, 10 Apr 2004, S.O. Voytyuk; CM: near Bet Oren, Nahal Oren, "Evolution Canyon-1", 32°49' N, 35°46' E, 20 May 2005, S.O. Voytyuk; Haifa, 15 Mar 2002, V.P. Heluta; Haifa, University of Haifa, National Park, 31°24' N, 34°52' E, 10 Jun 2004, S.O. Voytyuk; Muchraka, 17 Mar 2004, S.O. Voytyuk; Zikhron Ya'aqov (near railway station), 12 May 2006, S.O. Voytyuk; CN: Tel Keshet, near the road to Tel-Aviv, 31°18' N, 34°53' E, 25 Apr 2004, S.O. Voytyuk (anamorph); Yerucham, artificial forest near artificially impounded body, 30°59' N, 34°53' E, 25 May 2005, S.O. Voytyuk; GH: Qidmat-Zevi, 33°01' N, 35°41' E, 25 May 2005, S.O. Voytyuk; HP: Rosh-Pinna, 29 May 2005, S.O. Voytyuk; LG: Mi'ilya (near Ma'a lot), 33°00' N, 35°08' E, 25 Mar 2004, S.O. Voytyuk; PP: Tel-Aviv, 16 May 2005, S.O. Voytyuk; JV: Tel Yosef (kibbutz along side 'En Harod), 27 Apr 1930, T. Rayss (HUJ 301/11 105S); UG: Zefat, 32°57' N, 35°31' E, 24 May 2004, S.O. Voytyuk; Israel (Amano 1986).

General distribution: Europe (Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Greece, Hungary, Italy, the Netherlands, Norway, Poland, Portugal, Romania, Russia (European part), Spain, Sweden, Switzerland, Ukraine, Yugoslavia), Asia (Central Asia, China, India, Iran, Iraq, Israel, Japan, Kazakhstan, Russia (Far East, Siberia), Turkey), Africa (Canary Is., Egypt, Morocco), North America (Canada, USA).

Notes: *Golovinomyces depressus* is a fungus with chasmothecia depressed in the upper part and it parasitizes species of the Asteraceae family. But, according to reference data, specimens of this species could be referred mistakenly to *G. cichoraceorum*, which also is a parasite of plants of the same family but has somewhat depressed in the lower part chasmothecia.

Golovinomyces echinopsis (U. Braun) Heluta, Ukrainian Bot. J. 45(5): 62 (1988). (Fig. 8)

Mycelium on stems, leaves, floury. Hyphae 5-12 μm wide. Appressoria nipple-shaped. **Anamorph** *Oidium* s. str. **Conidiophores** erect, 150-250 μm (fresh material), foot-cells straight, cylindrical, 50-100 (-150) \times 13-20 μm – increasing from base to top. **Conidia** in chains, ellipsoid-ovoid to lemon-like, mostly with typically constricted ends, 25-40 \times (15-) 17-25 μm (dry material), 30-50 \times 20-30 μm (fresh material). **Chasmothecia** scattered, hemispheric, slightly depressed in the lower part, 100-170 μm diam. Peridium cells irregularly shaped, 5-20 μm diam. Appendages in the lower part of the ascocarp, often develop in the middle part, numerous, 0.5-1.5 times as long as the chasmothecia diam, sometimes shorter than the chasmothecia diam, 3-8 μm wide, thin-walled,

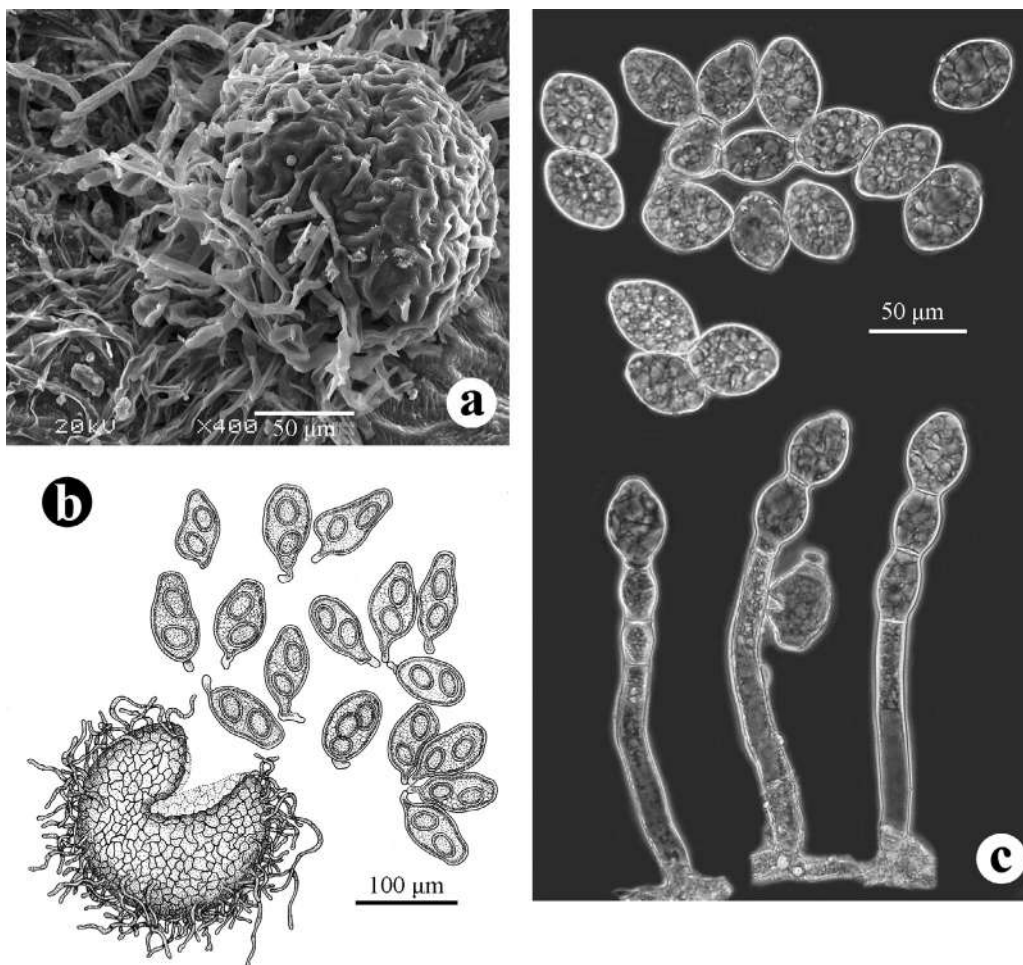


Fig. 8. *Golovinomyces echinopsis* on *Echinops gaillardotii*: a – chasmothecium under SEM; b – chasmothecium with asci; c – conidiophores and conidia (fresh material). Scale bars: a, c = 50 μm ; b = 100 μm

smooth, mycelium-like, septate, hyaline, later faintly colored. **Asci** numerous, 8–20, thin-walled, stalked, $60\text{--}100 \times 25\text{--}50$ (–60) μm , 2 (–3)-spored. **Ascospores** ellipsoid-ovoid, large, $20\text{--}40 \times 14\text{--}25$ μm .

Distribution in Israel (Fig. 9):

On *Echinops gaillardotii* Boiss.: CM: Haifa, University of Haifa, National Park, $31^{\circ}24' \text{N}$, $34^{\circ}52' \text{E}$, 19 Jun 2004, S.O. Voytyuk; near Haifa, $31^{\circ}24' \text{N}$, $34^{\circ}52' \text{E}$, 16 May & 19 Jun 2004, S.O. Voytyuk; near Bet Oren, Nahal Oren, “Evolution Canyon-1”, $32^{\circ}49' \text{N}$, $35^{\circ}46' \text{E}$, 5 May 2004, S.O. Voytyuk.

General distribution: Europe (England, France, Germany, Great Britain, Hungary, Italy, Norway, Romania, Russia (European part), Switzerland, Ukraine, Yugoslavia) and Asia (Israel, Korea).

Golovinomyces magnicellulatus (U. Braun) Heluta, Ukrainian Bot. J. 45(5): 62 (1988).

Distribution in Israel:

On *Phlox drummondii* Hook.: Israel (Amano 1986).

On *Phlox* sp.: Israel (Braun 1987).

General distribution: Europe, Asia (Central Asia, Israel, Japan, Russia (Siberia, Far East)), and North America (Canada, USA).

Notes: During our investigation in Israel, we did not find this fungus.

Golovinomyces orontii (Castagne) Heluta, Ukrainian Bot. J. 45(5): 63 (1988). (Fig. 10b)

Mycelium white or grayish, on stems, leaves, effuse or in patches. Hyphae 3–7 μm wide. Appressoria nipple-shaped. **Anamorph** *Oidium* s. str. **Conidiophores** erect, 100–180 μm (fresh material), foot-cells straight or often curved in the basal part, cylindrical, $37\text{--}100 \times 11\text{--}14$ μm (fresh material). **Conidia**

in chains, ellipsoid, ellipsoid-ovoid, after drying doliiform to doliiform-subcylindrical, $25\text{--}35 \times (10\text{--}) 13\text{--}20$ μm (dry material), $30\text{--}40 \times 17\text{--}25$ μm (fresh material). **Chasmothecia** not observed.

Distribution in Israel (Fig. 11):

On *Abelmoschus esculentus* (L.) Moench (*Hibiscus esculentus* L.): LG: Mikhmannim, Oct 1944, T. Rayss (HUJ 6648); SP: Hadera, 9 Nov 1935, T. Rayss (HUJ 957); Israel (Palti 1972a, b; Amano 1986) (anamorph).

On *Antirrhinum majus* L.: PP: Tel-Aviv, University of Tel-Aviv, Botanical Garden, $32^{\circ}06' \text{N}$, $34^{\circ}48' \text{E}$, 13 May 2004, S.O. Voytyuk; Israel (Amano 1986).

On *Begonia* sp.: Israel (Amano 1986).

On *Cucumis sativus* L.: Israel (Amano 1986).

On *Datura innoxia* Miller: CM: Haifa, 15 Jul 2005, S.O. Voytyuk; PP: Tel-Aviv, University of Tel-Aviv, Botanical Garden, $32^{\circ}06' \text{N}$, $34^{\circ}48' \text{E}$, 28 Apr 2004, S.O. Voytyuk.

On *Linum usitatissimum* L.: JM: Jerusalem, 12 Jun 1945, Z. Bumstein (HUJ 7018; Rayss 1947); Israel (Rayss 1947; Kenneth *et al.* 1975) (anamorph).

On *Luffa cylindrica* (L.) Roem.: Israel (Amano 1986).

On *Lycopersicon esculentum* Mill.: AV: near Hazeva (Tahanat Yair, experimental station), 23 Feb 2005, S.O. Voytyuk; Israel (Amano 1986).

On *Nicotiana tabacum* L.: JM: Jerusalem, 17 May 1955, T. Rayss (HUJ 301/12 111S); PP: (Rayss 1959; Kenneth *et al.* 1975); UG: (Rayss 1959; Palti 1972b; Kenneth *et al.* 1975); Israel (Amano 1986).

On *Sesamum indicum* L. – Israel (Kenneth *et al.* 1975; Amano 1986) (anamorph).

On *Solanum melongena* L.: Israel (Amano 1986).

On *S. tuberosum* L.: BS: Jan–May 1942, Dec 1943, Apr, May, Oct–Dec 1944 (Palti 1953); Tirat Zevi, 22 Apr 1942 (Palti 1953); EP: Apr–Jul 1942 (Palti 1953); Ramat Dawid, 09 Jun 1942 (Palti 1953); HP: Apr–Oct 1942, Jun–Jul 1943, Jan, Dec 1944, Jan 1945 (Palti 1953); Amir, 14 Dec 1944 (Palti 1953); Dafna, 25 Jun 1942 (Palti 1953); Apr–May, Nov 1942, Jul, Dec 1943, Jan 1944 (Palti 1953); PP: Giv’at Brenner, 1940s (Palti 1953); Dec 1943, Jan 1944 (Palti 1953); Giv’at Brenner, 13 Dec 1943 (Palti 1953); UG: Ayyelet HaShahar, 25 May 1942, 23 Apr 1943 (Palti 1953); UJ: Feb–May 1942, Apr, May, Oct, Nov 1944 (Palti 1953); Israel (Kenneth *et al.* 1970; Palti 1972a, b; Amano 1986).

On *Solanum* sp.: Israel (Amano 1986).

General distribution: circumglobal.

Notes: In Israel this species was observed only as an anamorph. Amano (1986) noted fungus also on *Papaver rhoeas* L. However, according to Feinbrun-Dothan & Danin (1998), this plant was not found in Israel. Thus, the location of *G. orontii* on this host plant is questionable. According to Amano (1986), *G. orontii* (as *Erysiphe cichoracearum*) was recorded on *Verbena rigida* Spreng. in Israel. However, during our observation, only *Sphaerotheca verbenae* Sav. et Negru was found on this plant.

Golovinomyces sordidus (L. Junell) Heluta, Ukrainian Bot. J. 45(5): 63 (1988). (Fig. 10 c-d)

Mycelium white or cream-coloured, on leaves, dense. Hyphae 3–8 μm wide. Appressoria nipple-shaped. **Anamorph** *Oidium* s. str. **Conidiophores** erect, 90–140 μm (fresh material), foot-cells straight or with curved basal half, cylindrical, $35\text{--}70 \times 11\text{--}14$ μm , followed by 1-

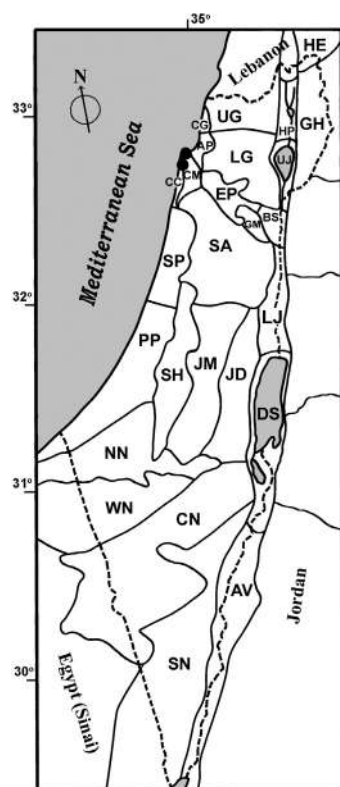


Fig. 9. Distribution of *G. echinopsis* in Israel

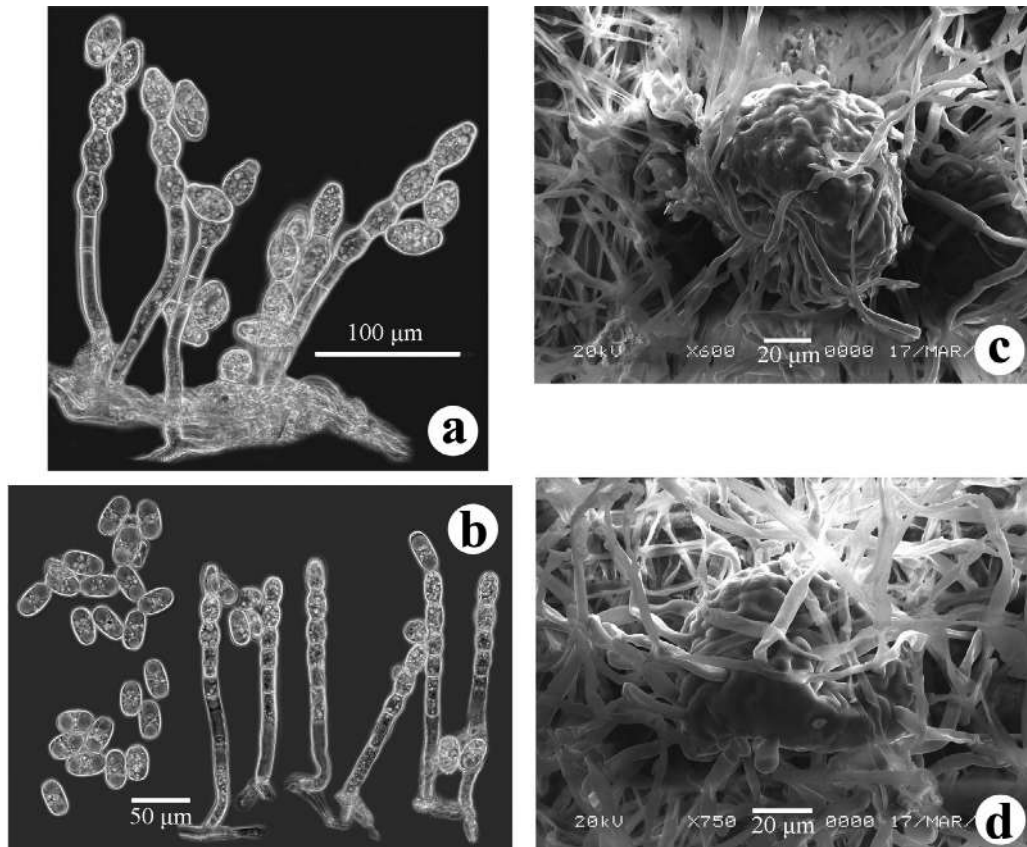


Fig. 10. *Golovinomyces*: **a** – *G. verbasci* on *Verbascum sinuatum* (conidiophores and conidia); **b** – *G. orontii* on *Datura innoxia* (conidiophores and conidia); **c-d** – *G. sordidus* on *Plantago lanceolata* under SEM (**c** – view from the bottom, **d** – side view). Scale bars: **a** = 100 µm, **b** = 50 µm, **c-d** = 20 µm

3 shorter cells. **Conidia** in chains, ellipsoid, ovoid, after drying cylindrical-ellipsoid to doliiform, 25-38 × 12-20 µm (dry material), 30-40 × 17-25 µm (fresh material). **Chasmothecia** gregarious, hemispheric, gently depressed in the lower part, 70-150 µm diam. Peridium cells irregularly shaped, 6-18 (–20) µm diam. Appendages in the lower part of the ascocarp, numerous, 0.5-1.5 times as long as the chasmothecia diam, 3-10 µm wide, thin-walled, smooth or somewhat rough, septate, brown throughout when mature. **Asci** numerous, 6-16 (–20), stalked, 40-67(–75) × 20-35 (–40) µm. **Ascospores** 2, occasionally 3, ellipsoid-ovoid, 20-30 × 10-18 µm.

Distribution in Israel (Fig. 12):

On *Plantago afra* L. (*P. psyllium* L.): HP: Dafna (kibbutz) (7 km northeast of Qiryat Shemona), 19 Mar 1940, T. Rayss (HUJ 790; Rayss 1940); JM: Deir esh Sheikh, 12 Mar 1941, T. Rayss (HUJ 792); Moza (5 km west of Jerusalem), 18 Mar 1939, T. Rayss (HUJ 791; Rayss 1940); Israel (Amano 1986).

On *P. arabica* Boiss.: Israel (Amano 1986).

On *P. cretica* L.: CM: Haifa, 2 Apr 1936, T. Rayss (HUJ 787; Rayss 1940); Regavim (kibbutz 3 km east of Giv'at 'Ada), 8 Apr 1946, T. Rayss (HUJ 7208); JM: Jerusalem, 10 May 1939, T. Rayss (HUJ 788; Rayss 1940); SA: 05 Apr 1943, T. Rayss (HUJ 5560); UJ: 'En Gev (kibbutz on east shore

of Lake Kinneret), 7 Apr 1945, T. Rayss (HUJ 7013); Tiberias (on shore of Lake Kinneret), 18 Mar 1938, T. Rayss (HUJ 785, 789; Rayss 1940); Israel (Amano 1986).

On *P. lagopus* L.: Israel (Amano 1986).

On *P. lanceolata* L.: CC: 'Atlit, Coast Sea, 32°42' N, 34°56' E, 26 Mar & 21 Apr 2004, S.O. Voytyuk (anamorph); Canyon between Haifa and 'Atlit (road to the Sea from University of Haifa), 31°24' N, 34°52' E, 26 Mar 2004, S.O. Voytyuk (anamorph); CM: Haifa, University of Haifa, National Park, 31°24' N, 34°52' E, 25 Jun 2004, S.O. Voytyuk; near Haifa, 31°24' N, 34°52' E, 20 May 2005, S.O. Voytyuk; near Bet Oren, Nahal Oren, "Evolution Canyon-1", 32°49' N, 35°46' E, 5 May 2004, S.O. Voytyuk; LG: Mi'elia (near Ma'alot), 33°00' N, 35°08' E, 25 Apr 2004, S.O. Voytyuk; PP: near Ashqelon (along the road) 31°46' N, 34°40' E, 19 Apr 2004, S.O. Voytyuk.

On *P. major* L.: Israel (Amano 1986) (anamorph).

General distribution: Europe (Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Hungary, Italy, the Netherlands, Norway, Poland, Portugal, Romania, Russia (European part), Spain, Sweden, Switzerland, Ukraine, Yugoslavia), Asia (Central and Minor Asia, China, India, Iran, Israel, Japan, Kazakhstan, Pakistan, Taiwan, Turkey), Africa (Algeria, Canary Is., Egypt, Ethiopia, Morocco, Tunisia), North America (Canada, USA), and South America (Venezuela).

Fig. 11. Distribution of *G. orontii* in Israel

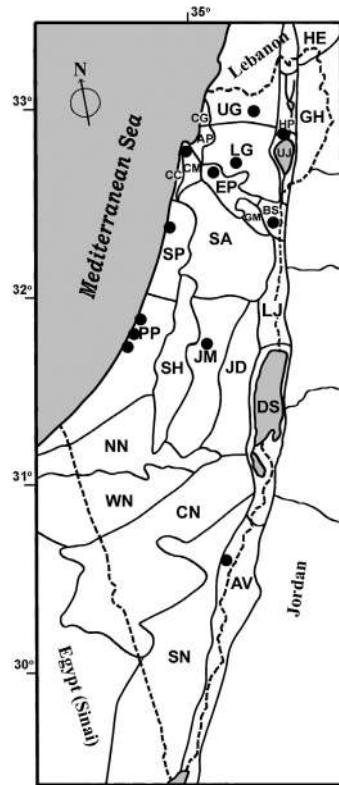
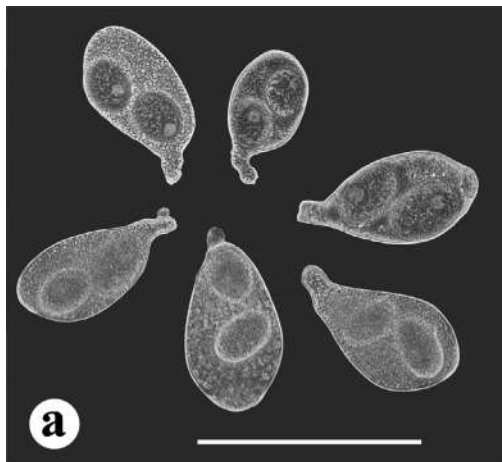
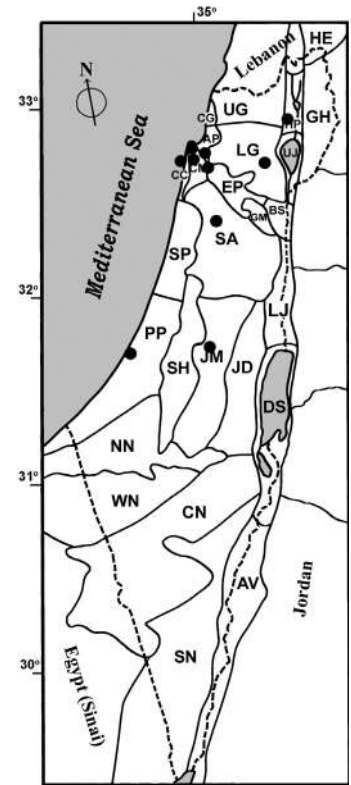
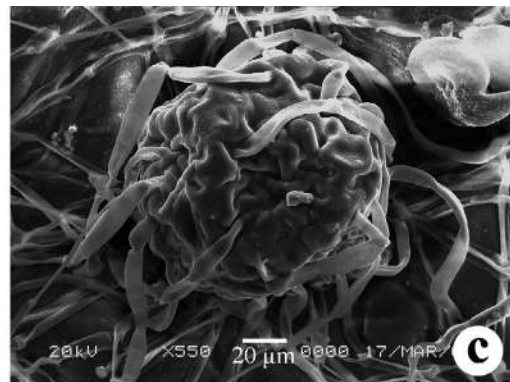


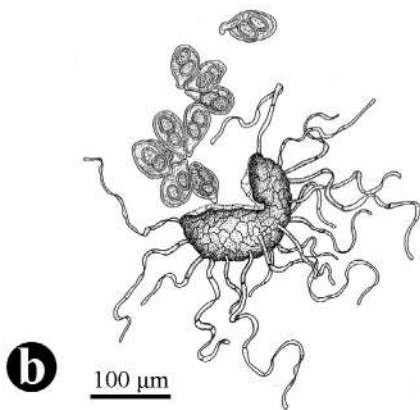
Fig. 12. Distribution of *G. sordidus* in Israel



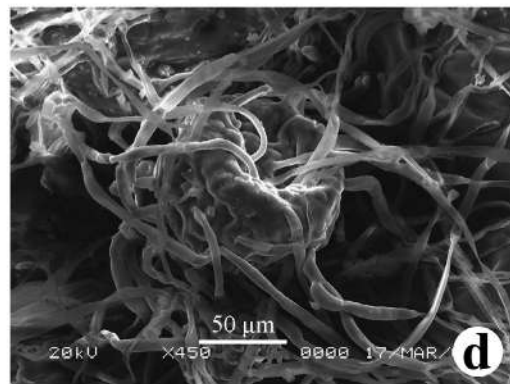
a



c



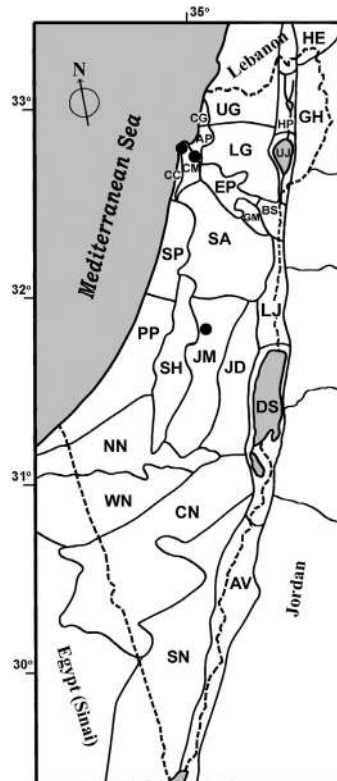
b



d

Fig. 13. *Golovinomyces valeriana* on *Valeriana dioscoridis*: a – asci with ascospores; b – chasmothecium with asci; c-d – chasmothecia under SEM. Scale bars: a-b = 100 μm, c = 20 μm, d = 50 μm

Fig. 14. Distribution of *G. valerianae* in Israel



Golovinomyces valerianae (Jacz.) Heluta, Ukrainian Bot. J. 45(5): 63 (1988). (Fig. 13)

Mycelium grayish, on leaves, thin, evanescent. Hyphae 2-6 μm wide. Appressoria nipple-shaped. **Anamorph** *Oidium* s. str. **Conidiophores** erect, 90-150 μm (fresh material), foot-cells straight, cylindrical, (35-) 40-70 \times 10-14 μm . **Conidia** in chains, ellipsoid-ovoid to doliiform, 25-40 \times 12-20 μm . **Chasmothecia** scattered or in large groups, brown, 80-150 μm diam. Peridium cells irregularly shaped, 8-25 (-30) μm diam. Appendages numerous, in the lower part of the ascocarp, sometimes develop in the upper half, 0.5-2 times as long as the chasmothecia diam, 4-15 μm wide, brown, thin-walled, septate, smooth or mostly verrucose, brown when mature. **Asci** numerous, 6-16 (-20), thin-walled, stalked, 40-67 (-80) \times 20-40 μm , often filled with numerous larger oil-drops. **Ascospores** ellipsoid, 20-35 \times 15-20 μm .

Distribution in Israel (Fig. 14):

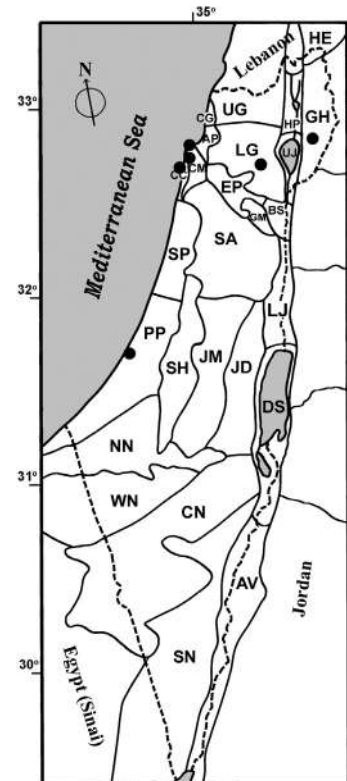
On *Centranthus* sp.: Israel (Braun 1987).

On *Valeriana dioscoridis* Sm.: CM: between Bet Oren and 'Atlit, 04 Apr 1943, T. Rayss (HUJ 7290); near Bet Oren, Nahal Oren, "Evolution Canyon-1", 32°49' N, 35°46' E, 3 Mar, 22 Mar & 20 Apr 2004, S.O. Voytyuk, 3 Apr 2005, V.P. Heluta; JM: Jerusalem, near 'Atarot, 21 Apr 1945, T. Rayss (HUJ 6897); Kafr 'Aqab (near Ramallah), 21 Apr 1945, D. Rijik (Rayss 1947); Israel (Amano 1986).

On *Valeriana* sp.: Israel (Braun 1987).

General distribution: Europe (Austria, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Great Britain, Greece, Hungary, Italy, the Netherlands, Norway, Poland, Portugal, Romania, Russia (European part), Sweden, Switzerland, Ukraine, Yugoslavia), Asia (Armenia,

Fig. 15. Distribution of *G. verbasci* in Israel



Central Asia, China, Israel, Kazakhstan, Korea, Russia (Siberia), Turkey), and North America (USA).

Golovinomyces verbasci (Jacz.) Heluta, Ukrainian Bot. J. 45(5): 63 (1988). (Fig. 10a)

Mycelium white, on leaves, floury. Hyphae 3-7 μm wide. Appressoria nipple shaped. **Anamorph** *Oidium* s. str. **Conidiophores** erect, 130-200 μm (fresh material), foot-cells straight, cylindrical, (50-) 80-150 \times 11-18 μm (fresh material). **Conidia** in chains, ovoid, often lemon-shaped, 25-45 \times (18-) 20-25 μm (dry material), 30-50 \times 23-30 μm (fresh material). **Chasmothecia** not observed.

Distribution in Israel (Fig. 15):

On *Verbascum agrimoniifolium* (C. Koch) Huber-Morath subsp. *syriacum* (Murb.) Feinbrun: GH: Nahal Gamla, near Nature Reserve, 32°54' N, 35°46' E, 16 May 2004, S.O. Voytyuk (anamorph).

On *V. sinuatum* L.: CC: 'Atlit, Coast Sea, 32°42' N, 34°56' E, 26 Mar & 21 Apr 2004, S.O. Voytyuk (anamorph); Canyon between Haifa and 'Atlit (road to the Sea from University of Haifa), 31°24' N, 34°52' E, 26 Mar 2004, S.O. Voytyuk (anamorph); CM: near Bet Oren, Nahal Oren, "Evolution Canyon-1", 32°49' N, 35°46' E, 23 Jul 2005, S.O. Voytyuk; Haifa, University of Haifa, 25 Jul 2006, S.O. Voytyuk; LG: Mi'elia (near Ma'alot), 33°00' N, 35°08' E, 25 Apr 2004, S.O. Voytyuk; PP: the road between Ashqelon and Ashdod, near road, 32°54' N, 35°46' E, 19 Apr 2004, S.O. Voytyuk.

General distribution: Europe (Austria, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Great Britain, Greece, Hungary, Italy, the Netherlands, Norway, Poland, Portugal, Romania, Russia (European part), Sweden, Switzerland, Ukraine), Asia (Central Asia, China, Israel, Kazakhstan, Russia (Siberia)), and North America (Canada, USA).

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