Revision of the *Andrena* (*Micrandrena*) *tiaretta* group: redescription of *A. tiaretta* WARNCKE, 1974 and description of two new species (*A. cyrenaica* nov.sp. and *A. orientalis* nov.sp.) demarcating the central and eastern part of the range (Libya, Israel, Syria)

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A b s t r a c t : Within the scope of a redescription of the *Andrena* (*Micrandrena*) *wollastoni* complex (Madeira Archipelago, Canary Islands) it was necessary to examine the taxonomical status of *A. tiaretta* s.l., the hypothesised continental ancestor. On the basis of the hypothesis that a colonisation took place by individuals of the western populations of *A. tiaretta* s.l. the question arose whether these populations differ morphologically from the eastern ones (especially from Israel and Syria). Within a qualitative morphological analysis (colour of integument, extent and colour of pubescence, different structural characters) plus a morphometric analysis of 18 characters in females and 16 characters in males (calculation of Pearson product-moment correlation coefficient and multivariate ratio analysis [MRA] as a tool set including shape PCA, LDA ratio extractor and allometry ratio spectrum), 20♀♀ and 23♂♂ of *A. tiaretta* s.l. were analysed in detail, including the holotype and all existing paratypes (15♀♀, 15♂♂). Holotype and paratypes selected by WARNCKE (1974) cover specimens from Morocco, Algeria, Libya, Egypt, Israel and Syria. Additionally specimens from Spain and Iran were analysed.

The differential diagnosis of specimens with western and eastern distribution had shown morphological differences in females and males primarily concerning colour of integument and pubescence. The best differentiation of the two taxa in females could be detected using the characters BL, CL, FVL, FVW, HL, HW, MSW, MTW, POD, PSL, WL for the MRA. In the shape PCA these 11 parameters demonstrate the highest eigenvalues of first axis (46.0 %) in combination with the best differentiation and compactness of western and eastern scatterplot groups. The LDA ratio extractor produced the HW/POD and FVL/MTW ratios as the most separating ratios in females. The results were slightly influenced by an allometric structure of the specimens.

In the case of males there are also differentiations in the scatterplot of first against second shape PCA (using the characters: Fl1, FL3, HL, HW, LPW, MSW, MTW, POD, PSL, WL). In the shape PCA these 10 parameters demonstrate the highest eigenvalues of first axis (46.4 %) in combination with the best differentiation and compactness of both scatterplot groups. The LDA ratio extractor produced the FL1/POD and LPW/WL ratios as the most separating in males. The results were also slightly influenced by an allometric structure of the specimens.

The scatterplots of two most discriminating ratios (females and males) reveal a clear discrimination between *A. tiaretta* s.str. (Spain, Morocco, Algeria) and *A. orientalis* nov.sp. (Israel, Syria). In male genital morphology both species are distinguishable.

Concerning morphological characteristics in the genital morphology of males, the

specimens from Libya (all paratypes of *A. tiaretta* s.l., 1♀ and 2♂♂) are recognised as a species of its own: *A. cyrenaica* nov.sp. Due to the small specimen number the morphometric analysis shows only in the case of one male clear differences in contrast to *A. tiaretta* s.str. and *A. orientalis* nov.sp.

One specimen from Egypt (with unclear provenance) determinated by Warncke as *A. tiaretta* differs slightly in morphology and is characterised by an edge position in morphometrics. The single specimen from Iran (locality Rudbar) shows many differences (qualitative morphological and morphometric characteristics) compared to all other specimens. Actually, due to only few specimens, a further classification is not possible.

K e y   w o r d s : Hymenoptera, Andrenidae, qualitative morphological analysis, morphometrics, multivariate ratio analysis, Palaearctic, biogeographical differentiation.

Introduction

WARNCKE (1974) described a new *Micrandrena* species from Morocco, Algeria, Libya and Egypt: *Andrena tiaretta*. According to his conception this should be the same taxon characterised many years ago by SAUNDERS (1909) as *A. mu* (3♂♂ from Algiers). SAUNDERS (1909) did not describe this taxon as a new species, because he had neither enough specimens nor the opportunity to elaborate a revision of the *Micrandrena* group of North Africa. Therefore he indicated the different morphological forms with Greek letters in the epitheton. A comparison of the description of SAUNDERS (1909) with males of *A. tiaretta* confirms the conception of WARNCKE (1974), although only few morphological features were considered.

In the 'Biology Centre of the Upper Austrian Provincial Museum Linz' the holotype of *A. tiaretta* (male) is deposited, collected in Tiaret/Algeria (also named as Tihert, Tahert or Tehert) with no collecting date or collector name. Tiaret is the capital of the homonymous province Tiaret and served as species epitheton. In the Warncke collection of Linz there are in addition to this holotype 14♀♀ and 15♂♂ classified by Warncke as paratypes (BLANK & KRAUS 1994). The distribution area of the whole set of specimens (20♀♀, 23♂♂), deposited in the Warncke collection, includes the large area from southern Spain, Morocco, Algeria, Libya, Egypt, Israel, to western Syria and (with one specimen) to northern Iran. The holotype and the paratypes selected by WARNCKE (1974), cover specimens from Morocco, Algeria, Libya, Egypt, Israel and Syria.

All specimens were determined by Warncke and characterised by a determination label. Distribution maps were published by GUSENLEITNER & SCHWARZ (2002) concerning the whole distribution area, and for Spain by DARDÓN PERALTA (2010). DARDÓN PERALTA (2010) and DARDÓN et al. (2014) give a detailed redescription of *A. tiaretta* analysing the holotype and the paratypes from the Warncke collection und further specimens from Spain. In this comprehensive characterisation important morphological features were described and also some differences between specimens of different provenances were conducted. A further differentiation (e.g. into subspecies) was not discussed.

Recently KRATOCHWIL & SCHEUCHL (2013) documented that *A. wollastoni* (Canary Islands, Madeira) and *A. dourada* (Porto Santo; formerly related to *A. wollastoni*) share different morphological similarities with *A. tiaretta* WARNCKE, 1974. This is especially true for genitalia morphology of males but also for other morphological features. We

hypothesised that *A. tiaretta* is probably the continental ancestor of all taxa of the *A. wollastoni* complex including *A. dourada* (KRATOCHWIL & SCHEUCHL 2013, KRATOCHWIL 2014).

Within the scope of a redescription of the subspecies of *A. wollastoni* (*A. w. wollastoni* COCKERELL, 1922 [Madeira], *A. w. acuta* WARNCKE, 1968 [Tenerife, La Palma], *A. w. gomerensis* WARNCKE, 1993 [El Hierro, La Gomera] and *A. w. catula* WARNCKE, 1968 [Gran Canaria], including the related *A. lineolata* WARNCKE, 1968 [Tenerife]), it was necessary to examine morphological characters of *A. tiaretta* in detail, the hypothesised ancestor of this taxonomically related group. In view of the hypothesis that the Madeira Archipelago and the Canary Islands were colonised by individuals of the western populations of *A. tiaretta* or the ancestor of this species, the question arose whether qualitative and quantitative morphological features are similar between western and eastern populations of *A. tiaretta*.

Already a first short analysis of some specimens by the author suggested that there are qualitative morphological differences between *A. tiaretta* from Spain, Morocco, Algeria on the one hand and specimens from Israel and western Syria on the other hand (e.g. colour of head, flagellum, pars parte tibia, basitarsus, mediotarsi, wings, pterostigma, veins, tergites; pubescence of vertex, mesoscutum, scutellum, metasoma). This raised the obvious possibility that the biogeographical history of *A. tiaretta* populations in this large range is reflected by morphological and taxonomical differentiation, dividing western from eastern populations.

Besides the qualitative morphological characteristics it would be necessary to combine these features with morphometrical data. The main problem was the limited specimen numbers. Specimens of *A. tiaretta* in collections are rare; this is especially true for individuals from Libya, Egypt, Syria or Iran. Most specimens in the Warncke collection are paratypes; therefore a molecular analysis is excluded. But newly developed multivariate morphometric methods (multivariate ratio analysis [MRA] as a tool set including shape PCA, LDA ratio extractor and allometry ratio spectrum) could be a very successful method for further differentiation even if there are only few specimens (BAUR & LEUENBERGER 2011, BAUR et al. 2014)

After initial morphological examinations of the specimens the following hypotheses will be tested:

1. Specimens from Spain, Morocco and Algeria indicate a western taxon.

2. Specimens from Israel and western Syria should be recognised as a separated eastern taxon.

3. Specimens from Libya should indicate an intermediate position.

Material and methods

Specimens

The following specimens (20♀♀ and 23♂♂) of the Warncke collection (Biology Centre of the Upper Austrian Provincial Museum Linz; abbreviation OLML) were analysed (identify number, labels):

<u>Females</u>: OLML 84: label 1: Rudbar, Nordpers., B. v. Bodemeyer 14; label 2: *Andrena* (printed) *tiaretta* WAR., det. Warncke (handwritten); OLML 85: label 1: Israel (printed), Tel Aviv Bg, 10.III.72 (handwritten), leg. Bytisnki-Salz; label 2: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 86: label 1: Israel (printed), Tel Aviv N, 27.3.73 (handwritten), leg. Bytisnki-Salz; label 2: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 87: label 1: Israel (printed), Sederot, 27.2.74 (handwritten), leg. A. Freidberg; label 2: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 88: label 1: Marokko-Fes 31-III-1980, leg. Warncke (printed); label 2: *Andrena tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 89: label 1: Estepona, 1.-11.4.1985, H. Wolf leg. (printed); label 2: *Andrena tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 110: label 1: Paratype (red paper, handwritten); label 2: Tanger (handwritten), Marokko (printed); label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 111: label 1: Paratype (red paper, handwritten); label 2: Sa Cruz-Oran, Algeria, Dr. J. Bequaert (printed); label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 115: label 1: Paratype (red paper, handwritten); label 2: Ramleh Israel (printed); label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 116: label 1: Paratype (red paper, handwritten); label 2: Ramleh Israel (printed); label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 120: label 1: Paratype (red paper, handwritten); label 2: Cyrenaica, Cyrene, 1,800 feet, 2.IV.1954 (printed); reverse side: K. M. Guichard, B. M. 1954-359; label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 121: Paratype (red paper, handwritten); label 2: Algir (handwritten); label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 122: label 1: Paratype (red paper, handwritten); label 2: Forêt de Baïnem, Alger, Dr. J. Bequaert (printed); reverse side: 9.VI.10; label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 126: label 1: Paratype (red paper, handwritten); label 2: Noiseux-Oran, Algeria, Dr. J. Bequaert (printed); reverse side: 19.IV.10; label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 127: label 1: Paratype (red paper, handwritten); label 2: Syrien (printed), 2.5.52 (handwritten), Seidenstücker (printed); reverse side: Damaskus (handwritten); label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 129: label 1: Paratype (red paper, handwritten); label 2: Alger, Dr. J. Bequaert (printed); reverse side: 24.V.10; label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 132: label 1: Paratype (red paper, handwritten); label 2: Ramleh Israel (printed); label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 133: label 1: Paratype (red paper, handwritten); label 2: J&T(?) (blue paper, handwritten); label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 134: label 1: Paratype (red paper, handwritten); label 2: Hadjar, Medina, Febr. 1937 (printed); label 3: Egypt, Min. Agric. (Egypt), coll. Kasim (printed); label 4: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 138: label 1: Paratype (red paper, handwritten); label 2: Ramleh Israel (printed); label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed).

<u>Males</u>: OLML 90: label 1: E Estepona, 1.-11.4.1985, H. Wolf leg. (printed); label 2: *Andrena tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 91: label 1: E Estepona, 1.-11. 4.1985, H. Wolf leg. (printed); label 2: *Andrena tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 92: label 1: Israel (printed) Tel Aviv Bg, 10.III.72 (handwritten), leg. Bytisnki-Salz; label 2: *Andrena* (printed), *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 93: label 1: Spain, Pr. Cadiz, Rio Palmones, b. Algeciras (printed); label 2: 7.4.1985, leg. W. Schacht; label 3: *Andrena tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 94: label 1: Spain, Pr. Cadiz, Rio Palmones, b. Algeciras (printed); label 2: 7.4.1985, leg. W. Schacht; label 3: *Andrena tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 95: label 1: Israel (printed), Tel Aviv Bg, 10.III.72 (handwritten), leg. Bytisnki-Salz; label 2: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 96: label 1: Israel (printed), Sederot, 27.2.74 (handwritten), leg. A. Freidberg; label 2: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 112: label 1: Holo-Typus (red paper, handwritten); label 2: Tiaret (handwritten), Algerien (printed); label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 113: label 1: Paratype (red paper, handwritten); label 2: Tanger (handwritten), Marokko (printed); label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 114: label 1: Paratype (red paper, handwritten); label 2: Tanger (handwritten); Marokko (printed); label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr.

Warncke (printed); OLML 117: label 1: Paratype (red paper, handwritten); label 2: Algeria (printed), 28.3.1890 (handwritten); label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 118: label 1: Paratype (red paper, handwritten); label 2: Tanger (handwritten), Marokko (printed); label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 119: label 1: Paratype (red paper, handwritten); label 2: Süd-(handwritten), Algerien (printed); label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 123: label 1: Paratype (red paper, handwritten); label 2: Tiaret (handwritten), Algerien (printed); label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 124: label 1: Paratype (red paper, handwritten); label 2: Marocco, Fez Dj. Zalagh, 25.3.23 (printed); label 3: *parvula* (handwritten), det. Schulthess 91; label 4: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 125: label 1: Paratype (red paper, handwritten); label 2: Ramleh, Israel (printed); label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 128: label 1: Paratype (red paper, handwritten); label 2: Cyrenaica, Cyrene, 1,800 feet, 26.III.1954 (printed); reverse side: K. M. Guichard, B. M. 1954-359; label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 130: label 1: Paratype (red paper, handwritten); label 2: Birmandreis, Alger, Dr. J. Bequaert (printed); reverse side: 24.III.10; label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 131: label 1: Paratype (red paper, handwritten); label 2: Sa Cruz-Oran, Alger, Dr. J. Bequaert (printed); reverse side: 9.IV.10; label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 135: label 1: Paratype (red paper, handwritten); label 2: Cyrenaica, Cyrene, 1,800 feet, 2.IV.1954 (printed); label 3: K. M. Guichard, B. M. 1954-359; label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 136: label 1: Paratype (red paper, handwritten); label 2: Ramleh Israel (printed); label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 137: label 1: Paratype (red paper, handwritten); label 2: Ramleh Israel (printed); label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed); OLML 139: label 1: Paratype (red paper, handwritten); label 2: Birmandreis, Alger, Dr. J. Bequaert (printed); reverse side: 24.III.10; label 3: *Andrena* (printed) *tiaretta* WAR. (handwritten), det. Dr. Warncke (printed).

Geographical distribution pattern of specimens

The localities of collected specimens from Spain, Morocco and Algeria are relatively equally distributed in an area extending for about 1,200 km (from west to east). Therefore these specimens were pooled for the multivariate treatments. The distance between the Israel specimens (Tel Aviv, Ramla, Sederot) and Damascus (Syria) is only about 250 km. Specimens from each of these countries were also pooled. The distance between the distribution points in eastern Algeria to the sampling locality in Libya is more than 1,700 km, without any detection of *A. tiaretta* specimens in between. Following the west-east line segment of the distribution points from Libya to northern Iran the following distances can be noted: Libya to Egypt: about 900 km; Egypt to Israel: about 500 km; Damascus (Syria) to Rudbar (northern Iran): more than 1,200 km.

Provenances

In the following some further comments are given, including problems of the label description and identification:

OLML 84: The collecting year is 1914; OLML 85, 92, 95: The meaning of 'Bg' is unclear; OLML 86: Tel Aviv N, abbreviation for Tel Aviv Nord; OLML 88: Fes = Fès or Fez; OLML 112-114: collector name missing; OLML 115, 125, 132, 138: Ramleh (dialect) = Ramla, without collector name; OLML 117-119: label without distinct locality and without collector name; OLML 121: without collector name; OLML 126, 130: Oran is the major city on the northwestern Mediterranean coast of Algeria and the capital

of the Oran Province. There are two possibilities to interpret the locality 'Noiseux': 'Place de Noiseux' in Oran City or the spring 'source Noiseux' about 2 km southeast of Oran. OLML 130: today 'Bir Mourad Raïs', formerly in French 'Birmendreïs'; OLML 133: The meaning of 'J&T' is unclear, provenance is unclear, collector name is missing; OLML 134: The undoubted provenance of this specimen is Egypt (label 3), but difficulties are caused by the name 'Hedjaz Medina'. 'Hedjaz' = 'hejaz' = 'Al-Hejaz' = 'Hijaz' is a region in the west of present-day Saudia-Arabia, bordered in the West by the Red Sea and in the north by the Jordan river, in the east by Najd and in the south by Asir with the main cities Jeddah, Mecca and Medina. In Egypt there is another village in context with the name 'Medina': 'Deir el-Medina', an ancient Egyptian village located on the west bank of the River Nile at Thebes. WARNCKE (1974), who selected this single specimen from Egypt as paratype, described the habitat characteristic as follows: 'stream oasis of the Nile, Egypt'. WARNCKE (l.c.) had an excellent knowledge of the geographic localities of these areas (he visited all countries of North Africa; see KRAUS & BLANK 1994), therefore it is unlikely that he made a mistake. In the distribution map of *A. tiaretta* GUSENLEITNER & SCHWARZ (2002) the distribution point for this specimen is placed near the Nile delta. The distance to Deir el-Medina is about 450 km. Actually it is not possible to solve this problem.

Collectors

Analysing the labels, remarkable personalities are mentioned as collectors.

OLML 84: Wilhelm Eduard Bodo von Bodemeyer (1883-1929) was a travel-book writer and entomologist (specialist for Carabidae). He absolved several collecting trips to Asia Minor (1911), East Siberia (1912), Tunisia, Oasis Gafra (1913), Iran, Elbur Mountains (1914); see BODO von BODEMEYER (1927), SCHNELL (1929), ANONYMUS (1939).

OLML 85, 86, 92: Hanan Bytinski-Salz (1903-1986) was Professor of Zoology at Tel-Aviv University, Israel. He described 168 new species from orders such as Lepidoptera, Hymenoptera, Coleoptera and Homoptera. He published among others papers dealing with the Vespoidea of Israel (1971 coauthored with J. Gusenleitner, Linz) and with the Halictidae of Israel (1974, coauthored with A.W. Ebmer, Linz); see FREIDBERG & MIENIS (2007).

OLML 111: Joseph Charles Bequaert (1886-1982), Professor of Zoology of the Museum of Comparative Zoology, Harvard, was an entomologist but also very competent in other fields of biology (e.g. Botany, Malacology); see CARPENTER (1982), CLENCH (1982).

OLML 127: Gustav Seidenstücker (1912-1998) was a famous Heteropterologist from Nuremberg (Germany); he described new species of Heteroptera e.g. from Syria; see KOTHE et al. (2004).

Phenology

There is an open question whether *A. tiaretta* establishes two generations per year or not. Eight females were collected between end of February until mid-April; three females from the beginning of May to the end of May. There are no phenological differences between the localities. Our data analysis concerning qualitative morphology or morphometrics did not show impact of phenology. The 13 analysed males reflect a flight time from end of February until mid-April.

Character selection and documentation

The following morphological and morphometric features were tested (terms according to MICHENER 2007, TADAUCHI & XU 1995, ARIANA et al. 2009, KRATOCHWIL & SCHEUCHL 2013, KRATOCHWIL et al. 2014):

Qualitative morphology: *Structure* of vertex surface, eye inner margin, face above antennal fossae, interrugal space, clypeus, labrum process, mesoscutum, scutellum, propodeum; *colour* of head, flagellum, mandible, thorax, tibia, basitarsus, mediotarsi, tergites; *pubescence* (mainly colour) of head (clypeus, paraocular area, scapus and antennal socket, genal area, facial fovea), vertex, mesoscutum, scutellum, mesepisternum, propodeal corbiculae, trochanteral and femoral flocculus, tibial scopa and tergites.

Some proofed morphological features characterised by DARDÓN PERALTA (2010) and DARDÓN et al. (2014) are added in the species description. Dissents according WARNCKE (1971) or DARDÓN PERALTA (2010) are mentioned.

Morphometrics: For the MRA the following characters were chosen (in alphabetical order; in brackets abbreviation and used magnification of measurement): *Body length* (BL, 16.25x): from antennal base to tip of pygidium; *clypeus length* (CL, 100x); *facial fovea maximal length* (FVL, 100x); *facial fovea maximal width* (FVW, 100x); *flagellomeres length* 1-3 (FL1-3, 100x): measured on ventral surfaces of flagellomeres when antenna stretched forward; *head length* (HL, 40x): from top of vertex to lower margin of clypeus excluding process of labrum; *head width* (HW, 40x); *labrum process width* (apical process width) at the top (LPW, 100x); *mesosomal width* (MSW, 40x): between outer rims of tegulae; *metasomal width* (MTW, 40x): maximum width of terga from dorsal view; *ocelloccipital distance* (OCD, 62.5x); *ocellocular distance* (OOD, 62.5x); *postocular distance* (POD, 62.5x); *propodeum basal area length* (PBAL, 100x); *pterostigma length* (PSL, 100x); *wing length* (WL, 16.25x): length of forewing including tegula.

Furthermore, indices/ratios were calculated (F1:F2:F3, HL/HW, OCD:OOD:POD) and puncture diameter (PD, in µm) of different body parts were specified.

The morphological and morphometric studies were carried out with a stereo microscope (Wild M3Z modular stereomicroscope, with a 25x eyepiece 16.25x, 40x, 62.5x and 100x); for measurements a micrometer eyepiece of Wild was used. The macro photographs were produced in the 'Biology Centre of the Upper Austrian Provincial Museum Linz' (Lisa Haitzinger) with a multizoom microscope from Nikon (Multizoom AZ100M) equipped with motorised zoom and motorised focusing. The combination of computer and camera produces accurate and efficient image acquisition.

Morphometric analysis

Pearson product-moment correlation coefficients were calculated for all character measurements with the function 'cor()' in R (R CORE TEAM 2013; v3.0.2) using default settings. The correlation table was ordered according the increasing number of significant correlations between characters (two-tailed test; $p < 0.10$).

For morphometric analysis multivariate ratio analysis (MRA) of BAUR & LEUENBERGER (2011) was applied. MRA offers several tools related to principal component analysis (PCA) and linear discriminant analysis (LDA) (see also BAUR et al. 2014 for an applica-

tion of those tools to some other Hymenoptera taxa). A shape PCA was calculated and shape PC1 plotted against shape PC2. Characters with lower correlation were excluded until the scatterplot reached the highest eigenvalue (the absolute value of variance explained) in the first axis and clearest compactness of scatterplots within differentiating groups. Shape PC1 was also plotted against isometric (the geometric mean of all variables), in order to estimate the amount of allometry in the data. Further graphical tools were implemented, the PCA ratio spectrum and the allometry ratio spectrum. Additionally the LDA ratio extractor was used to extract the four best ratios of morphometric features. The two best ratios were plotted. The R language was applied for data analysis (R Core Team, 2013; v3.0.2) with slightly modified versions of the R-scripts provided by BAUR et al. (2014, 'Supplementary material'). Scatterplots were generated with the package 'ggplot2' (WICKHAM 2009). The scatterplots were optimised with CorelDRAW Graphics Suite 11.

Distribution map

Using the 'OpenStreetMap' (www.openstreetmap.org/copyright) as base map the distribution data were compiled with QGIS version 2.8.1 Wien (www.qgis.org).

Results

1. Qualitative analysis of females

Fig. 1-3 show three paratypes of *Andrena tiaretta* s.l. selected by Warncke and collected in Tanger (Morokko), Ramla (Israel) and Cyrene (Libya).

Andrena tiaretta s.str. (Spain, Morocco, Algeria)

C o l o u r . Head (Fig. 4a): black integument (one specimen from Algeria with brown coloured integument); scapus black/brown; flagellomeres 1 and 2 as a rule darker than flagellomeres 3-10, flagellomeres (1, 2) 3-10: upper side brown, lower side light brown (one specimen from Algeria light brown flagellomeres); mandible black with a reddish tip. Mesosoma (Fig. 4b): black; femur, tibia and basitarsus black (dark brown) (Fig. 7a) (two specimens from Algeria brown to reddish-brown); mediotarsi pars parte reddish-brown (two specimens from Algeria reddish-brown); wings light toned, veins in most cases reddish-brown (Fig. 1a) (two specimens from Algeria yellowish), differing to DARDÓN et al. (2014): 'pale brown'; pterostigma reddish-brown marginated, in the centre reddish or reddish-yellowish (Fig. 1a) (two specimens from Algeria yellowish). Metasoma (Fig. 7b): T1-4 black, with black to dark reddish-brown depression zone (one specimen from Algeria with reddish brown depression zone); T5 translucent, reddish-brown.

P u b e s c e n c e . Head (Fig. 4a): frontview: paraocular area with whitish-yellowish hairs from malar area, overtopping line of antennal socket, hair length different; sideview: paraocular area with whitish-yellowish hairs, no brownish hairs between antennal socket and fovea facialis (differing to DARDÓN et al. 2014: 'In some paratypes, scarce brown hairs are present…'); clypeus with whitish-yellowish hairs, but not with dark

hairs; scapus with dorsal longer, ventral shorter whitish-yellowish hairs; genal area with whitish, in two cases (two specimens from Algeria) with whitish-yellowish hairs, upper zone of genal area with brownish hairs; facial fovea with velvety appearance of whitish iridescent pubescence, upper zone with reddish-brown hairs (one specimen from Spain, one from Morocco with whitish-reddish-brown hairs); vertex with some long whitish-yellowish and slightly reddish hairs. Mesosoma (Fig. 4b): mesoscutum and scutellum with only some shorter whitish-yellowish hairs, with yellowish-reddish hairs laterally; mesepisternum with longer whitish-yellowish hairs; propodeal corbicula with some whitish hairs, some hairs in the centre; trochanteral and femoral flocculus well developed with whitish hairs; tibial scopa with whitish hairs dorsal and ventral, and in the rule some reddish hairs dorsobasal (Fig. 7a); Metasoma (Fig. 7b): T2 and T3 (T4) with lateral fragmentary hair bands; T4 hair rows between tergite and tergite depression; T5: yellowish(-reddish) in the center, yellowish-white marginally; T6: reddish-brown hairs (one specimen from Morocco with reddish hairs).

S t r u c t u r e . Head (Fig. 4a): vertex surface structure with granulate punctures (rough microsculpture); face above antennal fossae (frons) with longitudinal rugulae well devel-oped, interrugal space shiny and impunctate; inner eye margin converging weakly; clypeus more or less convex with central area flattened, slightly hammer-blow-like microsculpture, not really dull but slightly shiny, chagreened at the base, without or with fragmented impunctate median line, clearly punctured (basal area: 14 µm, apical area: [14] 28 µm), punctures more or less scattered in the centre (according to WARNCKE 1974: 'totally chagreened, dull, punctures uniformly distributed'; according to DARDÓN et al. 2014: 'dull microsculpture, without obvious punctures'), labrum process trapezoid-liguliform; genal area with a distinct microsculpture with striated structures (small longitudinal rugulae) in the apical half; facial fovea narrowed at its lower zone, the top two times wider than the lower zone. Mesosoma (Fig. 4b): pronotum with transverse shagreened microsculpture; mesoscutum hammer-blow-like microsculpture, not really dull but rather shiny, distinctly punctured (PD = 0.14-0.28 µm), interspaces between punctures predominantly two or three puncture diameters, in front chagreened (according to WARNCKE 1974: 'totally chagreened, dull, finely punctured'; according to DARDÓN et al. 2014: 'dull microsculpture, shallow punctures'), with developed parapsidal lines; scutellum similar to scutum but not chagreened in front; metanotum rough microsculp-ture, laterally with punctures (according to DARDÓN et al. 2014: 'unpunctured'); propo-deum: clearly granular and rugose structure, in the centre and in the dorsolateral area, long basal lamina, no lateral boundary line. Mesepisternum with a shiny microsculpture. Metasoma (Fig. 7b): hammer-blow-like microstructure, not really dull but rather shiny (according to DARDÓN et al. 2014: 'dull microstructure'), T1 with very scarcely distri-buted flattened punctures (according to DARDÓN et al. 2014: 'unpunctured'), T2-T4 clearly but very scattered punctured, punctures especially lateral, punctures not only restricted to the side in contrast to the description of DARDÓN et al. (2014) (PD = 0.14-0.28 µm), posterior depression of (T1) T2 not well marked (but in specimens of Spain much more developed), posterior depression of T3-T4 marked well. The depression grade of the tergites differs between T2, T3 and T4 (range 0.39 to 0.47 times the length of the terga (DARDÓN et al. 2014: 0.4 times). The depression zones are not clearly punctured.

***Andrena orientalis* nov.sp. (Israel, Syria): differential diagnosis to *A. tiaretta* s.str.**

The following features of the specimens from Israel and western Syria are unlike those of the specimens from Spain, Morocco and Algeria (*A. tiaretta* s.str.):

C o l o u r . Head (Fig. 5a): brown, in some cases black (*A. tiaretta* s.str: all black); flagellomeres 3-10: without exception light brown (*A. tiaretta* s.str.: dorsal brown, ventral lighter brown); mandible black with a reddish tip or totally reddish (*A. tiaretta* s.str.: always black with a reddish tip). Mesosoma (Fig. 5b): femur, tibia and basitarsus brown/reddish-brown or totally reddish-brown (*A. tiaretta* s.str: black, brown only pars parte reddish-brown); mediotarsi without exception totally reddish-brown (Fig. 8a) (*A. tiaretta* s.str.: only pars parte reddish brown); wings light toned, very light toned or not toned; ptersostigma yellowish-reddish marginated, in the centre yellowish, veins reddish (Fig. 2a) (*A. tiaretta* s.str.: in all cases light toned; pterostigma reddish-brown marginated, in the centre reddish or reddish-yellowish [pars parte yellowish] and veins reddish). Metasoma (Fig. 8b): T1-4 black-brown, always with reddish-brown depression zone (*A. tiaretta* s.str.: black with black to dark reddish-brown depression zone). T1-T4 not clearly punctured.

P u b e s c e n c e . Head (Fig. 5a): upper zone of genal area in all cases without brownish hairs (*A. tiaretta* s.str.: with brownish hairs); facial fovea in all cases with whitish hairs (*A. tiaretta* s.str.: upper zone with reddish-brown hairs); vertex with some long whitish-yellowish hairs but no yellowish-reddish hairs (*A. tiaretta* s.str.: all specimens with whitish-yellowish and slightly reddish hairs). Mesosoma (Fig. 5b): mesoscutum and scutellum without yellowish-reddish hairs laterally; (*A. tiaretta* s.str.: with yellowish-reddish hairs laterally); tibial scopa without exception with whitish hairs dorsal and ventral (*A. tiaretta* s.str.: pars parte dorsobasal with reddish hairs).

S t r u c t u r e . No differences to *A. tiaretta* s.str.

***Andrena cyrenaica* nov.sp. (Libya): differential diagnosis to *A. tiaretta* s.str. and *A. orientalis* nov.sp.**

The males of the specimens of Libya show in genital morphology evident differences to *A. tiaretta* s.str. and *A. orientalis* nov.sp., therefore the morphological features of the female (only one specimen!) are presented, and differences to both other taxa are pointed out. It is necessary to prove the intrapopulation variance of these morphological features in future if more female specimens are available.

The following features of the specimens from Libya differ from those of the specimens from Spain, Morocco, Algeria (*A. tiaretta* s.str.) and of the specimens from Israel and western Syria (*A. orientalis* nov.sp.):

C o l o u r . Head (Fig. 6a): brown in contrast to *A. tiaretta* s.str. (black) and *A. orientalis* nov.sp. (black or brown); flagellomeres 3-10 (Fig. 6a): light brown similar to *A. orientalis* nov.sp.; mandible brown with a reddish tip in contrast to *A. tiaretta* s.str. (always black with a reddish tip) and *A. orientalis* nov.sp. (mandible black with a reddish tip or totally reddish). Mesosoma (Fig. 6b): thorax black; femur, tibia, basitarsus and mediotarsi reddish-brown (Fig. 9a) similar to *A. orientalis* nov.sp.; wing (very) light toned, pterostigma (Fig. 3a) similar to *A. orientalis* nov.sp.; tergites brown in contrast to *A. tiaretta* s.str. (black) and *A. orientalis* nov.sp. (black or brown) with reddish-brown depression zone; T5 translucent, reddish-brown.

P u b e s c e n c e . <u>Head</u> (Fig. 6a): genal area, facial fovea and vertex similar to *A. orientalis* nov.sp. <u>Mesosoma</u> (Fig. 6b): mesoscutum and scutellum, tibial scopa similar to *A. orientalis* nov.sp.

S t r u c t u r e . No differences.

In summary it can be stated that there are many more similarities in morphological features between *Andrena cyrenaica* nov.sp. and *A. orientalis* nov.sp. than between *Andrena cyrenaica* nov.sp. and *A. tiaretta* s.str (but see the results of the morphometric analysis). In contrast to *A. orientalis* nov.sp. no morphological differentiation of females can be detected.

Andrena tiaretta-group: specimens from Egypt, Iran and without provenance

There are two specimens, one from Egypt and one from Iran. Both are definitively members of the *A. tiaretta*-group.

The female of Egypt (see comments chapter 'provenances') has no clear provenance and show morphological characters between *A. cyrenaica* nov.sp. and *A. orientalis* nov.sp. Without knowing exactly the provenance and testing more specimens (especially males) a further classification (grouping to *A. cyrenaica* nov.sp. or *A. orientalis* nov.sp.) is not possible (see also the comments of the morphometric analysis). The same is true in the case of the female specimen which was collected in North Iran. There are some indications of an affinity to *A. orientalis* nov.sp., but also some decisive differences occur: most parts of the clypeus are chagreened. T6 is characterised by yellowish-reddish hairs in contrast to *A. tiaretta* s.str., *A. cyrenaica* nov.sp. and *A. orientalis* nov.sp. Without testing more specimens (especially males) a further classification is not possible. The provenance of one female specimen (OLML 133, paratype) is not known. The morphological analysis indicates a relationship to *A. orientalis* nov.sp. or A. *cyrenaica* nov.sp., but not with *A. tiaretta* s.str. (see morphometric results of OLML 133).

2. Morphometric characters of females

Tab. 1 shows the results of the morphometric approach (all characters including different indices and ratios) divided into five groups (1. Spain, Morocco, Algeria; 2. Israel, Syria; 3. Libya; 4. Egypt; 5. Iran). A comparison is only appropriate between groups 1 and 2, because from Libya, Egypt and Iran in each case only one specimen is available. The characters document differences between the groups. This is also given by the calculated indices and ratios. According to BAUR et al. (2014) primarily all characters were checked with Pearson product-moment coefficients. Ocellocular distance (OOD) and labrum process (apical process) width at the top (LPW) was not significantly correlated with all other characters (Tab. 2). Neither character should be used for the multivariate ratio analysis (MRA). But in many cases the correlation between the characters are very slow (Tab. 2). Therefore the correlation table was ordered according the increasing number of significant correlations between characters (two-tailed test; $p < 0.10$) and divided into 8 groups (Tab. 3).

Table 1: Values for all characters including indices and ratios of *A. tiaretta* s.l. females (N = number of specimens; for abbreviations of characters see chapter: Material and methods: Morphometrics).

in mm	Spain, Morocco, Algeria N = 8 mean ± SD, max, min	Israel, Syria N = 9 mean ± SD, max, min	Lybia N = 1	Egypt N = 1	Iran N = 1
BL	6.84 ± 0.44, 7.33, 6.17	6.89 ± 0.47, 7.75, 6.17	6.33	6.83	7.33
CL	0.56 ± 0.44, 0.60, 0.50	0.57 ± 0.04, 0.63, 0.50	0.56	0.54	0.57
FL1	0.23 ± 0.02, 0.27, 0.20	0.20 ± 0.02, 0.24, 0.17	0.24	0.21	0.23
FL2	0.10 ± 0.01, 0.11, 0.09	0.10 ± 0.02, 0.13, 0.07	0.11	0.11	0.14
FL3	0.11 ± 0.01, 0.13, 0.10	0.11 ± 0.02, 0.13, 0.09	0.10	0.11	0.13
FL1:FL2:FL3	2.3:1.0:1.1	2.2:1.0:1.2	2.4:1.1:1.0	1.9:1.0:1.0	1.8:1.1:1.0
FVL	0.89 ± 0.05, 0.97, 0.81	0.91 ± 0.03, 0.94, 0.86	0.91	0.83	1.00
FVW	0.16 ± 0.02, 0.19, 0.14	0.18 ± 0.01, 0.20, 0.16	0.16	0.14	0.20
FVL/FVW	5.49 ± 0.37, 6.00, 4.92	5.15 ± 0.37, 5.91, 4,64	5.82	5.80	5.00
HL	1.71 ± 0.06, 1.80, 1.60	1.74 ± 0.08, 1.87, 1.60	1.77	1.63	1.77
HW	2.10 ± 0.07, 2.20, 2.00	2.11 ± 0.08, 2.23, 2.00	2.10	2.10	2.13
HL/HW	0.81 ± 0.01, 0.83, 0.97	0.82 ± 0.01, 0.84, 0.80	0.84	0.78	0.83
HW:MSW:MTW	1.1:1.0:1.0	1.0:1.0:1.0	1.0:1.0:1.0	1.0:1.0:1.0	1.0:1.0:1.0
LPW	0.12 ± 0.02, 0.16, 0.10	0.13 ± 0.03, 0.19, 0.10	0.14	0.11	0.14
MSW	2.02 ± 0.09, 2.13, 1.83	2.05 ± 0.14, 2.27, 1.87	2.10	2.03	2.10
MTW	2.01 ± 0.13, 2.20, 1.80	2.11 ± 0.09, 2.23, 2.00	2.13	2.03	2.07
OCD	0.10 ± 0.01, 0.11, 0.09	0.11 ± 0.01, 0.11, 0.09	0.11	0.11	0.13
OOD	0.44 ± 0.02, 0.47, 0.42	0.44 ± 0.02, 0.47, 0.42	0.44	0.44	0.42
OOD:POD:OCD	4.3:3.4:1.0	4.1:3.6:1.0	4.0:3.2:1.0	4.0:3.4:1.0	3.2:2.7:1.0
PBAL	0.41 ± 0.02, 0.43, 0.37	0.42 ± 0.04, 0.47, 0.37	0.40	0.39	0.40
POD	0.35 ± 0.03, 0.38, 0.29	0.39 ± 0.02, 0.44, 0.38	0.36	0.38	0.36
PSL	0.80 ± 0.06, 0.86, 0.71	0.82 ± 0.03, 0.86, 0.77	0.81	0.79	0.93
WL	5.17 ± 0.24, 5.50, 4.83	5.16 ± 0.18, 5.85, 5.00	5.17	5.17	5.58

Table 2: Pearson's product-moment correlation coefficient for all characters of *A. tiaretta* s.l. females; a: number of cases with a level of significance for a two-tailed test: p< 0.10 = 0.400; df = 16 (in brackets: character number; for abbreviations of characters see chapter: Material and Methods: Morphometrics).

	OOD(1)	LPW(2)	FL3(3)	OCD(4)	FL2(5)	PBAL(6)	FL1(7)	FVW(8)	BL(9)	CL(10)	POD(11)	MTW(12)	MSW(13)	HW(14)	PSL(15)	FVL(16)	WL(17)	HL(18)
OOD(1)	1.000	-0.267	0.014	0.080	-0.217	-0.041	-0.123	-0.173	-0.324	0.199	-0.357	0.087	-0.016	-0.088	-0.280	-0.188	-0.046	-0.124
LPW(2)	-0.267	1.000	0.049	0.201	0.123	-0.426	-0.151	0.209	0.020	-0.259	0.095	-0.203	-0.213	-0.311	-0.159	0.091	-0.200	-0.155
FL3(3)	0.014	0.049	1.000	0.303	0.566	0.141	-0.051	0.265	0.133	-0.077	-0.049	0.123	-0.036	-0.012	0.391	0.203	0.088	0.094
OCD(4)	0.080	0.201	0.303	1.000	0.487	0.248	-0.161	0.221	0.207	0.193	-0.014	0.172	0.152	0.139	0.434	0.236	0.281	0.386
FL2(5)	-0.217	0.123	0.566	0.487	1.000	0.155	0.103	0.284	0.085	0.076	-0.188	0.006	-0.010	0.025	0.371	0.165	0.393	0.137
PBAL(6)	-0.041	-0.426	0.141	0.248	0.155	1.000	0.163	0.189	0.068	0.279	0.141	0.321	0.294	0.377	0.452	0.203	0.261	0.561
FL1(7)	-0.123	-0.151	-0.051	-0.161	0.103	0.163	1.000	0.036	0.122	0.256	0.051	0.303	0.379	0.398	0.242	0.495	0.553	0.451
FVW(8)	-0.173	0.209	0.265	0.221	0.284	0.189	0.036	1.000	0.100	0.383	0.514	0.295	0.147	0.279	0.629	0.749	0.414	0.395
BL(9)	-0.324	0.020	0.133	0.207	0.085	0.068	0.122	0.100	1.000	0.211	0.361	0.309	0.608	0.632	0.292	0.342	0.442	0.545
CL(10)	0.199	-0.259	-0.077	0.193	0.076	0.279	0.256	0.383	0.211	1.000	0.306	0.630	0.592	0.549	0.335	0.447	0.492	0.529
POD(11)	-0.357	0.095	-0.049	-0.014	-0.188	0.141	0.051	0.514	0.361	0.306	1.000	0.598	0.439	0.513	0.335	0.557	0.324	0.452
MTW(12)	0.087	-0.203	0.123	0.172	0.006	0.321	0.303	0.295	0.309	0.630	0.598	1.000	0.730	0.693	0.598	0.453	0.430	0.694
MSW(13)	-0.016	-0.213	-0.036	0.152	-0.010	0.294	0.379	0.147	0.608	0.592	0.439	0.730	1.000	0.866	0.462	0.629	0.474	0.721
HW(14)	-0.088	-0.311	-0.012	0.139	0.025	0.377	0.398	0.279	0.632	0.549	0.513	0.693	0.866	1.000	0.539	0.703	0.495	0.828
PSL(15)	-0.280	-0.159	0.391	0.434	0.371	0.452	0.242	0.629	0.292	0.335	0.335	0.598	0.462	0.539	1.000	0.639	0.542	0.614
FVL(16)	-0.188	0.091	0.203	0.236	0.165	0.203	0.495	0.749	0.342	0.447	0.557	0.453	0.629	0.539	0.639	1.000	0.586	0.673
WL(17)	-0.046	-0.200	0.088	0.281	0.393	0.261	0.553	0.414	0.442	0.492	0.324	0.430	0.474	0.495	0.542	0.586	1.000	0.676
HL(18)	-0.124	-0.155	0.094	0.386	0.137	0.561	0.451	0.395	0.545	0.529	0.452	0.694	0.721	0.828	0.673	0.673	0.676	1.000
a:	0	0	1	1	2	2	3	4	4	6	6	8	9	9	9	10	10	11

Table 3: Results of scatterplot analysis of first against second shape PCA concerning eigenvalues, differentiation and compactness; groups 1 to 8: excluding characters with lower significance (for character number see Tab. 2).

group	characters (N)	eigenvalue 1. axis	eigenvalue 2. axis	differentiation	compactness
1	1-18 (18)	32.2	21.8	no	no
2	3-18 (16)	36.1	18.2	yes	no
3	5-18 (13)	36.5	20.8	yes	yes
4	7-18 (12)	40.5	23.2	yes	yes
5	8-18 (11)	46.0	19.5	best value	best value
6	9-18 (9)	41.1	21.8	yes	no
7	11-18 (7)	39.5	23.2	no	no
8	13-18 (5)	48.4	16.7	no	no

The scatterplot of first against second shape PCA with all characters did not show any differentiation of the geographically separated populations from Spain, Morocco, Algeria in contrast to populations of Israel and Syria (Tab. 3: group 1). The same results were observed even if the number of characters is too low (Tab. 3: groups 7 and 8). All other groups (Tab. 3: 2-6) show distinct differentiation between western and eastern populations. The 11 parameters of group 5 used for the MRA (BL, CLP, FVL, FVW, HL, HW, MSW, MTW, POD, PSL, WL) demonstrate the highest eigenvalue (first axis: 46.0 %) in combination with best differentiation and compactness of the scatterplot groups (Tab. 3, Fig. 10).

If the blue symbols (specimens from Spain, Morocco, Algeria) are compared with red symbols (specimens from Israel, Syria), two clusters are separated. No. 133 with unknown provenance is situated in the cluster of the western populations. The specimen from Libya is grouped in the western-specimens scatterplot, the specimen from Egypt nearby the borderline of the western-specimens scatterplot. The north Iran specimen is separated top right of the diagram, lying closer to the western-specimens scatterplot.

The eastern specimens (Israel, Syria) are on average slightly larger than the western ones (Spain, Morocco, Algeria) but the ranges of the sizes are broadly overlapping (Fig.11). The scatterplot thus revealed a moderate amount of allometric variation. The two specimens from Libya and Egypt are grouped within or near to the western-specimens scatterplot (the same is true for the specimen with unknown provenance OLML 133). The north Iran specimen is separated on the right side of the diagram (larger size range) and is situated closer to the eastern-specimens scatterplot in contrast to Fig. 10.

The best separating ratios need not necessarily correspond to the most important ratios of the PCA ratio spectrum (PETERS & BAUR 2011; see also the comments in BAUR et al. 2014). All four best ratios were neither in the PCA nor in the allometry ratio spectrum among the dominant ratios (Fig. 12, 13). The conclusion is a negligible influence of the ratios for the discrimination of both groups. The four best ratios are only partly influenced by allometric behaviour.

Fig. 12 demonstrates the PCA ratio spectrum for shape PC1, Fig. 13 the allometry ratio spectrum (horizontal bars represent 68 % bootstrap confidence intervals based on 1000

replicates). The variables lying at the opposite ends of the spectrum are relevant for a particular shape PCA (BAUR & LEUENBERGER 2011). In the PCA ratio spectrum these variables in opposite position are FVW and BL, in the case of the allometry ratio spectrum FVW and HW. Accordingly, the two spectra are not dominated by the same variables; the most important ratio concerning the first shape PCA is not totally the allometric one. The variables FVW and HW are mostly influenced by allometric behaviour; for all other parameters allometric behaviour is negligible.

The results concerning the LDA ratio extractor document, that the best separating ratios are: ratio no.1= HW/POD (range group 1: 5.64-7.00; range group 2: 5.00-5.71); ratio no.2 = FVL/MTW (range group 1: 0.41-0.46, range group 2: 0.41-0.46; standard distance: 8, δ = 8), ratio no.3: FVL/FVW and ratio no.4: HL/WL.

In the further analysis we focus on the differentiation between western specimens (Spain, Morocco and Algeria; *A. tiaretta* s.str according the qualitative analysis) and eastern specimens (Israel and Syria; *A. orientalis* nov.sp.). Fig. 14 shows the scatterplot of the two best ratios (HW/POD; FVL/MTW) and documents a clear separation of both taxa. This is expressed by a high standard distance value in the ratio no. 2. *A. orientalis* nov.sp. is much more homogeneous within the scatterplot structure than the *A. tiaretta* s.str.

3. Qualitative analysis of males

Fig. 15-23 show the holotype and two paratypes from *Andrena tiaretta* selected by Warncke and collected in Algeria (Tiaret), Ramla (Israel) and Cyrene (Libya).

Andrena tiaretta s.str. (Spain, Morocco, Algeria)

C o l o u r . Head (Fig. 18a): black; scapus black/brown; flagellomeres 1 and 2 as a rule darker than flagellomeres 3-10, flagellomeres 3-10: dark brown to brown. Mesosoma (Fig. 18b): black; femur, tibia and basitarsus reddish-brown or pars parte reddish-brown, in two cases black (higher variation between specimens of Spain and Algeria; specimens of Morocco consistently reddish-brown); mediotarsi reddish-brown; wings light toned; pterostigma yellowish (two cases reddish-yellowish and one case reddish in specimens of Spain, one case reddish-yellowish concerning an Algerian specimen), pterostigma brown marginated, veins reddish-brown (Fig. 15a). Metasoma (Fig. 21a): T1-5 black, with black to dark reddish-brown depression zone; T6 reddish-brown or T1-T5 depression reddish (higher variation between specimens from Spain and Algeria; specimens of Morocco consistently reddish-brown).

P u b e s c e n c e . Head (Fig. 18a): frontview: whitish hairs, paraoccular area with whitish hairs, no or only some brown hairs, hair length different; sideview: paraoccular-area with whitish and with or without some brown hairs; clypeus with longer whitish hairs; scapus with long whitish-yellowish (three specimens with totally white) hairs, no difference between dorsal and ventral site; genal area with light brownish dorsal hairs in specimens from Spain (one specimen yellowish), light brownish or brown dorsal hairs in specimens from Morocco, brown dorsal hairs in specimens from Algeria (in two specimens white hairs); ventral constantly whitish hairs; vertex with some long whitish-yellowish, slightly reddish hairs. Mesosoma (Fig. 18b): mesoscutum and scutellum only with some whitish-yellowish hairs intermingled with brown hairs, hairs especially

situated in front, laterally yellowish hairs, or totally scattered covered with yellowish hairs; mesepisternum with whitish, pars parte yellowish hairs. Metasoma (Fig. 21a): tergites scarcely hairy, T2-3 in most of all specimens with lateral longer whitish hairs, no distinct hair bands (3 specimens from Spain, Morocco and Algeria with fragmentary whitish hairbands in T2/T3), but hair rows between tergite and tergite depression (hair rows T2, T3 often fragmentary); T5 and T6 with white, slightly yellowish hairs (one specimen from Spain yellowish); sternite 8 with long whitish (in two cases yellowish) hairs at the end.

S t r u c t u r e . Head: vertex surface densely sculptured; face above antennal fossae with longitudinal rugulae, interrugal space shiny; inner eye margin converging weakly; clypeus similar to females but in all cases without impunctate median line; labrum process trapezoid, emarginated, ends left and right side slightly thickened. Mesosoma (Fig. 18b): mesoscutum and scutellum similar to female, very scattered punctured, shallow punctures (pd = 0.14-0.28 μm), with developed parapsidal lines; propodeum: strongly rugose primarily in the centre and in the dorsolateral area, no lateral boundary line. Metasoma (Fig. 21a): similar to female, very scattered punctured (pd = 0.14 μm), posterior depression of (T1)T2-T4 not well marked; tergite 1 carinate. Genital (Fig. 21b): penisvalvae slightly vesicularly thickened, ending distal acuminated; gonocoxit inward concave, dorsal lobus well developed.

Andrena orientalis nov.sp. (Israel, Syria): differential diagnosis to *A. tiaretta* s.str.

C o l o u r . Only the following features in the specimens of Israel are different to the specimens of Spain, Morocco and Algeria (*A. tiaretta* s.str.): Head (Fig. 19a): flagellomeres 3-10: brown or light brown in contrast to *A. tiaretta* s.str. with only brown coloured flagellomeres. Mesosoma (Fig. 19b): black or reddish-brown in contrast to *A. tiaretta* s.str. with only black coloured thorax; femur, tibia and basitarsus constantly reddish-brown in contrast to *A. tiaretta* s.str. with reddish-brown or pars parte reddish-brown femur, tibia and basitarsus; wings very light toned (*A. tiaretta* s.str.: light toned), veins yellowish or reddish-brown (*A. tiaretta* s.str.: reddish-brown).

P u b e s c e n c e . Head (Fig. 19a): paraoccular area with whitish hairs in contrast to *A. tiaretta* s.str. with whitish and as a rule with some brown hairs; scapus and antennal socket with whitish hairs (*A. tiaretta* s.str.: as a rule whitish-yellowish hairs); genal area in all cases with whitish hairs (*A. tiaretta* s.str.: as a rule brownish hairs upper side, whitish hairs downwards); vertex with some long yellowish hairs (*A. tiaretta* s.str.: additionally with slightly reddish hairs). Metasoma (Fig. 22a): scarcely hairy, T2-4 as a rule with distinct whitish hair bands (*A. tiaretta* s.str.: T2-3 with lateral longer whitish hairs, but no distinct hair bands).

S t r u c t u r e . Genital (Fig. 22b): gonocoxit inwardly extending, more or less linear and without dorsal lobus.

Andrena cyrenaica nov.sp. (Libya): differential diagnosis to *A. tiaretta* s.str. and *A. orientalis* nov.sp.

The specimens of Libya are characterised by colour of flagellomeres (light brown; Fig. 20a), of thorax (reddish-brown), of tibia and basitarsus (reddish-brown) and of wings and metasoma (very light toned, pterostigma yellowish and brown marginated, veins yellow-

ish or reddish-brown). There is a similarity to *A. orientalis* nov.sp. in the <u>pubescence</u> of the head (paraocular area whitish and no brown hairs), scapus and antennal socket (long white hairs, no difference between dorsal and ventral), genal area (whitish hairs; Fig. 20a) and vertex (whitish hairs). The metasoma of the studied specimens is scarcely hairy but there is a possibility that the hairs are rubbed. Concerning all these morphological features it can be concluded that the specimens from Libya are more similar to *A. orientalis* nov.sp. than *A. tiaretta* s.str. Clearly different to *A. orientalis* nov.sp. and *A. tiaretta* s.str. is the <u>structure</u> of the gonocoxit, with a well exposed and dominant dorsal lobus (Fig. 23b).

4. Morphometric characters of males

Analogously to the females, Tab. 4 shows the morphometric results for males (all characters including different indices and ratios) divided into three specimen groups (1. Spain, Morocco, Algeria; 2. Israel; 3. Libya).

Similar to the analysis of females, the analysis with the Pearson product-moment coefficients documents in many cases slow correlation between the characters (Tab. 5). The correlation table of the Pearson product-moment coefficients, ordered according to the increasing number of significant correlations between characters (two-tailed test; $p < 0.10$), was divided into 6 groups (Tab. 6).

Table 4: Values for all variables including indices and ratios of *A. tiaretta* s.l.males.

in mm	Spain, Morocco, Algeria N = 15 mean ± SD, max, min	Israel N = 5 mean ± SD, max, min	Lybia N = 2 mean ± SD, max, min
BL	5.98 ± 0.34, 6.42, 5.17	6.07 ± 0.48, 6.83, 5.50	6.46 ± 0.29, 6.67, 6.25
CL	0.49 ± 0.03, 0.54, 0.43	0.52 ± 0.03, 0.54, 0.47	0.54 ± 0.02, 0.56, 0.53
FL1	0.21 ± 0.02, 0.24, 0.19	0.20 ± 0.01, 0.21, 0.19	0.21 ± 0.02, 0.23, 0.20
FL2	0.12 ± 0.01, 0.13, 0.09	0.11 ± 0.01, 0.13, 0.10	0.11 ± 0.00
FL3	0.13 ± 0.01, 0.14, 0.11	0.14 ± 0.01, 0.14, 0.13	0.16 ± 0.00
FL1:FL2:FL3	1.8:1.0:1.2	1.8:1.0:1.3	1.9:1.0:1.4
HL	1.53 ± 0.10, 1.80, 1.43	1.57 ± 0.08, 1.67, 1.47	1.65 ± 0.07, 1.70, 1.60
HW	1.90 ± 0.09, 2.17, 1.80	1.92 ± 0.06, 2.03, 1.87	1.98 ± 0.02, 2.00, 1.97
HL/HW	0.80 ± 0.05, 0.98, 0.77	0.81 ± 0.02, 0.84, 0.79	0.83 ± 0.03, 0.85, 0.81
HW:MSW:MTW	1.1:1.0:1.0	1.1:1.0:1.0	1.1:1.0:1.0
LPW	0.13 ± 0.01, 0.14, 0.11	0.14 ± 0.02, 0.16, 0.11	0.16 ± 0.03, 0.19, 0.14
MSW	1.71 ± 0.09, 1.97, 1.60	1.74 ± 0.11, 1.93, 1.60	1.82 ± 0.02, 1.83, 1.80
MTW	1.70 ± 0.11, 1.93, 1.53	1.73 ± 0.09, 1.90, 1.67	1.78 ± 0.02, 1.80, 1.77
OCD	0.11 ± 0.01, 0.11, 0.09	0.11 ± 0.00	0.11 ± 0.00
OOD	0.43 ± 0.02, 0.47, 0.40	0.42 ± 0.02, 0.44, 0.40	0.44 ± 0.03, 0.47, 0.42
OOD:POD:OCD	4.1:3.2:1.0	3.8:3.5:1.0	4.0:3.4:1.0
PBAL	0.35 ± 0.03, 0.43, 0.31	0.39 ± 0.02, 0.43, 0.36	0.40 ± 0.00
POD	0.34 ± 0.03, 0.40, 0.29	0.39 ± 0.04, 0.44, 0.31	0.38 ± 0.00
PSL	0.73 ± 0.04, 0.81, 0.66	0.76 ± 0.03, 0.79, 0.71	0.79 ± 0.00
WL	4.64 ± 0.18, 4.92, 4.33	4.57 ± 0.15, 4.83, 4.42	4.96 ± 0.06, 5.00, 4.92

Table 5: Pearson's product-moment correlation coefficient for all parameters of *A. tiaretta* s.l. males (the partly damaged specimens no. 96 and no. 117 were excluded).

	FL2(1)	OCD(2)	PBAL(3)	OOD(4)	BL(5)	CLP(6)	POD(7)	FL1(8)	LPW(9)	HL(10)	FL3(11)	WL(12)	MTW(13)	PSL(14)	HW(15)	MSW(16)
FL2(1)	1.000	0.035	-0.092	-0.115	-0.146	-0.058	-0.114	-0.299	0.136	-0.180	-0.208	-0.220	-0.298	-0.212	-0.119	-0.150
OCD(2)	0.035	1.000	0.432	0.130	0.283	-0.242	0.294	0.152	0.322	0.186	-0.074	0.122	0.057	0.268	0.124	0.191
PBAL(3)	-0.092	0.432	1.000	0.090	0.381	-0.210	0.389	0.234	0.356	0.065	-0.085	0.198	0.164	0.218	0.059	0.130
OOD(4)	-0.115	0.130	0.090	1.000	0.308	0.185	0.297	0.260	0.163	0.323	0.136	0.152	0.295	0.420	0.378	0.519
BL(5)	-0.146	0.283	0.381	0.308	1.000	0.246	0.361	0.530	0.172	0.571	0.135	0.330	0.271	0.327	0.582	0.615
CLP(6)	-0.058	-0.242	-0.210	0.185	0.246	1.000	0.376	-0.121	0.203	0.418	0.538	0.052	0.307	0.261	0.526	0.438
POD(7)	-0.114	0.294	0.389	0.297	0.361	0.376	1.000	0.095	0.187	0.484	0.259	0.290	0.431	0.777	0.605	0.463
FL1(8)	-0.299	0.152	0.234	0.260	0.530	-0.121	0.095	1.000	0.195	0.174	0.233	0.609	0.537	0.320	0.457	0.522
LPW(9)	0.136	0.322	0.356	0.163	0.172	0.203	0.187	0.195	1.000	0.144	0.564	0.473	0.488	0.397	0.410	0.428
HL(10)	-0.180	0.186	0.065	0.323	0.571	0.418	0.484	0.174	0.144	1.000	0.309	0.346	0.227	0.412	0.587	0.506
FL3(11)	-0.208	-0.074	-0.085	0.136	0.135	0.538	0.259	0.233	0.564	0.309	1.000	0.523	0.500	0.457	0.416	0.413
WL(12)	-0.220	0.122	0.198	0.152	0.330	0.052	0.290	0.609	0.473	0.346	0.523	1.000	0.410	0.441	0.520	0.425
MTW(13)	-0.298	0.057	0.164	0.295	0.271	0.307	0.431	0.537	0.488	0.227	0.500	0.410	1.000	0.531	0.665	0.717
PSL(14)	-0.212	0.268	0.218	0.420	0.327	0.261	0.777	0.320	0.397	0.412	0.457	0.441	0.531	1.000	0.674	0.554
HW(15)	-0.119	0.124	0.059	0.378	0.582	0.526	0.605	0.457	0.410	0.587	0.416	0.520	0.665	0.674	1.000	0.839
MSW(16)	-0.150	0.191	0.130	0.519	0.615	0.438	0.463	0.522	0.428	0.506	0.413	0.425	0.717	0.554	0.839	1.000
a:	0	1	1	2	4	4	5	5	5	6	7	7	8	8	11	12

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Table 6: Results of scatterplot analysis of first against second shape PCA concerning eigenvalues, differentiation and compactness; group 1 to 6: excluding characters with lower significance between characters (character number: see Tab. 5).

group	characters (N)	eigenvalue 1. axis	eigenvalue 2. axis	differentiation	compactness
1	1-16 (16)	25.7	19.3	no	no
2	5-16 (12)	40.4	20.1	yes	no
3	7-16 (10)	46.4	23.0	best value	best value
4	10-16 (7)	41.4	23.5	no	yes
5	11-16 (6)	50.3	19.9	no	yes
6	13-16 (4)	54.9	32.2	no	no

The scatterplot of first against second shape PCA (with all characters) did not show any differentiation of the geographically separated populations from Spain, Morocco, Algeria in contrast to populations of Israel and Syria (Tab. 6: group 1). The same results were observed, if the number of characters is too low (Tab. 6: groups 4-6). Groups 2 and 3 (Tab. 6) show clear differentiations between western and eastern populations. The 10 parameters of group 3 used for the MRA (FL1, FL3, HL, HW, LPW, MSW, MTW, POD, PSL, WL) demonstrate the highest eigenvalue (first axis: 46.4 %) in combination with best differentiation and compactness of the scatterplot groups (Tab. 6, Fig. 24).

An analysis and comparison of the blue symbols (specimens from Spain, Morocco, Algeria) with the red symbols (Israel, Syria) demonstrate that the plot of only one specimen coming from Algeria (no. 112; holotype) is situated in the scatterplot of the eastern populations (red symbols). The specimen no. 135 from Libya (green symbol) is situated in the western scatterplot, whereas the specimen no. 128 lies outside and nearer to the eastern scatterplot.

The amplitudes of the sizes are broadly overlapping (Fig. 25). The scatterplot thus revealed a very moderate amount of allometric variation. The two specimens from Libya are grouped outside the western and eastern specimen scatterplot.

Fig. 26 demonstrates the PCA ratio spectrum for shape PC1, Fig. 27 the allometry ratio spectrum (horizontal bars represent 68 % bootstrap confidence intervals based on 1000 replicates). In the PCA ratio spectrum these variables in opposite position are LPW and POD, in the case of the allometry ratio spectrum LPW and WL. The most important ratio concerning the first shape PCA is not totally the allometric one. The variables LPW and WL are mostly influenced by allometric behaviour; for all other parameters allometric behaviour is negligible.

Testing the correlation with Pearson product-moment coefficients, FL2, OCD, PBAL and OOD correlated much less strongly than all other variables (Tab. 5).

The results with the LDA ratio extractor show that the best separating ratios are: ratio no.1= FL1/POD (range group 1: 0.53-0.79, range group 2: 0.48-0.61, standard distance: 9, $\delta = 7$); ratio no. 2 = LPW/WL (range group 1: 0.02-0.03, range group 2: 0.02-0.03, standard distance: 6, $\delta = 5$), ratio no. 3: HL/HW and ratio no.4: FL1/WL. Fig. 28 shows

the scatterplot with both best ratios (FL1/POD; LPW/WL). There is with one exception a clear separation of the two groups. This is documented by a high standard distance value in the ratios no. 1 and no. 2.

With one exception (second best ratio in the allometry ratio spectrum) all other best ratios were neither in the PCA nor in the allometry ratio spectrum among the dominant ratios (Fig. 26, 27). The conclusion is a negligible influence of the ratios for the discrimination of both groups with one exception.

5. Taxonomical differentiation and distribution map

Taking into account all results of the differential diagnosis of females and males, the existence of three species is concluded, reflecting the biogeographical pattern between western and eastern populations of the *A. tiaretta* group: *A. tiaretta* s.str. (specimens from Spain, Morocco and Algeria), *A. cyrenaica* nov.sp. (specimens from Libya) and *A. orientalis* nov.sp. (specimens from Israel and Syria); Map 1.
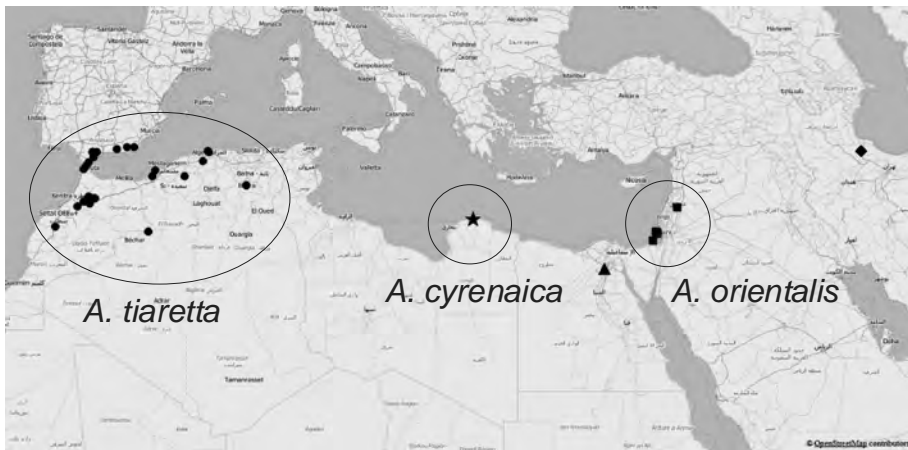
Map 1: Distribution of *A. tiaretta* s.str., *A. cyrenaica* nov.sp. und *A. orientalis* nov.sp. Besides the localities of specimens analysed in this study, data of WARNCKE (1974), GUSENLEITNER & SCHWARZ (2002) and DARDÓN PERALTA (2010) are included.

Discussion

1. Redescription of the *A. tiaretta* group

Corresponding to the 'Phylogenetic Species Concept' (PSC) it is accepted that smallest detectable differences may be the basis for taxonomical differentiation. Besides qualitative morphological features and their analysis, newly developed morphometric methods for analysis (BAUR & LEUENBERGER 2011, BAUR et al. 2014) are useful tools to detect hidden species or subspecies, especially if only a few specimens are available.

It is remarkable that the combination of a qualitative morphological (colour, pubescence, different structures) and morphometric analysis using Pearson product-moment correlation coefficient, multivariate ratio analysis, linear discriminant analysis, PCA and

allometry ratio spectrum, are exact tools to detect taxonomic differences based on only a few specimens. The results concerning the *A. tiaretta* group also show the following problem: if there are many paratypes which represent specimens sampled in large areas, there will often be morphologically heterogeneous features.

Following our hypotheses 1 and 2 the differential morphological diagnoses show the existence of two species: *A. tiaretta* s.str. including specimens from Spain, Morocco and Algeria and *A. orientalis* nov.sp. including specimens from Israel and Syria. WARNCKE (1974) chose a male from Algeria as holotype (OLML 112), therefore the western specimens should be taxonomically grouped to *A. tiaretta* WARNCKE (1974). All former paratypes respresenting these western populations are now also paratypes of *A. tiaretta* s.str. (females: OLML 110, 111, 121, 122, 126, 129; males: OLML 113, 114, 117, 118, 119, 123, 124, 129, 130, 139). The former holotype of *A. tiaretta* (male from Tiaret; OLML 112) is holotype of *A. tiaretta* s.str.

The new holotype of *A. orientalis* nov.sp. is determined (female: OLML 138), formerly a paratype of *A. tiaretta* s.l. The other paratypes of the eastern populations (Israel, Syria) are now paratypes of *A. orientalis* nov.sp. (females: OLML 115, 116, 127, 132; males: OLML 125, 136, 137).

For the few specimens from Libya (one female, two males) a morphometric analysis with the LDA ratio extractor was not possible, but the remarkable morphology of the male genital, different to *A. tiaretta* s.str. and to *A. orientalis* nov.sp., confirm an own species status. In this case the female shows higher similarities in qualitative morphological features with the specimens of Israel and Syria; this is also true for the males, but in morphometrics the female shows similarity to western populations; this also applies in the case of one male specimen, but the other male is located in the scatterplot far away from *A. tiaretta* s.str. and from *A. orientalis* nov.sp. Larger numbers of specimens would be needed to get more significant results. The female OLML 120, formerly paratype of *A. tiaretta* s.l., is now holotype of *A. cyrenaica* nov.sp. The two males (OLML 128, 135) formerly paratypes of *A. tiaretta* s.l., are now paratypes of *A. cyrenaica* nov.sp.

An analogous situation (changing paratype status by the description of a new species) is given in the case of *Andrena tebessana* SCHEUCHL, BENARFA & LOUADI, 2011 (see SCHEUCHL et al. 2011).

The female of Egypt (OLML 134, paratype with unclear provenance) and one other female (OLML 133, paratype), cannot be assigned to *A. cyrenaica* nov.sp. or *A. orientalis* nov.sp. For both of them the qualitative morphological features exclude the relationship to *A. orientalis* nov.sp. In morphometrics the specimens OLML 133 and 134 are much more similar to *A. tiaretta* s.str or *A. cyreniaca* nov.sp. Because the provenance of the paratype OLML 133 is unknown or in the case of OLML 134 uncertain, we should exclude both specimens from a paratype status.

The single specimen from Iran (Rudbar, female OLML 84) shows in many qualitative morphological and morphometric characters differences to all other specimens; the taxonomic relationship of this specimen is unclear. KHODAPARAST & MONFARED (2012) detected a second *Micrandrena* species, *A. rugulosa* STOECKHERT, 1935, in the region of Bahr Ghan and Sepidan (Iran). The morphology and the literature concerning *A. rugulosa* are documented in GUSENLEITNER & SCHWARZ (2002), also the distribution area is shown: southern central and eastern Europe, Mediterranean region (Greece), Crimea, Caucasus, and since 2002 also specimens from southern parts of the Iran

(KHODAPARAST & MONFARED 2012). A comparison of the first description of *A. rugulosa* by STOECKHERT (1935) with features of the specimen of Rudbar shows morphological differences (puncturing of the clypeus and mesonotum, colour of flagellum, wing and other characters). The description of STOECKHERT (1935) employed specimens from Germany and Austria exclusively, so differences to eastern populations are possible. A further analysis should elucidate this complex problem (if more specimens are available).

2. Biogeographical analysis of the *A. tiaretta* group

According to DUBITZKY (2005) the genus *Andrena* evolved with high probability in the Old World, presumably between the Mediterranean region and Central Asia. Mining bees prefer dry and warm climatic conditions like those in the Mediterranean region and the steppes of central Asia, where the genus shows its highest diversity. The Holarctic distribution of *Andrena* is probably based on dispersal events which could have occurred during the late Cretaceous time and early Tertiary (DUBITZKY 2005).

The west palaeartic distribution of bees is influenced by glacial and interglacial processes determining climatic and ecological parameters (e.g. PATINY & MICHEZ 2007). The Sahara-Arabian desert has undergone several cycles of climatic change during the Tertiary and Quaternary, summarised as dry and moist environmental conditions.

The optimum of the bee species richness was probably in the so-called Sahara greening phase with surrounding steppe-like ecosystems. This subpluvial phase began not before 10,000 years BC and persisted for about 5,000 years (SPAULDING 1991). Then the current dry phase developed and the populations were probably separated.

The Palaearctic Middle East has today an immense biodiversity of bees (GRACE 2010) characterised by desert and semi-desert species (Lebanon, Syria, Jordan, Israel, the Palestinian Territories); GRACE (2010).

A. tiaretta WARNCKE, 1974, *A. cyrenaica* nov.sp. and *A. orientalis* nov.sp. each occupy a clearly distinct distribution area, which is the result of genetic separation including changes in ecological factors over a very long period. It seems probable that the Irano-Turano region is the centre of origin of many *Andrena* taxa. According to this hypothesis, the ancestors of *A. tiaretta* s.str. should be *A. cyrenaica* nov.sp. and *A. orientalis* nov.sp. Furthermore, *A. wollastoni* (Canary Islands, Madeira) and *A. dourada* (Porto Santo) share high morphological similarities with *A. tiaretta* WARNCKE, 1974 (KRATOCHWIL & SCHEUCHL 2013) and *A. tiaretta* s.str. is the continental ancestor of all taxa of the *A. wollastoni* complex including *A. dourada* (KRATOCHWIL & SCHEUCHL 2013, KRATOCHWIL 2014) of the Madeira Archipelago and the Canary Islands.

PATINY & MICHEZ (2007) studied the distribution of 57 bee species within a region including Sahara and Arabian deserts and their adjacent areas. The endemism rate is with 58 % very high. It was shown by PATINY & MICHEZ (2007) that regional bee diversity hotspots (Dasypodainae, Fideliinae, Lithurginae, Meganomiinae, Melittinae, Panurginae and Rophitinae) in North Africa and Arabia could be detected in the following areas: western Atlas (Morocco), eastern Atlas (Tunisia), Tripolitania, Cyrenaica, Nile Valley, Jordan Valley and Oman hills. Five distributional patterns of species groups were described by PATINY & MICHEZ (2007): 1. Multilocular (distributes over the total range); 2. Mauritanian; 3. Arabian; 4. Sahelian; 5. Local distribution.

With a distribution area from Spain, Morocco and Algeria, *A. tiaretta* s.str. represents a species of the Afro-Atlanto-Mediterranean region. The area of *A. tiaretta* s.str. is very similar to that, e.g., of *Panurgus calceatus* PÉREZ, 1895 (PATINY & MICHEZ 2007: Fig. 8a), but the latter species is missing in Spain. *A. cyrenaica* nov.sp. and *A. orientalis* nov.sp. have a regional distribution and can be compared (referring to the distribution) with other endemics: *Panurgus cyrenaikensis* WARNCKE, 1972 (Libya) and *Melliturga krausi* SCHWARZ, 2003 (Israel).

Many species of the Sahara-Arabian area are characterised by disjunctions of many hundred kilometres. Between these localities there are no suitable habitats. *Dasypoda sinuata* PÉREZ, 1895 was detected in Morocco, Algeria, Tunisia, Libya, Egypt and, remarkably, with presence in the Canary Islands on Lanzarote and Fuerteventura (PATINY & MICHEZ 2007: Fig. 7). This is also a model species as colonizer of the Canary Islands. Another interesting distribution area is the range of *Panurgus nigriscopus* PÉREZ, 1895 known from Morocco, Egypt, Jordan and Oman (PATINI et al. 2005).

Before the taxonomical differentiation of *A.tiaretta* s.str, *A. cyrenaica* nov.sp. and *A. orientalis* nov.sp. was detected, *A. tiaretta* s.l. would have been regarded as one multilocular species of the Sahara-Arabian area. But these disjunctions are often the reason for species radiation. Similar results were obtained by a revision of the Western Palaearctic species of the *Andrena taraxaci* group (SCHWENNINGER 2015) with a detection of new endemic species for Tunesia.

The single specimen from Iran (Rudbar, female OLML 84) cannot be identified yet. Iran is a concentration centre of four main biogeographical regions. The sampling point in northern Iran reflects the eurosiberian region. It seems that there is no biogeographical relationship with the distribution area of *A. tiaretta* s.l. in the south-eastern part of the range, characterised by elements e.g. of (North) Africa (ZIEGLER 2011). This is documented also by other taxonomical groups, exemplarily by the *Hyles euphorbiae* complex (Lepidoptera, Sphingidae, Macroglossinae); see HUNDSDÖRFER et al. (2011). It can be hypothesised that there is a border in Iran between Eurasian and North African populations as well as populations from the Palaearctic Middle East. This was also shown in the case of the butterfly species *Melitaea cinxia* (WAHLBERG & SACCHARI 2007) and *Pararge aegeria* (WEINGARTNER et al. 2006).

Many bee species were primarily described on the basis of only some specimens. In combination with the further detection of specimens of new localities, ordered in the known taxonomical system, the knowledge of the distribution area grew. In all cases with disjunctions and an area of many hundred or thousand kilometres, species identification has to be established in detail based on qualitative morphological features, morphometrics or (if possible) with molecular methods determining homogeneity or heterogeneity of specimens. Probably many hidden species will be detected by using this approach.

E t y m o l o g y : '*orientalis*': from the Latin word 'oriens' ('east'); the usual meaning of 'orient' comprises the area 'Middle East'. '*cyrenaica*': from 'Cyrenaica' which is a landscape in the eastern part of Libya originating from name of the city 'Cyrene' (Arabic: 'Barqah') in the eastern coastal region of Libya.

Acknowledgements

Zusammenfassung

Im Rahmen einer Überarbeitung des *Andrena* (*Micrandrena*) *wollastoni*-Komplexes (Madeira Archipel, Kanarische Inseln) war es notwendig, den taxonomischen Status von *A. tiaretta* s.l., dem wahrscheinlichen Vorfahren auf dem Festland, zu untersuchen. Basierend auf der Hypothese, dass eine Kolonisation über Individuen der westlich verbreiteten Populationen stattfand, ergab sich die Frage, ob sich diese von östlichen Populationen (besonders denen von Israel und Syrien) morphologisch unterscheiden. Über eine qualitative morphologische Analyse (Färbung bestimmter Körperbereiche, Umfang und Farbe der Behaarung, verschiedene strukturelle Merkmale) sowie über eine morphometrische Analyse von 18 Merkmalen bei den Weibchen und 16 Merkmalen bei den Männchen (Berechnung der Produkt-Moment-Korrelation von Pearson und multivariate Ratio-Analyse [MRA] mit Methoden der Hauptkomponenten-Analyse, linearen Diskriminanzanalyse und der Berechnung des Allometrie-Ratio-Spektrums), wurden 20♀♀ und 23♂♂ von *A. tiaretta* s.l. näher analysiert. Darunter befinden sich neben dem Holotypus alle existierenden Paratypen (15♀♀ 15♂♂). Holotypus und Paratypen, die von WARNCKE (1974) festgelegt wurden, umfassen Individuen aus Marokko, Algerien, Libyen, Ägypten, Israel und Syrien. Zusätzlich wurden Individuen aus Spanien und aus dem Iran in die Analyse einbezogen.

Eine Differentialdiagnose von Individuen westlicher Verbreitung mit denen östlicher belegt deutliche morphologische Unterschiede bei den Weibchen und Männchen in Färbung und Behaarung. Bei den Weibchen wird eine klare Trennung von zwei Taxa durch das Streudiagramm der ersten gegenüber der zweiten Achse der PCA deutlich, wenn die Parameter BL, CL, FVL, FVW, HL, HW, MSW, MTW, POD, PSL, WL zugrunde gelegt werden. Diese 11 Merkmale führen zu dem höchsten eigenvalue-Wert der ersten Achse (46,0 %), der deutlichsten Differenzierung zwischen den beiden Gruppen im Streudiagramm und der höchsten Kompaktheit innerhalb der Gruppen. Die lineare Diskrimanzanalyse (LDA ratio extractor) ergab, dass bei den Weibchen das Verhältnis HW/POD und das von FVL/MTW zur Trennung der beiden Taxa am besten geeignet ist. Die Ergebnisse werden durch allometrische Zusammenhänge leicht beeinflusst.

Bei den Männchen ist innerhalb des Streudiagramms (erste gegenüber der zweiten Achse der PCA) ebenfalls eine Differenzierung der beiden Taxa erkennbar, wenn die Parameter Fl1, FL3, HL, HW, LPW, MSW, MTW, POD, PSL, WL zugrunde gelegt werden. Diese 11 Merkmale führen zu dem höchsten eigenvalue-Wert der ersten Achse (46,4 %), der deutlichsten Differenzierung zwischen den beiden Gruppen im Streudiagramm und der höchsten Kompaktheit innerhalb der Gruppen. Die lineare Diskrimanzanalyse (LDA ratio extractor) ergab, dass bei den Männchen das Verhältnis von FL1/POD und von LPW/WL zur Trennung der beiden Taxa am besten geeignet ist. Die Ergebnisse werden auch hier durch allometrische Zusammenhänge leicht beeinflusst.

Die Streudiagramme der am besten trennenden Merkmalsrelationen ergeben bei den Weibchen und Männchen eine Trennung zwischen den beiden Taxa *A. tiaretta* s.str. (Spanien, Marokko, Algerien) und *A. orientalis* nov.sp. (Israel, Syrien). Beide Taxa sind bei den Männchen auch genitalmorphologisch gut unterscheidbar.

Aufgrund der genitalmorphologischen Unterschiede der Männchen, können die Tiere aus Lybien (alles Paratypen von *A. tiaretta* s.l., 1♀ and 2♂♂) als neue Art beschrieben werden (*A. cyrenaica* nov.sp.). Aufgrund der geringen Anzahl von Individuen zeigt innerhalb der morphometrischen Analyse nur ein Männchen Unterschiede gegenüber *A. tiaretta* s.str. und *A. orientalis* nov.sp.

Ein Weibchen aus Ägypten mit nicht eindeutiger Herkunft (von Warncke als *A. tiaretta* determiniert) zeigt geringe morphologische Unterschiede und nimmt auch morphometrisch eine Randposition ein. Ein Weibchen aus dem Iran (Lokalität Rudbar) besitzt sowohl in qualitativ morphologischer als auch in morphometrischer Hinsicht deutlich abweichende Merkmale gegenüber allen übrigen Individuen. Aufgrund der geringen Individuenzahl ist in beiden Fällen eine taxonomische Zuordnung derzeit nicht möglich.

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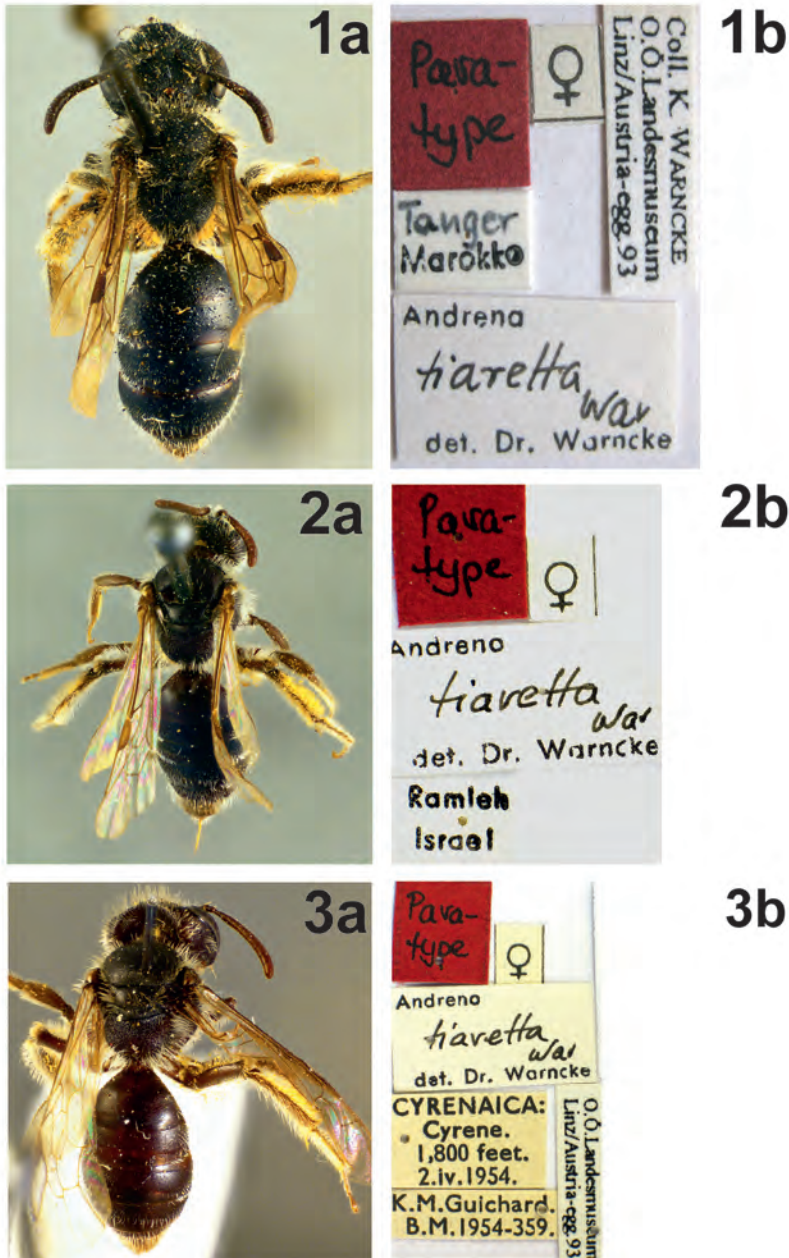
Fig. 1: *Andrena tiaretta* s.str. (female) from Morocco, OLML 110. **Fig. 2**: *A. orientalis* nov.sp. (female) from Israel, OLML 116. (**a**) dorsal view; (**b**) labels. **Fig. 3**: *A. cyrenaica* nov.sp. (female) from Lybia, OLML 120. (**a**) dorsal view; (**b**) labels. All specimens deposited in the 'Biology Centre of the Upper Austrian Provincial Museum Linz' (Austria). Photos L. Haitzinger.
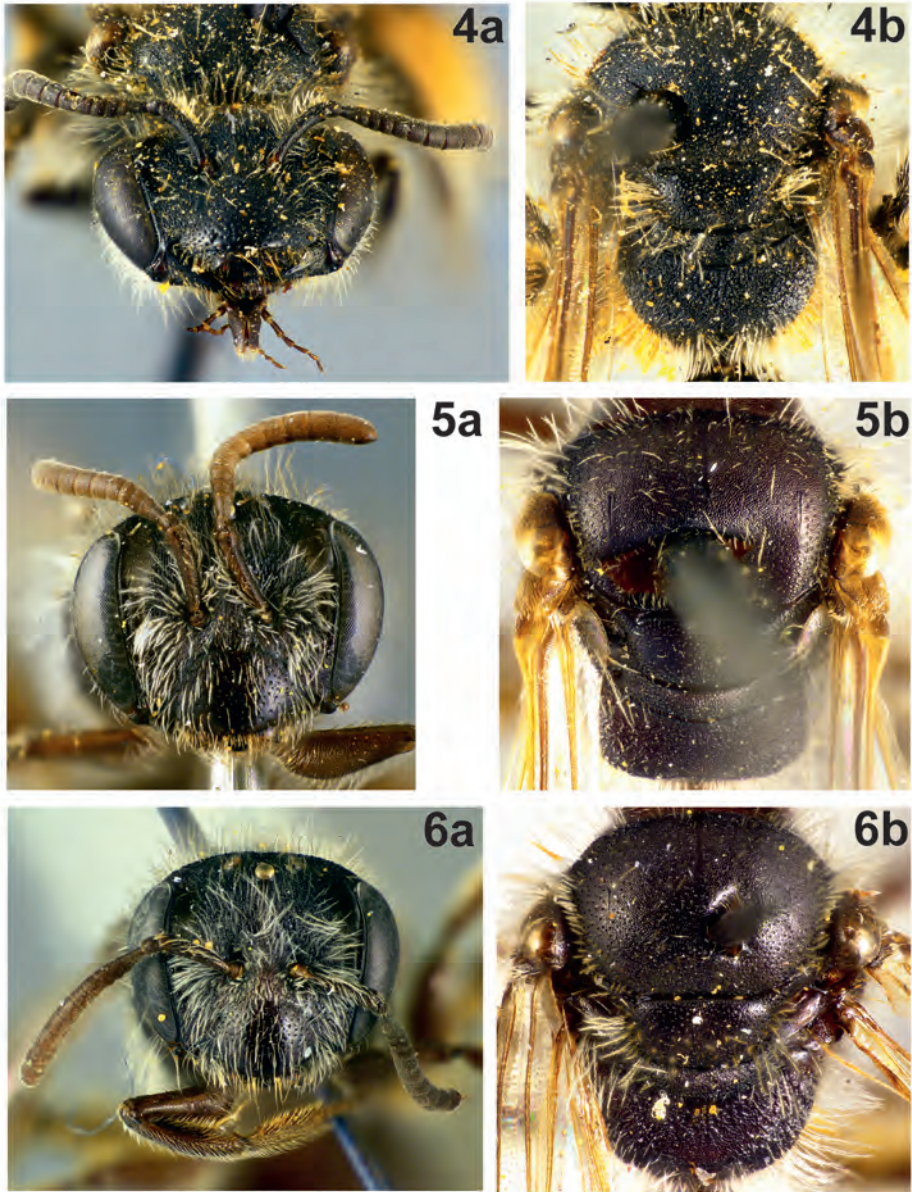
Fig. 4: *Andrena tiaretta* s.str. (female) from Morocco, OLML 110; **Fig. 5**: *A. orientalis* nov.sp. (female) from Israel, OLML 116; **Fig. 6**: *A. cyrenaica* nov.sp. (female) from Lybia, OLML 120; (**a**) head frontal view; (**b**) dorsal view mesoscutum, scutellum, postscutellum, propodeum. Photos L. Haitzinger.
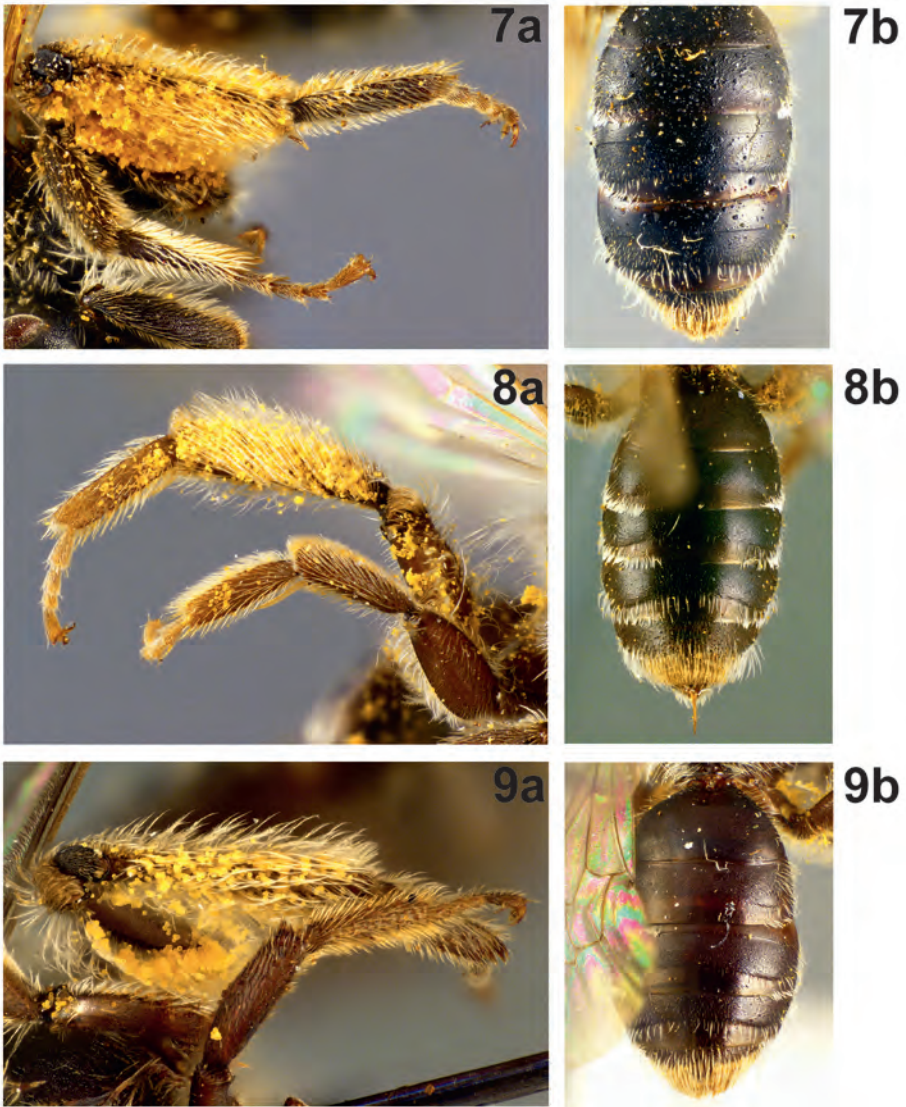
Fig. 7: *Andrena tiaretta* s.str. (female) from Morocco, OLML 110; **Fig. 8**: *A. orientalis* nov.sp. (female) from Israel, OLML 116; **Fig. 9**: *A. cyrenaica* nov.sp. (female) from Lybia, OLML 120; (**a**) tibia, metatarsus, tarsi 2, 3, tibial scopa; (**b**) dorsal view mesoscutum. Photos L. Haitzinger.
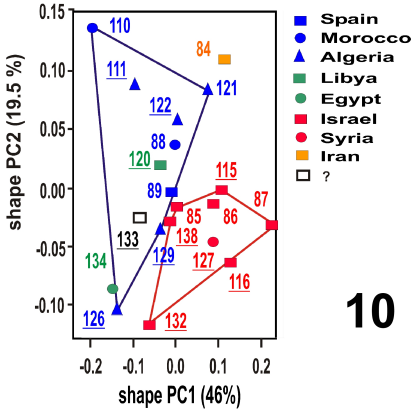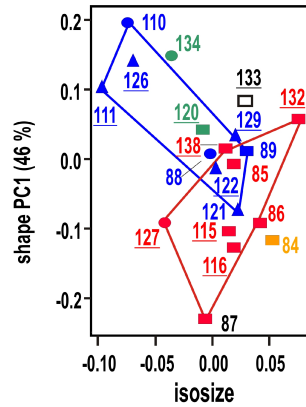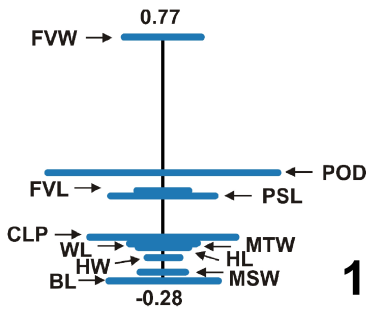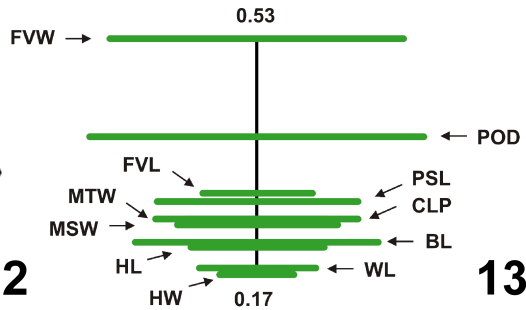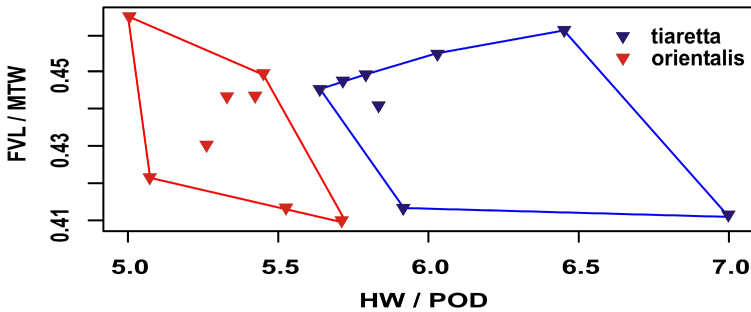
Fig. 10: Shape PCA, scatterplot of first against second shape PCA of *Andrena tiaretta* s.l. females from all localities, using all variables without OCD and LPW. **Fig. 11**: Scatterplot of isosize against first shape PCA of *Andrena tiaretta* s.l. females using the data set of Fig. 10. **Fig. 12**: PCA ratio spectrum for shape PC1 of *Andrena tiaretta* s.l. females; **Fig. 13**: Allometry ratio spectrum of *Andrena tiaretta* s.l. females. **Fig. 14**: Scatterplot of the both best ratios (FL1/POD; HW/MTW) of *Andrena tiaretta* s.str. and *A. orientalis* nov.sp. females.
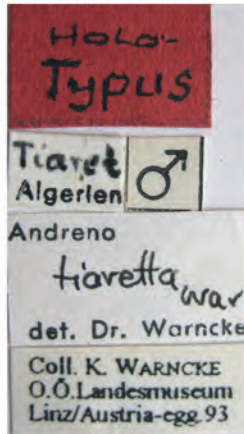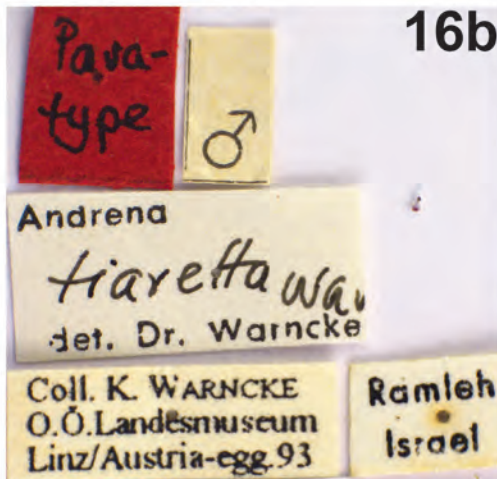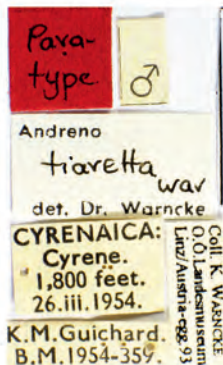
Fig. 15: *Andrena tiaretta* s.str. (male) from Algeria, OLML 112. **Fig. 16**: *A. orientalis* nov.sp. (male) from Israel, OLML 125. (**a**) dorsal view; (**b**) labels. **Fig. 17**: *A. cyrenaica* nov.sp. (male) from Lybia, OLML 128. (**a**) dorsal view; (**b**) labels. All specimens deposited in the 'Biology Centre of the Upper Austrian Provincial Museum Linz' (Austria). Photos L. Haitzinger.
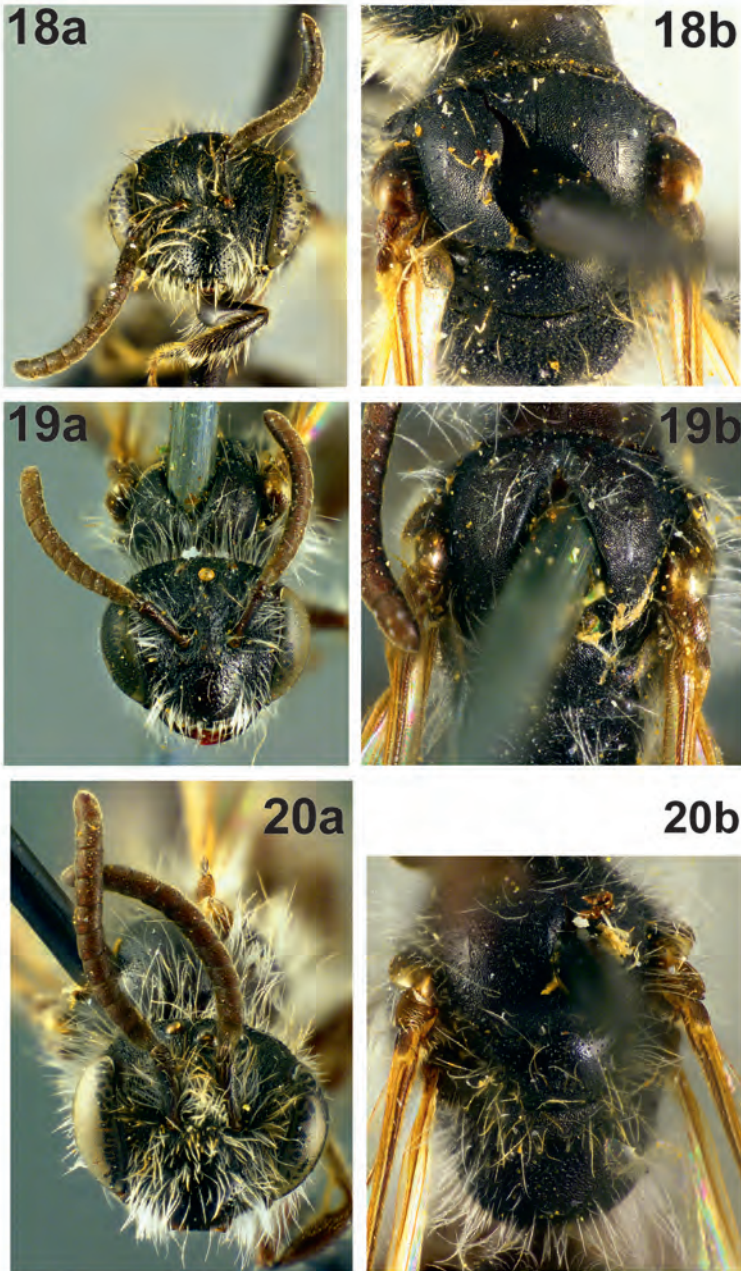
Fig. 18: *Andrena tiaretta* s.str. (male) from Algeria, OLML 112; **Fig. 19**: *A. orientalis* nov.sp. (male) from Israel, OLML 125; **Fig. 20**: *A. cyrenaica* nov.sp. (male) from Lybia, OLML 128; (**a**) head frontal view; (**b**) dorsal view mesoscutum, scutellum, postscutellum, propodeum. Photos L. Haitzinger.
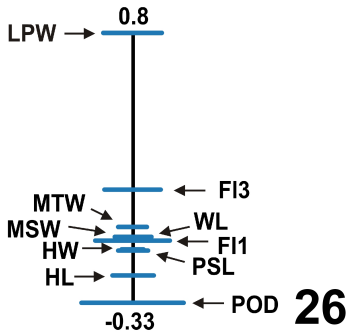
Fig. 21: *Andrena tiaretta* s.l. (male) from Algeria, OLML 112; **Fig. 22**: *A. orientalis* nov.sp. (male) from Israel, OLML 125; **Fig. 23**: *A. cyrenaica* nov.sp. (male) from Lybia, OLML 128; (**a**) dorsal view mesoscutum. (**b**) genital. Photos L. Haitzinger.
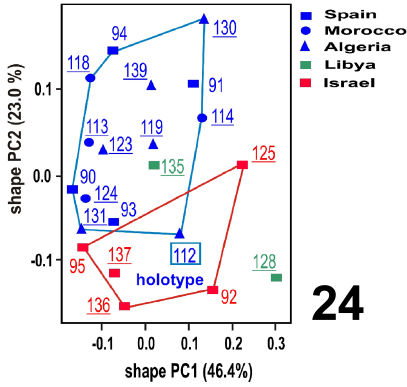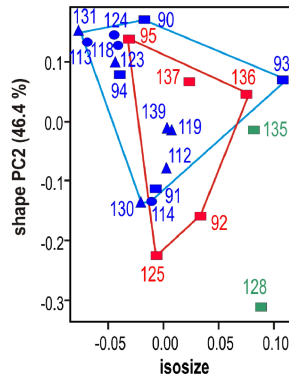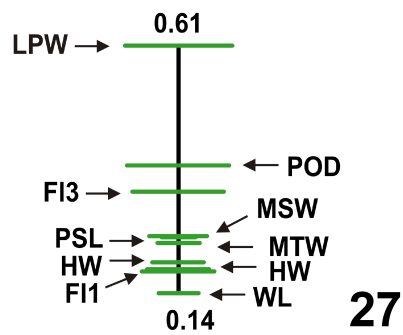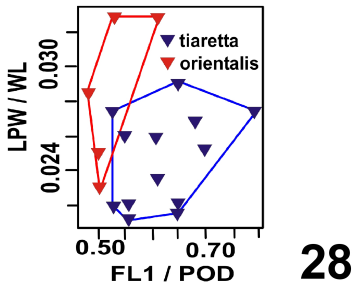
Fig. 24: Shape PCA, scatterplot of first against second shape PCA of *Andrena tiaretta* s.l. males from all localities, using all variables without FL2. **Fig. 25**: Scatterplot of isosize against first shape PCA of *Andrena tiaretta* s.l. males using the data set of Fig. 24. **Fig. 26**: PCA ratio spectrum for shape PC1 of *Andrena tiaretta* s.l. males. **Fig. 27**: Allometry ratio spectrum of *Andrena tiaretta* s.l. males. **Fig. 28**: Scatterplot of the both best ratios (FL1/POD; LPW/WL) of *Andrena tiaretta* s.str. and *A. orientalis* nov.sp. males.