

**A contribution to the rust flora (*Uredinales*) on  
*Zygophylloideae* (*Zygophyllaceae*) in Africa\***

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**Abstract**—Five African species of rust fungi infecting the plant subfamily *Zygophylloideae* are described in detail and illustrated by line drawings, three of which are described as new: *Uromyces dinteri* (Anamorph *Uredo zygophylli*) on *Tetraena decumbens* (= *Zygophyllum decumbens*) and on cf. *Tetraena* sp., *Uromyces namaqualandus* on *Roepera cordifolia* (= *Zygophyllum cordifolium*) and on cf. *Roepera* sp., and *Uromyces paulshoekensis* on cf. *Roepera foetida* (= *Zygophyllum cf. meyeri* = *Zygophyllum foetidum*). Furthermore, we examined *Uromyces trollipi* on *Roepera foetida* (= *Zygophyllum foetidum*) and *Uredo zygophyllina* (= *Uredo zygophylli*) on *Tetraena cornuta* (= *Zygophyllum cornutum*) and on *Tetraena prismatocarpa* (= *Zygophyllum prismatocarpum*). The description of a sixth species, *Uredo augeae* on *Augea capensis*, is added from literature.

**Key words**—Algeria, biodiversity, Egypt, Namibia, South Africa

**Introduction**

Up to now, five rust species producing uredinio- and/or teliospores have been described from representatives of the subfamily *Zygophylloideae*, four from Africa and one from Australia. Beier et al. (2003) revised the *Zyghophylloideae* and transferred most of the former *Zygophyllum* species from Africa into the genera *Roepera* and *Tetraena*. Thus, *Zygophyllum* in its new circumscription is no longer occurring in Africa.

During the course of a biodiversity study in the western parts of southern Africa, we collected four rust specimens on *Zygophylloideae*. These and herbarium specimens of the hitherto known African rusts on *Zygophylloideae* were examined. The nine investigated specimens belong to five rust species, three of which are new. The description of a sixth African rust species which we have not seen is added from literature.

**Materials and methods**

The following observations are based on collections made in South Africa by the first author between 02.IX.2002 and 30.IX.2002. These collections as well as specimens from herbaria were studied as we performed freehand sections and scrape mounts of infected plant material. The samples were heated in "Hoyer's fluid" (Cunningham 1972)

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and subsequently examined with a Carl Zeiss microscope equipped with bright field and phase contrast optics. Spore sizes are based on measurements of 50 spores of each occurring spore state. For scanning electron microscopy, air-dried fragments of rust infected leaves were put onto double-sided adhesive tape fixed to an observation stub, spattered with gold-palladium and observed with a Cambridge Stereoscan 250 Mk-2. In order to identify the rust fungi we checked several publications concerning the rust flora of Africa, which are available via internet under <http://www.mycology.uni-tuebingen.de/databases/rust-literature/>.

## Results

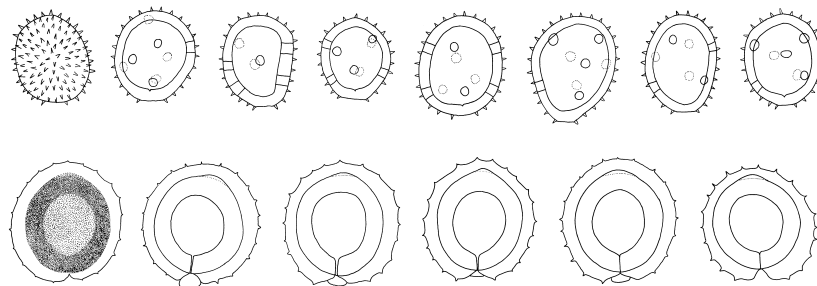
The examined species are listed in alphabetical order. The following abbreviations are used: 0 = spermogonia = pycnia; I = aecia; II = uredinia; III = telia; IV = basidia.

***Uromyces dinteri*** Mennicken, Maier & Oberw. sp. nov. (Fig. 1).

Anamorph. *Uredo zygophylli* Henn. non Jacz. (Hennings 1893): 113. Type on *Tetraena decumbens* (Delile) Beier & Thulin (= *Zygophyllum decumbens* Delile). Egypt, Majo, leg. Ehrenberg (B 70 0007286).

Pycnia et aecia ignota. Uredinia amphigena vel caulicola, subepidermalia, usque ad 0.5 mm diam., rubro-brunnea, mox nuda, pulverulenta. Urediniosporae subgloboideae, ovoideae vel ellipsoideae, 31–40 (–42) x (22–) 24–36 µm, pariete echinulato, 2.5–4 (–5) µm crasso, aureo-fusco, 6–9 poris germinationis dispersis. Telia amphigena vel caulicola, subepidermalia, usque ad 1 mm diam., atro-rubro-brunnea, mox nuda, compacta, pulverulenta. Teliosporae unicellulares, globoideae vel subgloboideae, bilaminatae, strato exteriori dilute aureo vel hyalino, usque ad 5 µm crasso, breviter echinulato, strato interiore castaneo, 5–8 µm crasso, (31–) 34–44 x 30–42 µm, poro germinationis apicali, pedicello hyalino, brevi.

In foliis caulisque cf. *Tetraena* sp. (= *Zygophylli* sp.), *Zygophyllaceae*.



**Fig. 1.** *Uromyces dinteri* on cf. *Tetraena* sp. Uredinio- and teliospores. (Holotype K(M) 116414). Scale bar = 10 µm.

Pycnia and aecia unknown.

Uredinia amphigenous on leaves and on stems, subepidermal, scattered or arranged in groups, minute, round to ellipsoid, up to 0.5 mm wide, reddish-brown, exposed, pulverulent, surrounded by the torn epidermis. Urediniospores subglobose, ovoid to ellipsoid, 31–40 (–42) x (22–) 24–36 µm, echinulate, spore wall uniformly about 2.5–4 (–5) µm thick, yellowish-brown, germ pores inconspicuous, 6 to 9, scattered, without papillae, but with cuneiform lucency of the spore wall.

Telia amphigenous on leaves and on stems, subepidermal, developing from the uredinia, scattered or arranged in groups, round, up to 1 mm wide, dark reddish-brown to black, exposed, compact, pulverulent, surrounded by the torn epidermis. Teliospores unicellular, globoid to subgloboid, rounded above and below, bilaminar, outer layer pale yellowish to hyaline, up to 5  $\mu\text{m}$  thick, shortly echinulate, inner layer chestnut-brown, uniformly about 5–8  $\mu\text{m}$  thick, up to circa 2  $\mu\text{m}$  thicker in the range of the germ pore, smooth, size of spores (without hyaline outer layer) (31–) 34–44 x 30–42  $\mu\text{m}$ , germ pore apical, partly with slightly brightened and yellowed papilla that is weakly developed, pedicel persistent or not, very short, thin-walled, hyaline. Most of the teliospores had germinated, so that the outer layer of the spore wall is lacinated and divided into patches, lacking pedicel and papilla. The inner layer of the spore wall is perforated in the area of the germ pore.

On the leaves of cf. *Tetraena* sp. (= *Zygophyllum* sp.), *Zygophyllaceae*.

**Etymology.** Named after the collector, Kurt Dinter (1868 – 1945), who was an important botanist in Namibia.

#### Specimens examined:

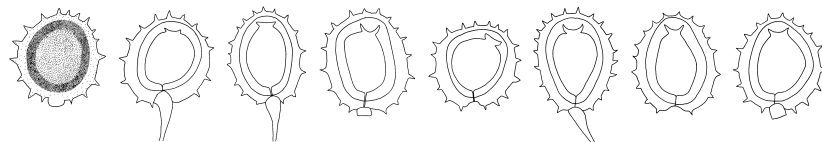
- On cf. *Tetraena* sp. (= *Zygophyllum* sp.). Namibia, Kalkfontein-Süd, near Karasberg, 29.VII.1923, leg. Kurt Dinter No. 4740, II III (Holotype K(M) 116414, Isotype B 70 0007285).
- On *Tetraena decumbens*. Egypt, Majo, leg. Ehrenberg, II (Type of *Uredo zygophylli* Henn., B 70 0007286).

The Namibian collection of *Uromyces dinteri* sp. nov. was erroneously labelled and/or determined as *Uromyces trollipi* (See below). The incorrect name was mentioned in Doidge (1927) and in Doidge (1950).

#### *Uromyces namaqualandus* Mennicken, Maier & Oberw. sp. nov. (Fig. 2).

Pycnia, aecia et uredinia ignota. Telia amphigena, subepidermalia, usque ad 2 mm diam., atro-brunnea vel nigra, mox nuda, compacta, pulverulenta. Teliosporae unicellulares, globoideae vel subgloboideae, bilaminatae, strato exteriori dilute aureo vel hyalino, lateraliter usque ad 8  $\mu\text{m}$  crasso, apicaliter usque ad 3  $\mu\text{m}$  crasso, grosse echinulato, strato interiore castaneo, lateraliter 5–8  $\mu\text{m}$  crasso, apicaliter 4–10  $\mu\text{m}$  crasso, 31–49 x 23–32  $\mu\text{m}$ , poro germinationis apicali, annuliformi, pedicello hyalino, brevi, subinde usque ad 50  $\mu\text{m}$ .

In foliis *Roeperae cordifoliae* (L.f.) Beier & Thulin (= *Zygophylli cordifolii* L.f.), *Zygophyllaceae*.



**Fig. 2.** *Uromyces namaqualandus* on *Roeperae cordifolia*. Teliospores (Holotype RSA 147). Scale bar = 10  $\mu\text{m}$ .

Pycnia, aecia, and uredinia unknown.

Telia amphigenous on leaves, subepidermal, separate, scattered or arranged in concentric groups up to 5 mm wide, single sori round, ellipsoid or oblong, up to 2 mm wide, dark chocolate-brown to black, without leaf spots surrounding telia, compact, early exposed, pulverulent, surrounded by the torn epidermis. Teliospores unicellular, globoid,

subglobose to ellipsoid,  $\pm$  rounded above and below, bilaminar, outer layer pale yellowish to hyaline, up to 8  $\mu\text{m}$  thick at the sides, up to 3  $\mu\text{m}$  thick at the apex, coarsely echinulate, inner layer chestnut-brown, about 2–5  $\mu\text{m}$  thick at the sides, about 4–10  $\mu\text{m}$  thick at the apex, smooth, size of spores (without hyaline outer layer) 31–49 x 23–32  $\mu\text{m}$ , ring-shaped germ pore apical, without papilla, pedicel mostly persistent, normally broken immediately below the attachment, occasionally up to 50  $\mu\text{m}$  long, thin-walled, collapsing, hyaline.

On the leaves of *Roepera cordifolia*, *Zygophyllaceae*.

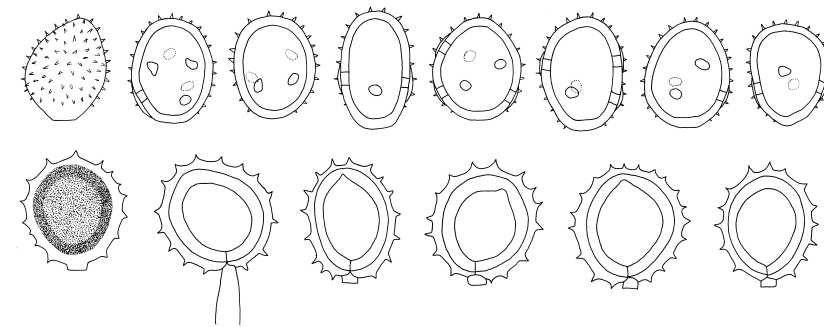
**Etiology.** Named after the region of occurrence in South Africa, Namaqualand.

**Specimens examined:**

- On *Roepera cordifolia*. South Africa, Northern Cape Province, BIOTA-observatory at Quaggafontein 478, S 30° 11' 31.0", E 17° 33' 11.1", 11.IX.2002, leg. M. Mennicken No. RSA 147, III (Holotype PREM, Isotype M).
- On cf. *Roepera* sp. South Africa, Northern Cape Province, Richtersveld, BIOTA-observatory at Yellow Dune, S 28° 36' 56.2", E 16° 39' 22.2", 14.IX.2002, leg. M. Mennicken No. RSA 157, III (Paratypes PREM, M).

***Uromyces paulshoekensis* Mennicken, Maier & Oberw. sp. nov. (Figs. 3–5)**

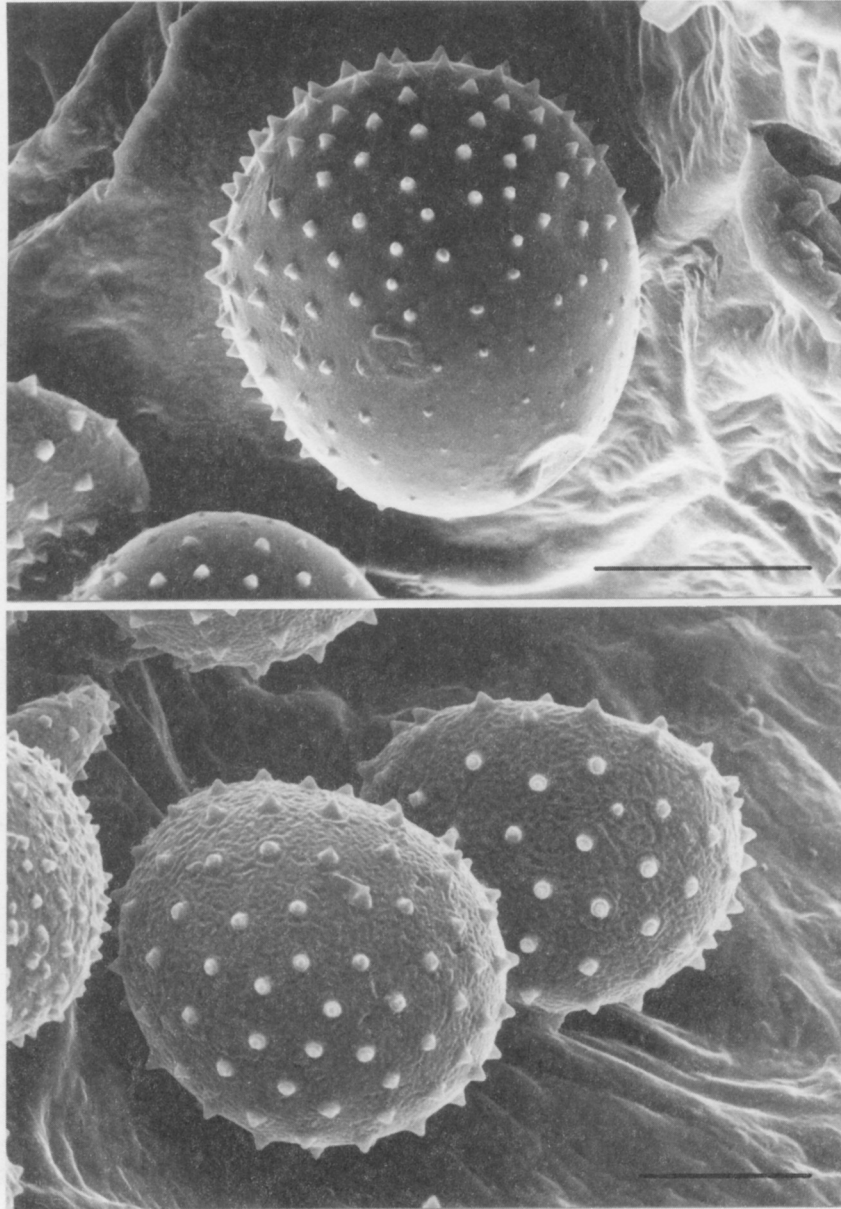
**Pycnia et aecia ignota.** Uredinia amphigena, subepidermalia, usque ad 0.5 mm diam., cinnamomea, mox nuda, pulverulenta. Urediniosporae subgloboideae, ovoideae vel ellipsoideae, 27–38 (–44) x 22–28  $\mu\text{m}$ , pariete supra basim echinulato, 2–3  $\mu\text{m}$  crasso, aureo-fusco vel dilute castaneo, 3–6 poris germinationis dispersis. Telia amphigena, subepidermalia, usque ad 0.8 mm diam., atro-brunnea vel nigra, mox nuda, pulverulenta. Teliosporae unicellulares, globoideae, subgloboideae vel ellipsoideae, bilaminatae, strato exteriori dilute aureo vel hyalino, usque ad 3  $\mu\text{m}$  crasso, breviter echinulato, strato interiore castaneo, lateraliter 2–4.5  $\mu\text{m}$  crasso, apicaliter 3.5–5  $\mu\text{m}$  crasso, 27–36 x 20–27  $\mu\text{m}$ , poro germinationis apicali, pedicello hyalino, brevi, subinde usque ad 50  $\mu\text{m}$ . In foliis cf. *Roeperae foetidae* (Schrad. & J.C. Wendl.) Beier & Thulin, *Zygophyllaceae*.



**Fig. 3.** *Uromyces paulshoekensis* on cf. *Roepera foetida*. Uredinio- and teliospores (Holotype RSA 133). Scale bar = 10  $\mu\text{m}$ .

**Pycnia and aecia unknown.**

Uredinia amphigenous on leaves, subepidermal, separate or scattered, minute, round, up to 0.5 mm wide, cinnamon-brown, on slightly paler and yellowed leaf spots, early exposed, pulverulent, surrounded by the torn epidermis. Urediniospores subglobose, ovoid to ellipsoid, borne singly on pedicels, 27–38 (–44) x 22–28  $\mu\text{m}$ , echinulate, echination stronger pronounced at the apex, sometimes absent at the base, spore wall uniformly about 2–3  $\mu\text{m}$  thick, yellowish-brown to pale chestnut-brown, germ pores



**Fig. 4.** *Uromyces paulshoekensis* on cf. *Roepera foetida*. Surface of a urediniospore (Holotype RSA 133). SEM. Scale bar = 10  $\mu$ m. **Fig. 5.** *Uromyces paulshoekensis* on cf. *Roepera foetida*. Surface of two teliospores (Holotype RSA 133). SEM. Scale bar – 10  $\mu$ m.

inconspicuous, 3 to 6, scattered, often irregularly in outline, with hyaline papillae that are weakly developed. Telia amphigenous on leaves, subepidermal, (partly) developing from the uredinia, separate or scattered, round, up to 0.8 mm wide, dark chocolate-brown to black, on slightly paler and yellowed leaf spots, early exposed, pulverulent, surrounded by the torn epidermis. Teliospores unicellular, globoid, subgloboid to ellipsoid, rounded above and below, bilaminate, outer layer pale yellowish to hyaline, up to 3  $\mu\text{m}$  thick, coarsely echinulate, inner layer chestnut-brown, about 2–4.5  $\mu\text{m}$  thick at the sides, about 3.5–5  $\mu\text{m}$  thick at the apex, smooth, size of spores (without hyaline outer layer) 27–36 x 20–27  $\mu\text{m}$ , germ pore apical, pedicel mostly persistent, very short, occasionally up to 50  $\mu\text{m}$  long, thin-walled, hyaline.

On the leaves of cf. *Roepera foetida*, (recorded as *Zygothellium* cf. *meyeri* Sond. which is according to Van Zyl (2000) (Beier, pers. comm.) synonymous to *Roepera foetida* (Schrad. & J.C. Wendl.) Beier & Thulin), *Zygothellaceae*.

**Etymology.** Named after the neighbouring community in South Africa, Paulshoek.

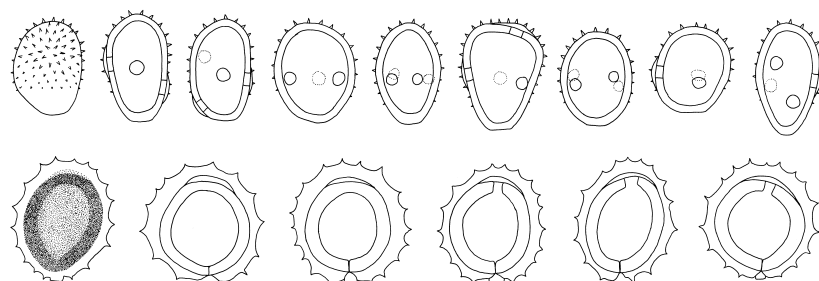
**Specimen examined:**

- On cf. *Roepera foetida*. South Africa, Northern Cape Province, BIOTA-observatory at Leliefontein 624, S 30° 23' 22.4", E 18° 16' 50.2", 10.IX.2002, leg. M. Mennicken No. RSA 133, II III (Holotype PREM, Isotype M).

***Uromyces trollipi* Kalchbr. & MacOwan in Kalchbrenner (1882): 21. (Fig. 6)**

Type on *Roepera foetida* (Schrad. & J.C. Wendl.) Beier & Thulin (= *Zygothellium foetidum* Schrad. & J.C. Wendl.) (as *Hypophyllum foetidum* Schrad.). South Africa, Kagaberg, near Bedford, leg. Stud. Trollip, No. 1404 (K(M) 116415).

Syn. *Dichlamys trollipi* (Kalchbr. & MacOwan) Syd. & P. Syd. (Sydow & Sydow 1919): 105.



**Fig. 6.** *Uromyces trollipi* on *Roepera foetida*. Uredinio- and teliospores (Type K(M) 116415). Scale bar = 10  $\mu\text{m}$ .

**Pycnia and aecia unknown.**

Uredinia amphigenous on leaves, separate, scattered or in irregular groups, minute,  $\pm$  roundish, up to 0.7 mm wide, cinnamon-brown, on slightly paler leaf spots, early exposed, pulverulent, surrounded by the torn epidermis. Urediniospores subgloboid, ovoid, ellipsoid to oblong, often somewhat angular, borne singly on pedicels, 30–37 x 20–29  $\mu\text{m}$ , echinulate, echinulation stronger pronounced at the apex, absent at the base,

spore wall uniformly about 2–2.5  $\mu\text{m}$  thick, yellowish-brown, germ pores conspicuous, 3 to 4, mostly  $\pm$  equatorial, occasionally scattered, with hyaline papillae that are weakly developed.

Telia amphigenous on leaves, (partly) developing from the uredinia, separate or scattered, round, up to 0.7 mm wide, dark chocolate-brown to black, on slightly paler leaf spots, early exposed, compact to cushion-like, surrounded by the torn epidermis. Teliospores unicellular, globoid, subgloboid to ovoid, rounded above and below, bilaminate, outer layer hyaline, coarsely echinulate, inner layer chestnut-brown, about 3–5  $\mu\text{m}$  thick at the sides, about 3–6  $\mu\text{m}$  thick at the apex, size of spores (without hyaline outer layer) (31–) 33–39 (–43)  $\times$  24–32  $\mu\text{m}$ , germ pore apical, with yellow papilla that is weakly developed, pedicel mostly persistent, very short, thin-walled, hyaline.

**Specimen examined:**

- On *Roepera foetida* (as *Hypophyllum foetidum* Schrad.). South Africa, Kagaberg, near Bedford, leg. Stud. Trolip No. 1404, II III (Type K(M) 116415).

The bilaminate character of the spore wall of the teliospores is cited in all available descriptions of *Uromyces trollipi* (Kalchbrenner 1882; Winter 1884; Sydow & Sydow 1919; Doidge 1927; Thirumalachar 1951). The conspicuous echinulation of the outer layer of the teliospores, which is also visible in water, in heated lactophenol, or in air, is not yet mentioned in literature. Doidge (1927) and Winter (1884) described the surface of the teliospores as verrucous. Sydow & Sydow (1919) characterized the outer layer as striped or as ridged. In the diagnosis (Kalchbrenner 1882) and in Thirumalachar (1951) no properties of the teliospore surface were mentioned.

***Uredo augeae* Pole-Evans (Pole Evans 1915): 115.**

Type on *Augea capensis* Thunb., Namibia, Lüderitzbucht, XI.1912, leg. H. H. W. Pearson No. 8029 (Pole Evans No. 8409).

Syn. *Uredo augeae* Syd. & P. Syd. (Sydow & Sydow 1916): 259. Type on *Augea capensis*. Namibia, Lüderitzbucht, 1913, leg. A. Engler.

We have not seen this rust fungus. The description is adapted from Doidge (1927):

“Sori amphigenous, not on leaf spots, scattered or arranged in circles, often sparsely and evenly covering the whole leaf surface, round, 0.5–1.5 mm. diam., long covered by the blistered epidermis, then surrounded by torn epidermis, chestnut brown. Spores subglobose, ellipsoid or ovoid, often more or less angular, yellow-brown to brown, 23–34  $\times$  18–25  $\mu$ ; epispore 2.5–3  $\mu$  thick, closely and minutely verruculose-echinulate, and with 6–8 scattered germ pores.”

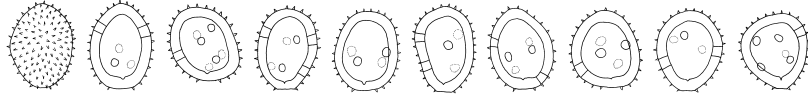
***Uredo zygophyllina* (Jacz.) Sacc. in Saccardo (1895): 223. (Fig. 7)**

Syn. *Uredo zygophylli* Jacz. non Henn. (De Jacewski 1893): 47. Type on *Tetraena cornuta* (Coss.) Beier & Thulin (= *Zygophyllum cornutum* Coss.). Algeria, Oued Biskra.

Pycnia, aecia, and telia unknown.

Uredinia amphigenous on leaves, subepidermal, separate, scattered, or arranged in concentric groups up to 3 mm wide, single sori round or ellipsoid, up to 1.5 mm wide, chocolate-brown, without leaf spots surrounding uredinia, early exposed, pulverulent, surrounded by the torn epidermis. Urediniospores globoid, subgloboid to ellipsoid, born

singly on pedicels, 24–36 x 20–27 µm, coarsely echinulate, spore wall uniformly about 2.5–4 µm thick, yellowish-brown to pale chestnut-brown, germ pores inconspicuous 4 to 7, scattered, often without papillae, but with cuneiform lucency of the spore wall.



**Fig. 7.** *Uredo zygophyllina* on *Tetraena prismatocarpa*. Urediniospores (RSA 163). Scale bar = 10 µm.

#### Specimens examined:

- On *Tetraena cornuta*. Algeria, Biskra near Hammâm Salakin, IV.1901, leg. G. Schweinfurth, Vestergren Micromycetes rariores selecti No. 572, II (B 70 0007282).
- On *Tetraena prismatocarpa* (Sond.) Beier & Thulin (= *Zygophyllum prismatocarpum* Sond.) South Africa, Northern Cape Province, Richtersveld National Park, BIOTA-observatory at Koeroegapvlakte, S 28° 13' 47.2'', E 17° 01' 49.2'', 15.IX.2002, leg. M. Mennicken No. RSA 163, II (KSAN, PREM).

Sydow & Sydow (1924: 466) erroneously regarded *Uredo zygophylli* Henn. and *Uredo zygophyllina* (Jacz.) Sacc. as synonyms, although Saccardo in the diagnosis and Hennings (1901) observed some differences between both the rust fungi. As far as could be established *Uredo zygophyllina* is new to the rust flora of South Africa. *Tetraena prismatocarpa* seems to be a new host plant of *Uredo zygophyllina*.

In Table 1 a summary of the most important characters of the six known African rust species on *Zygophylloideae* is given.

We have not seen *Uromyces vesiculosus* G. Winter (Winter 1885: 22), which is known from several *Roepera* species (= *Zygophyllum*) in Australia (Shivas 1989; McAlpine 1906). According to McAlpine (1906) *Uromyces vesiculosus* has “densely warted, even prickly”, thin-walled urediniospores “with 3 to 5 equatorial germ pores on one face, 26–35 x 19–24 µ, average 28 x 20 µ”. The teliospores are “globose, elliptic, ovate or pear-shaped, thickened at the apex, rounded or with a broad apiculus more or less shortly conical, 21 µ diam., or 23–31 x 17–22 µ, average 25 x 20 µ; episporium thick, smooth, dark brown when mature; pedicel long, thick, persistent, may be flexuous, pale olivaceous, up to 150 µ”. Thus, *Uromyces vesiculosus* differs markedly from all cited *Uromyces* species collected in Africa in having long persistent pedicels and especially in the absence of bilaminar teliospore cell walls. *Uromyces vesiculosus* differs from both of the *Uredo* species from Africa in having urediniospores with equatorial germ pores and thin-walled spore walls.

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**Table 1.** Schedule of characters of the rust species on *Zygophylloideae* (*Zygophyllaceae*) from Africa.  
\* Formerly known as *Zygophyllum*. <sup>1</sup> According to DoIDGE 1927.

Rust species	Host genus	Urediniospores						Teliospores				
		measurement µm	number	arrangement	µm	spore wall	measurement µm	spore wall	lateral µm	apical µm	exo-spore spore wall	thickness
<i>Uromyces dinteri</i>	<i>Tetraena</i> *	31-40(42) x (22)24-36	6 to 9	scattered	2.5-4(5)	± uniform	(31)34-44 x 30-42	± uniform	5-8	5-8	± uniform	± uniform
<i>Uromyces namaqualandus</i>	<i>Roepera</i> *	-	-	-	-	-	31-49 x 23-32	thinner at the apex	2-5	4-10	thinner at the apex	-
<i>Uromyces paulshoekensis</i>	cf. <i>Roepera</i> *	27-38(44) x 22-28	3 to 6	scattered	2-3	apically stronger pronounced, basally ± absent	27-36 x 20-27	thinner at the apex	2-4.5	3.5-5	thinner at the apex	-
<i>Uromyces trollipi</i>	<i>Roepera</i> *	30-37 x 20-29	3 to 4	± equatorial	2-2.5	apically stronger pronounced, basally absent	36-60 x 17-31(34)	± uniform	3-5	3-6	± uniform	-
<i>Uredo augeae</i> <sup>1</sup>	<i>Augea</i>	23-34 x 18-25	6 to 8	scattered	2.5-3	?	-	-	-	-	-	-
<i>Uredo zygophyllina</i>	<i>Tetraena</i> *	24-36 x 20-27	4 to 7	scattered	2.5-4	± uniform	-	-	-	-	-	-

Education and Research in Germany through the sourcing of the BIOTA (Biodiversity Monitoring Transect Analyses) Southern Africa project. We thank the Northern Cape Department of Nature and Environmental Conservation and the Conservation Services of the South African National Parks for issuing research permits and all land owners and decision makers for the permission to enter the BIOTA-observatories and to collect rust-infected plants. The botanical BIOTA working group of Norbert Jürgens from the University of Hamburg is gratefully acknowledged for help in determination of the host plants.

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