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POLLEN MORPHOLOGY IN THE TRIBE *NIGELLEAE* (RANUNCULACEAE): A WORLDWIDE PALYNOLOGICAL INVESTIGATION INTO THE SPECIES

SERAP IŞIK[1*], EMEL OYBAK DÖNMEZ[2*], ZÜBEYDE UĞURLU AYDIN[2] AND ALİ A. DÖNMEZ[2]

[1]*Department of Mathematics and Science Education, Hacettepe University, Beytepe, Ankara, Turkey*

[2]*Laboratory of Plant Molecular Systematic (MOBİS), Department of Biology, Hacettepe University, Beytepe, Ankara, Turkey*

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The pollen morphology of many collections of taxa of the tribe *Nigelleae* from the family Ranunculaceae which occur worldwide is presented in this study. A total of 88 specimens from 21 taxa, some of which were recently proposed, belonging to the genera *Komaroffia*, *Garidella*, and *Nigella* of *Nigelleae* were examined using light microscopy (LM) and scanning electron microscopy (SEM). In the tribe, the pollen type is mostly trizonocolpate, but in many taxa and specimens, both trizonocolpate and non-trizonocolpate types occur together. The pollen grains are small to medium (25–53.75 μm × 20–55 μm) in size and oblate to prolate in shape. The exine pattern at the mesocolpium in all the taxa investigated is similar: micro-echinate in LM and micro-echinate-punctate in SEM. The colpus membrane in *Komaroffia* and *Nigella* is micro-echinate in both LM and SEM. In *Garidella*, it is micro-echinate in LM but echinate (spinulose) in SEM.

In this study, multivariate analyses, principal component analysis (PCA), and unweighted pair group method with arithmetic mean (UPGMA), were used to evaluate relationships between the genera and species within the tribe with respect to pollen morphology. PCA results show three main groups in the tribe: *Garidella*, *Komaroffia*, and *Nigella*. Moreover, the UPGMA tree also chiefly supports generic segregation into the smaller genera. An overall synthesis of the pollen characteristics of the three genera is provided and discussed.

Keywords: *Garidella*, *Komaroffia*, multivariate analysis, *Nigella*, Ranunculaceae, pollen morphology

INTRODUCTION

Komaroffia, *Garidella*, and *Nigella* are morphologically similar taxa that were recently accepted as three separate genera of the tribe *Nigelleae*, belonging to the family Ranunculaceae (Tamura, 1993; Strid, 1997). However, the previous taxonomic treatments of the taxa by several authors varied, and they were based only on morphological grounds (Terraciano, 1897-1898; Krasheninnikov, 1937; Davis, 1965; Meikle, 1977; Zohary, 1983; Riedl, 1992; Tutin and Akeroyd, 1993). In the present study, the recent and most comprehensive revision of the tribe by Dönmez et al. (under revision) is followed, in which *Komaroffia*, *Garidella*, and *Nigella* are evaluated separately in the tribe *Nigelleae*. The revision is based on the studies of several aspects of the species worldwide, including taxonomy, pollen morphology, cytology, seed morphology, numerical analyses, and biochemistry.

The tribe *Nigelleae* comprises 18 species from the three genera. *Komaroffia* and *Garidella* are small genera; the former having been recently proposed to be represented by two species (Dönmez et al., under revision), while the latter is accepted to be represented by two species. The genus *Nigella* is represented by 14 species, including one newly accepted species, *N. koyuncui* (Dönmez et al., 2015) and three taxa proposed as varieties.

The members of the tribe mainly occur throughout the Mediterranean region and western Asia. *Nigella* populations also extend westward to central Europe and eastward to central Asia

* Corresponding author, email: serapi@hacettepe.edu.tr; emeloybakdonmez@gmail.com

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(Zohary, 1983; Tamura, 1993). Studies of chloroplast DNA variation in the populations of the so-called *Nigella arvensis* complex revealed the presence of three major lineages, with largely non-overlapping distributions in the western, central, and eastern Aegean region (Bittkau and Comes, 2005; Comes et al., 2008). The flowers of the genera are mainly insect-pollinated (Weber, 1993; Zaitoun et al., 2008; Munawar et al., 2009). Some species in the *N. arvensis* complex are known to be autogamous (Ellmer and Andersson, 2004).

Nigella has several species of ethnopharmacological interest (*N. arvensis*, *N. damascena*, and *N. sativa*), as their seeds have substances with pharmacological activities (Baytop, 1999; Kökdil et al., 2006; Moghaddasi, 2011; Heiss et al., 2013). *Nigella sativa* is locally cultivated in southwestern Asia, northern Africa, and in Europe. Its aromatic seeds are also used to flavor bread and cheese.

The pollen morphology of Ranunculaceae has received a great deal of attention by research workers (Erdtman et al., 1961; Santisuk, 1979; Fernandez, 1986; Clarke et al., 1991; Lee and Blackmore, 1992; Khan, 1994; Tatlıdil et al., 2005; Perveen and Qaiser, 2006; Penny and Steven, 2009; Xie and Li, 2012; Zhang et al., 2015; Humphrey, 2016). However, previous studies on pollen morphology of the closely related genera from the family, i.e., *Komaroffia*, *Garidella*, and *Nigella*, included only some species and a few specimens (Wodehouse, 1936; Aytuğ, 1971; Skvarla and Nowicke, 1979; Al-Eisawi, 1986; Clarke et al., 1991; Liang-qian, 1995; Qureshi et al., 2002; Oybak Dönmez and Işık, 2008; Takhtajan, 2009; Oberschneider et al., 2016).

The aim of this study was to investigate pollen morphology of the *Nigelleae* species on a global scale. The study was based on the examination of many specimens by light and electron microscopy together with size measurements and multivariate analyses.

MATERIALS AND METHODS

PLANT MATERIAL

The pollen material used in the present study was either collected by Ali A. Dönmez (*AAD*) in the field in several countries in Eurasia, including Cyprus, Greece, Syria, and Turkey or taken from the herbaria of Ankara University-Pharmacy Faculty (AEF) and Hacettepe University (HUB) in Turkey, Coimbria (COI) in Portugal, and Austria National Herbarium (W) in Vienna. The voucher specimens are listed in Supplementary material S1. The plant specimens collected from Turkey are all deposited at HUB. In many cases more than one specimen per taxon was investigated to try to determine any possible intraspecific variation in pollen morphology, but for few taxa adequate material was not available to enable such investigation.

The species and the taxonomic order given in this study followed the recent revision of the tribe *Nigelleae* by Dönmez et al. (under revision). In this revision, there are new proposals for some taxa that are treated differently from those given in the previous studies: *Nigella bucharica* N. Schipcz. is named as *Komaroffia bucharica*, while *N. arvensis* L. subsp. *aristata* Nyman is treated as a variety, *N. arvensis* L. var. *aristata*. In addition, *Nigella latisecta* P.H. Davis and *N. lancifolia* Hub.-Mor. are proposed as varieties of *Nigella oxypetala*, *N. oxypetala* var. *latisecta*, and *N. oxypetala* var. *lancifolia*, respectively. The genus *Nigella* is also treated according to infrageneric classification of three sections, *Erobathos*, *Nigellaria*, and *Nigellastrum*, following De Candolle (1817, 1824) and Willkomm and Lange (1880).

A total of 88 specimens from the accepted and proposed 21 taxa were investigated: *Komaroffia* (2 species, 4 specimens), *Garidella* (2 species, 13 specimens), and *Nigella* (17 species, 71 specimens) (Table 1 in Supplementary material).

LIGHT MICROSCOPIC (LM) STUDIES

For LM observations, the pollen was first treated with 70% ethyl alcohol to remove oily substances, and then embedded in glycerin-jelly and stained with safranin to prepare pollen slides (Wodehouse, 1935). Photomicrographs were produced using a Leica DFC 320 digital camera connected to a Leica DM 4000 B microscope. To determine pollen types, two pollen slides for each sample were examined from traverses covering the whole slide. Size measurements were made on the most frequent trizonocolpate type pollen grains. The following parameters were measured: pollen size, given by the polar axis (P) and equatorial axis (E); exine (sexine and nexine) and intine thickness in the polar area; mesocolpium and margo; and colpus width (Clt) in the equatorial view. The colpus length (Clg) could not be measured in the equatorial view because the colpi extend to almost the full length of the grain. The apocolpium index (polar area index) was calculated as the ratio of the mean distance between the apices of two colpi to its equatorial diameter. The pollen size (P and E) was measured for 50 pollen grains per specimen. Pollen grains from < 20–40 μm were defined as 'small' and 41–55 μm as 'medium'. The other measurements were made on ten grains per specimen. The means (M), standard deviations (SD), and ranges (V) for P and E measurements as well as the means and ranges for the other

measurements are given in Table 1 (Supplementary material). All statistical analyses were run by PASW (SPSS) Statistics 17.0 and IBM Minitab 18.1.

SCANNING ELECTRON MICROSCOPIC (SEM) STUDIES

For SEM study, the pollen was first treated with 70% ethyl alcohol, then air-dried before being mounted on SEM specimen stubs and subsequently coated with gold. The photomicrographs were taken using a Zeiss EVO 50 EP electron microscope.

The clearest LM and SEM photographs representing the main pollen features were selected for this paper. The palynological terminology mainly follows Punt et al. (2007) and Hesse et al. (2009).

MULTIVARIATE DATA ANALYSES

Individual value plot analysis was utilized for the mean polar (P) and equatorial (E) axes, while principal component analysis (PCA) was utilized for the following pollen characteristics: the mean polar and equatorial axes, apocolpium index, and the mean length of colpus. Exine and intine size values were excluded from the analyses. Cluster analysis was also performed using the unweighted pair group method with arithmetic mean (UPGMA) method using Past 3.2 version (Hammer et al., 2001). The taxa and their acronyms are as follows: *Garidella nigellastrum* GN, *G. unguicularis* GU, *Komaroffia integrifolia* KI, *K. bucharica* KB, *Nigella arvensis* var. *arvensis* NAVA, *N. arvensis* var. *aristata* NAVAR, *N. koyuncui* NK, *N. stellaris* NS, *N. fumariifolia* NF, *N. sativa* NSA, *N. turcica* NT, *N. gallica* NG, *N. papillosa* subsp. *atlantica* NPVA, *N. segetalis* NSE, *N. damascena* ND, *N. elata* NE, *N. orientalis* NO, *N. oxypetala* var. *oxypetala* NOVO, *N. oxypetala* var. *lancifolia* NOL, *N. oxypetala* var. *latisecta* NOLA, and *N. ciliaris* NC.

RESULTS

GENERAL POLLEN CHARACTERISTICS OF THE TRIBE *NIGELLEAE*

Pollen grains occur as monads. The most frequent pollen type is trizonocolpate (with three equatorially situated colpi) (Table 1 in Supplementary material, Figs. 1a–n, 2a,c). In some taxa and specimens both trizonocolpate and non-trizonocolpate pollen grains occur together. Non-trizonocolpate pollen grains are represented by some pollen types, including zona-aperturate (with a ring-like aperture), dicolpate, and synaperturate with various forms of colpi/apertures (Figs. 1o–t, 2g,h).

Trizonocolpate pollen grains are radially symmetrical, isopolar, and small to medium in size; the polar axis (P) measures 25–53.75 μm, and the equatorial axis (E) measures 20–55 μm. The pollen is usually prolate-spheroidal, occasionally subprolate in *Komaroffia*; usually subprolate and occasionally prolate-spheroidal in *Garidella*; and usually oblate-spheroidal, occasionally prolate-spheroidal, or subprolate in *Nigella*. The shape in polar view is angular in *Komaroffia* and *Garidella* (Figs. 1a,f), while it is circular (Fig. 1k) or angular in *Nigella*. The apocolpium index ranges from 0.19 to 0.41. In trizonocolpate pollen grains the colpi are usually long and 1–16.25 μm wide, the colpi ends are usually obtuse, occasionally acute; the margins are distinct and irregular. In LM, the colpus membrane is micro-echinate in all *Nigelleae* species (Figs. 1e,j,n); in SEM, it is echinate (spinulose) in *Garidella* (Fig. 2d), while it is micro-echinate in *Komaroffia* (Fig. 2b) and *Nigella* (Fig. 2e). The exine is thick; sexine thickness is 1–5 μm in the mesocolpium, 1.5–4 μm in the polar area, and 1–3 μm in the margo. The sexine is usually thinner than the adjacent mesocolpium and it is thicker than the nexine; the nexine thickness is 0.5–1 μm in the polar area, 0.5–1.5 μm in the mesocolpium, and 0.5–2 μm in the margo. In all taxa, the exine is tectate-columellate; in LM, the exine pattern is micro-echinate (Figs. 1b,d,g,i,n), and in SEM it is micro-echinate-punctate (perforate) (Fig. 2f). The intine is quite thin, < 1 or 1 μm thick, having almost the same thickness throughout the pollen.

POLLEN MORPHOLOGY IN *KOMAROFFIA*

Pollen grains are usually trizonocolpate (Table 1 in Supplementary material, Figs. 1a–e, 2a,b). In *K. integrifolia*, both trizonocolpate and non-trizonocolpate pollen grains occur. The pollen is small to medium in size; P 25–48 μm, E 23–49 μm. The pollen shape is prolate-spheroidal, with the exception of one specimen of *K. integrifolia* (from the province of Dschebel-Seradsch in Afghanistan by *A. Gilli* 827) which has subprolate pollen grains. The shape in polar view is angular; the apocolpium index is 0.23–0.26. The colpi are 5–14 μm wide; the colpi ends are obtuse; the margins are distinct, irregular; the colpus membrane is micro-echinate in LM and SEM. The exine is thick; the sexine thickness is 1.5–2.75 μm in the polar area, 1–2 μm in the mesocolpium, 0.9–1.75 μm in the margo; the sexine is thicker than the nexine, and the nexine thickness is 0.50–1 μm in the polar area, mesocolpium and margo. The exine is tectate-columellate; the exine pattern is micro-echinate in LM and micro-echinate-punctate in SEM. The intine is thin; it is < 1 μm or 1 μm thick, having almost the same thickness throughout the pollen.

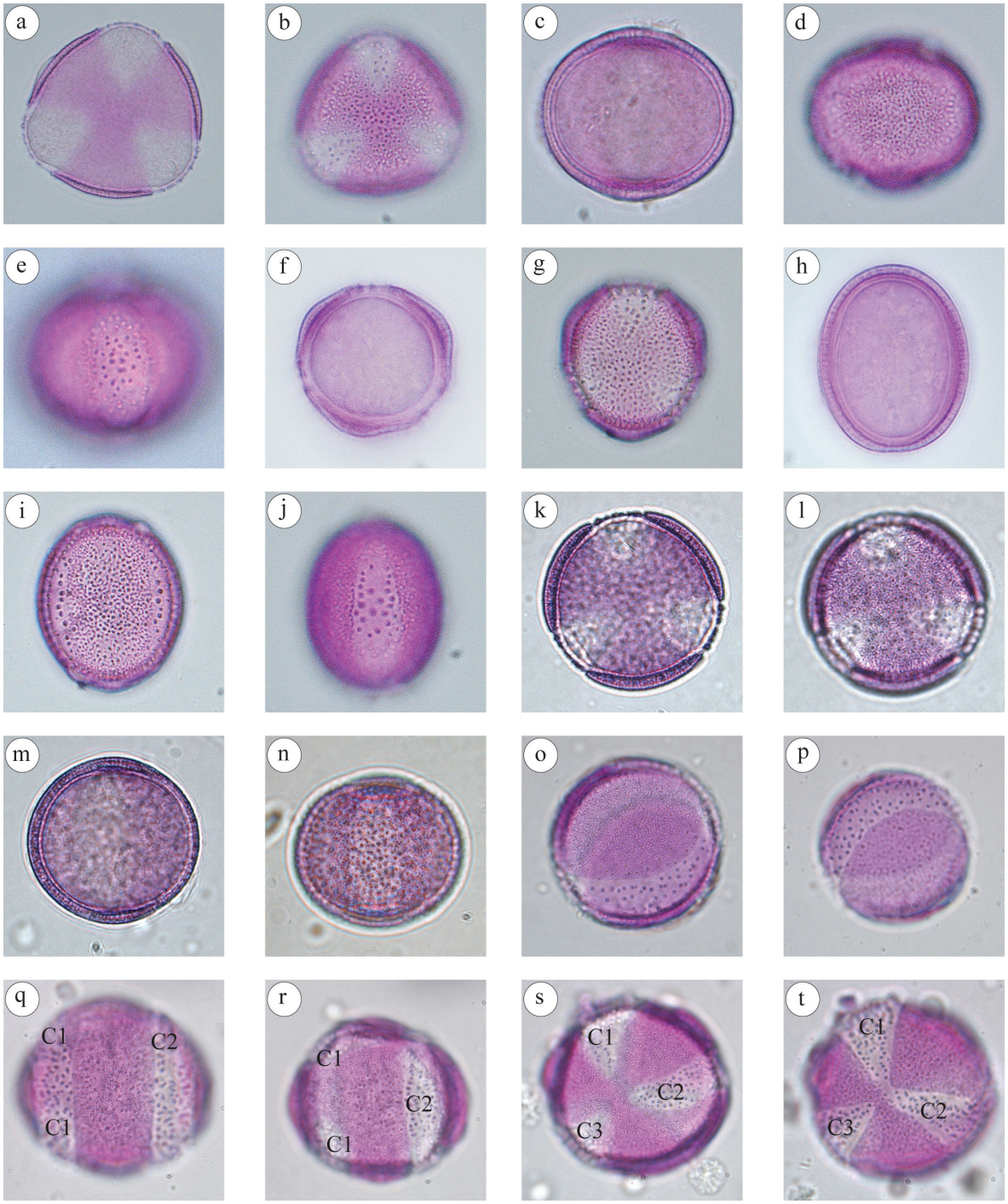

Fig. 1. Selected LM micrographs of pollen grains in the tribe *Nigelleae* (1000×). (**a**–**e**) trizonocolpate pollen in *Komaroffia integrifolia* (**a**) polar view, (**b**) micro-echinate exine pattern in polar area, (**c**) equatorial view in optical cross section, (**d**) micro-echinate exine pattern in mesocolpium, (**e**) colpus with micro-echinate membrane, (**f**–**j**) trizonocolpate pollen in *Garidella unguicularis*, (**f**) polar view, (**g**) micro-echinate exine pattern in polar area, (**h**) equatorial view in optical cross section, (**i**) micro-echinate exine pattern in mesocolpium, (**j**) colpus with micro-echinate membrane, (**k**–**n**) trizonocolpate pollen in *Nigella* (**k**–**l**; *N. arvensis* var. *aristata*) (**k**) polar view, (**l**) micro-echinate exine pattern in polar area, (**m**) equatorial view in optical cross section in *N. segetalis*, (**n**) micro-echinate exine pattern in mesocolpium and colpus membrane in *N. sativa*, (**o**–**t**) non-trizonocolpate in *N. orientalis*, (**o**–**p**) zona-aperturate pollen with a ring-like aperture at different foci, (**q**–**r**) dicolpate pollen at different foci (C – colpus, C1 and C2 represent two separate semi-circled colpi), (**s**–**t**) syn-aperturate pollen with two anastomosing colpi (C1, C2) and one free colpus (C3) at different foci.

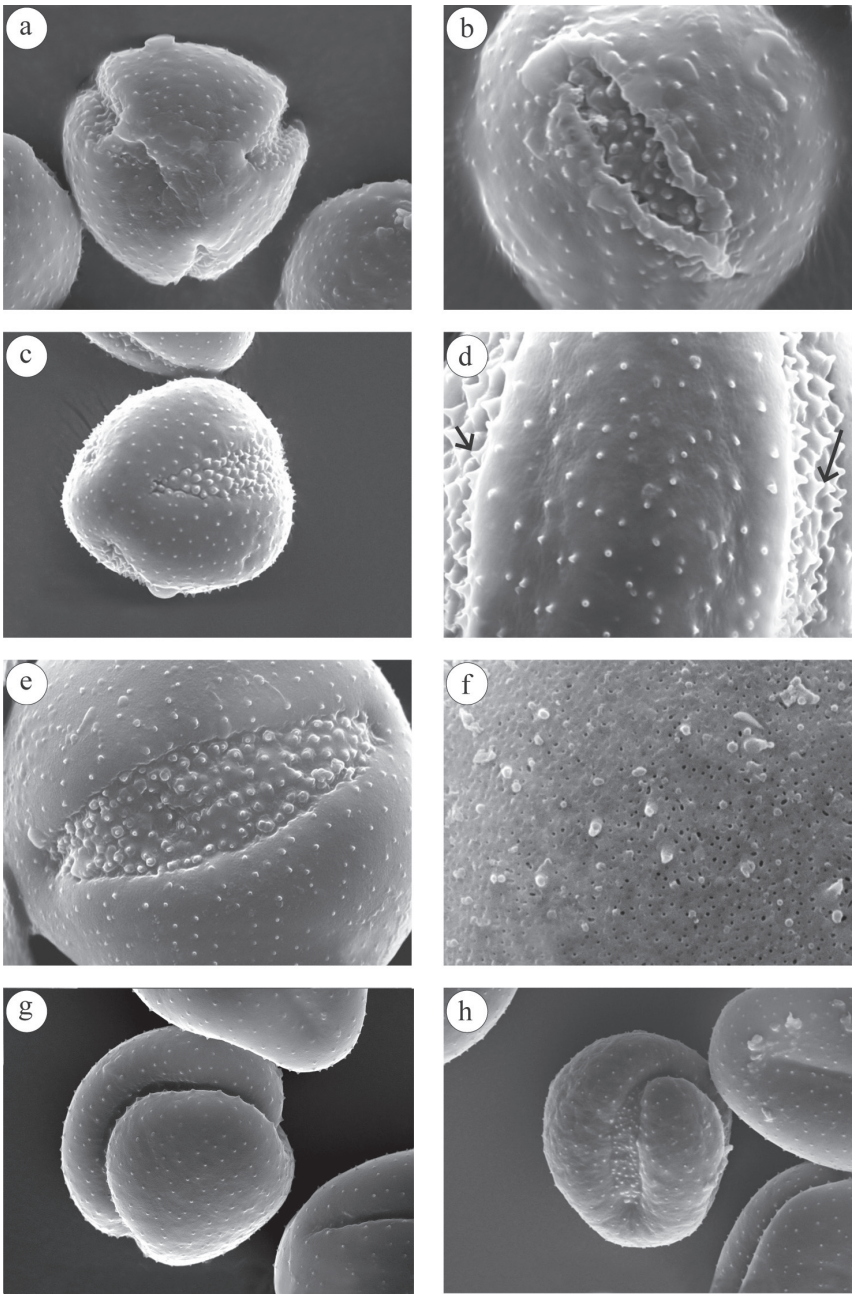

Fig. 2. Selected SEM micrographs of pollen grains in *Nigelleae*. (**a**–**f**) trizonocolpate pollen grains: (**a**–**b**) *Komaroffia integrifolia* (**a**) pollen in polar view (7330×), (**b**) micro-echinate colpus membrane (12080×), (**c**–**d**) *Garidella unguicularis* (**c**) pollen with echinate (spinulose) colpus membrane in polar view (7160×), (**d**) a closer view of echinate (spinulose) colpus membrane (arrowed) (17880×), (**e**) micro-echinate colpus membrane in *Nigella papillosa* subsp. *atlantica* (10000×), (**f**) micro-echinate-punctate exine pattern in mesocolpium in *N. arvensis* var. *aristata* (35000×), (**g**–**h**) non-trizonocolpate pollen grains in *N. elata* (**g**, 6100× and **h**, 4560×).

POLLEN MORPHOLOGY IN *GARIDELLA*

Pollen grains are usually trizonocolpate (Table 1 in Supplementary material, Figs. 1f–j, 2c–d). In one specimen of *G. nigellastrum* (from the province of Gazimagusa in Cyprus by *AAD* 15928) and two specimens of *G. unguicularis* (from the province of Kahramanmaraş in Turkey by Z. Aytaç 4867-H. Duman and from the province of Damascus in Syria by AAD 15440), both trizonocolpate and non-trizonocolpate pollen grains occur. The pollen

is small in size; P 25–36.25 μm, E 20–32.5 μm. The pollen shape is subprolate, with the exception of one specimen of *G. nigellastrum* (from the province of Mersin in Turkey by *AAD* 15965) and of *G. unguicularis* (from the province of Damascus in Syria by *AAD* 15440), both of which have prolate-spheroidal pollen grains. The shape in polar view is angular; the apocolpium index is 0.24–0.36. The colpi are 6–10 μm wide; the colpi ends are obtuse; the margins are distinct, irregular; the colpus membrane is micro-echinate in LM and echinate (spinulose) in SEM. The exine is thick; the sexine thickness is 1.5–2.5 μm in the polar area and mesocolpium, 0.7–1.5 μm in the margo; the sexine is thicker than the nexine, and the nexine has almost the same thickness in the polar area (0.9–1 μm), mesocolpium and margo (0.5–1 μm). The exine is tectate-columellate; the exine pattern is micro-echinate in LM, micro-echinate–punctate in SEM. The intine is thin; it is < 1 μm or 1 μm thick, having almost the same thickness throughout the pollen.

POLLEN MORPHOLOGY IN *NIGELLA*

Pollen grains are usually trizonocolpate (Table 1 in Supplementary material, Figs. 1k–n, 2e–f). Both trizonocolpate and non-trizonocolpate (Figs. 1o–t, 2 g–h) pollen grains occur in some specimens of many taxa (*N. damascena*, *N. elata*, *N. gallica*, *N. arvensis* var. *arvensis*, *N. arvensis* var. *aristata*, *N. segetalis*, *N. sativa*, *N. turcica*, *N. orientalis*, *N. oxypetala* var. *oxypetala*, *N. oxypetala* var. *latisecta*, *N. oxypetala* var. *lancifolia* and *N. ciliaris*) in the genus. The pollen is small to medium in size; P 25–53.75 μm, E 25–55 μm. The pollen shape is usually oblate-spheroidal. *N. damascena*, *N. gallica*, *N. papillosa subsp. atlantica* and *N. arvensis* var. *arvensis* have both oblate-spheroidal and prolate-spheroidal pollen grains, while *N. fumariifolia* has both prolate-spheroidal and subprolate pollen grains. The shape is circular or angular in polar view; the apocolpium index is 0.19–0.41. The colpi are 1–16.25 μm wide; the colpi ends are usually obtuse, occasionally acute; the margins are distinct, irregular; the colpus membrane is micro-echinate in LM and SEM. The exine is thick; the sexine thickness is 2–4 μm in the polar area, 1–5 μm in the mesocolpium and 1–3 μm in the margo; the sexine is thicker than the nexine, and the nexine thickness is 0.5–1.5 μm in the polar area and mesocolpium, 0.5–2 μm in the margo. The exine is tectate-columellate; the exine pattern is micro-echinate in LM, micro-echinate-punctate in SEM. The intine is thin; it is < 1 μm or 1 μm thick, having almost the same thickness throughout the pollen.

EVALUATION OF MULTIVARIATE ANALYSES OF SOME POLLEN CHARACTERISTICS IN THE TRIBE *NIGELLEAE*

Individual value plot analysis shows that pollen grains of *Komaroffia* and *Garidella* are smaller than those of *Nigella* (Figs. 3a,b). The PCA result revealed affinities among the taxa; three main groups are clustered in the plot (Fig. 4). All *Nigella* taxa are loaded separately from the remaining taxa, while *Garidella* and *Komaroffia* are located closer to each other. Moreover, cluster analysis produced the phenogram with three groups with an insufficient bootstrap value (Supplementary material S2). However, *Garidella* and *Komaroffia* taxa are nested together with *N. arvensis* var. *aristata* and *N. sativa*. The other two groups included the remaining *Nigella* taxa with one individual of *Garidella nigellastrum*.

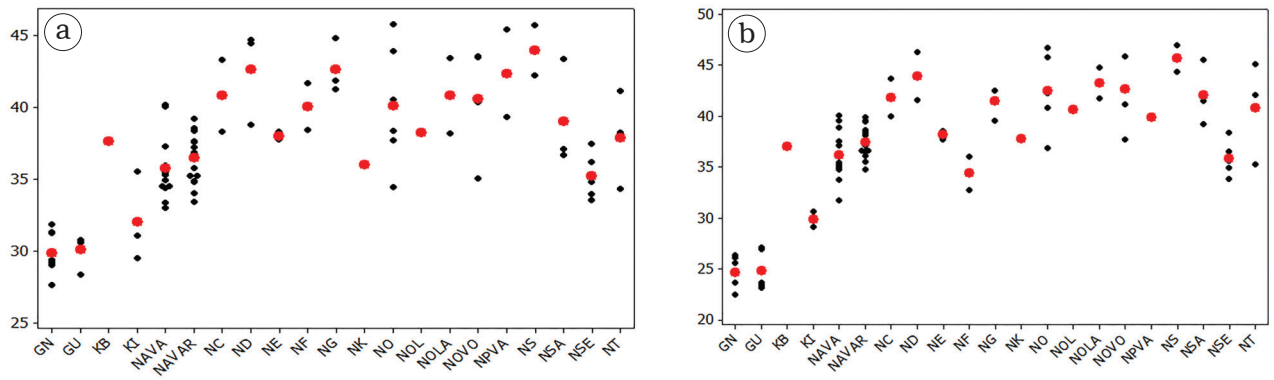

Fig. 3. Individual Value Plot of pollen polar axis (P) and equatorial axis (E) in *Nigelleae*. (**a**) individual value plot of polar axis (black dot = individual value of each value, red dot = mean value of polar axis), (**b**) individual value plot of equatorial axis (black dot = individual value of each value, red dot = mean value of equatorial axis).

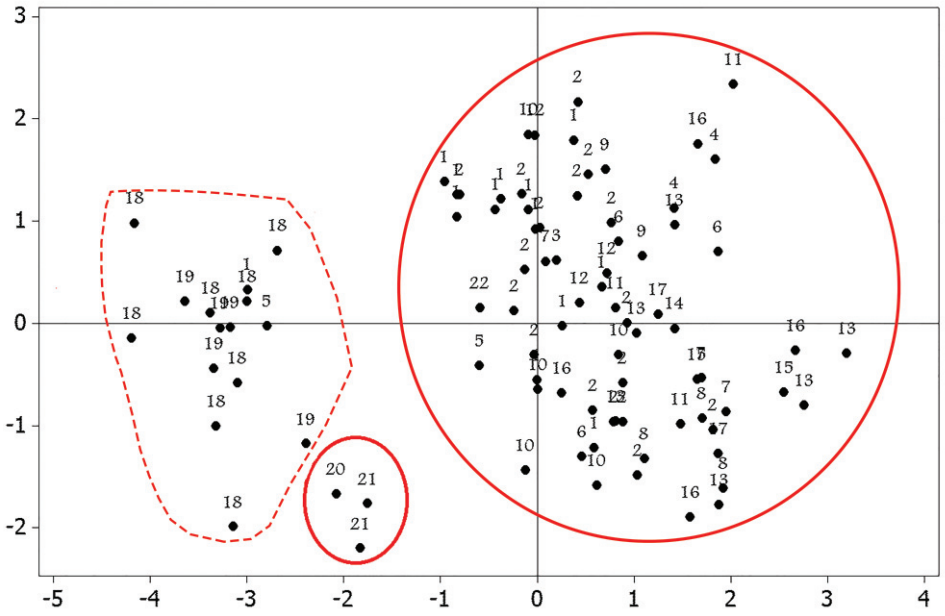

Fig. 4. Plot of PCA based on quantitative values: 1 – *Nigella arvensis* var. *arvensis*, 2 – *N. arvensis* var. *aristata*, 3 – *N. koyuncui*, 4 – *N. stellaris*, 5 – *N. fumariifolia*, 6 – *N. sativa*, 7 – *N. turcica*, 8 – *N. gallica*, 9 – *N. papillosa* subsp. *atlantica*, 10 – *N. segetalis*, 11 – *N. damascena*, 12 – *N. elata*, 13 – *N. orientalis*, 14 – *N. oxypetala* var. *lancifolia*, 15 – *N. oxypetala* var. *latisecta*, 16 – *N. oxypetala* var. *oxypetala*, 17 – *N. ciliaris*, 18 – *Garidella nigellastrum*, 19 – *G. unguicularis*, 20 – *Komaroffia integrifolia*, 21 – *K. bucharica*. (three main groups are represented in the three circles based on PCA results).

DISCUSSION

All the investigated species of the tribe *Nigelleae* have pollen features that are common to many Ranunculaceae types: the grains are predominantly trizonocolpate and the exine pattern is microechinate in LM. In some species, both trizonocolpate and non-trizonocolpate grains occur. The present study revealed that the genera *Komaroffia*, *Garidella*, and *Nigella* are similar in most respects of pollen morphology. The resemblance between anatomies of the genera was discussed by Corneanu et al. (1987) and Kökdil et al. (2006). However, there are some palynological differences between these closely related genera, even within the genera (Table 1 in Supplementary material).

The genera in *Nigelleae* were treated differently in taxonomy by several authors. Sibthorp and Smith (1806) and Bentham-Hooker (1862) placed the three genera under infrageneric taxa in the genus *Nigella*, while Zohary (1983), Tamura (1993), and Strid (1997) placed them separately at the generic level. Based on PCA results in the present study, *Garidella* and *Komaroffia* taxa are well differentiated from *Nigella* taxa. UPGMA shows comparable results and provides mainly two groups (Figs. 4–5). Multivariate analyses indicate that *Nigella* species are clearly different from *Garidella* and *Komaroffia* species. A specimen of *N. fumariifolia* is nested in the *Garidella* group and the other one is in the *Nigella* group, according to the PSA analysis (Fig. 4). Both specimens have relatively smaller pollen grains. Pollen features of the tribe *Nigelleae* support this generic segregation.

Both *Komaroffia* and *Garidella* differ from *Nigella* in the pollen size. The pollen grains of *Komaroffia* and *Garidella* are smaller than those of *Nigella* (Figs. 3a,b). The results from PCA also support the differentiation between the three genera based on the pollen size (Fig. 4). The smallest dimensions are recorded in *Garidella*, while the largest dimensions are recorded in *Nigella*. In the genus *Komaroffia*, *K. bucharica* has larger pollen than *K. integrifolia* (Figs. 3a,b). These two species are also separated based on PCA and UPGMA (Figs. 4–5). The former species is also significantly bigger in habit, especially in the flower size, than the latter one (Dönmez et al., 2011). In addition, a correlation exists between ploidy and the increased pollen size. Karyological data have shown that *K. bucharica* has a higher chromosome number (2n = 14) (Zakharyeva 1985) than *K. integrifolia*, which has 2n = 12 (IPCN, 2011). Thus, for the first time, pollen morphology provides support for the separation of *K. bucharica* from *K. integrifolia*. The subspecies of the *Nigella arvensis* complex, which have been reported to be

characterized by phenotypic divergence, appear to be similar in their pollen characteristics.

In this study, it is revealed that many taxa and specimens from the species of the genera belonging to the tribe *Nigelleae* comprise other pollen types, along with trizonocolpate pollen within the same pollen sac. However, in several previous palynological studies, only the trizonocolpate pollen was recorded in the genera of the tribe (Wodehouse, 1936; Aytuğ, 1971; Al-Eisawi, 1986; Clarke et al., 1991). The co-occurrence of trizonocolpate and non-trizonocolpate pollen was noticed in several other genera of the family Ranunculaceae, such as *Actaea* L., *Adonis* L., *Anemone* L., *Caltha* L., *Clematis* L., *Ranunculus* L., and *Thalictrum* L. (Clarke et al., 1991; Tamura, 1993; Liang-qian, 1995; Humphrey, 2016). Pollen morphological variability, a fairly common phenomenon in modern angiosperms, may occur within the same individual and it may be related to several factors, such as functional specialization and ploidy within individuals (Borsch and Wilde, 2000). The aperture number, position, and form in pollen grains are the result of a series of developmental processes that comprise the type of microsporogenesis (related to the resulting tetrad shape), pollen polarity, and pollen wall formation (Furness and Rudall, 2004; Banks et al., 2007).

Based on the SEM studies, the pollen of *Komaroffia* and *Nigella* with a micro-echinate colpus membrane was distinguished from that of *Garidella* with a distinctly echinate (spinulose) colpus membrane. The exine is thick in all the genera. The presence of exinous structures on the colpus membrane in combination with the thick exine in the members of the genera would probably be an adaptive response to terrestrial conditions to protect the pollen protoplasm from dehydration since the species thrive mainly in dry habitats. They also probably function against the entry of pathogens into the apertures. They may also have a harmomegathic function, allowing expansion and contraction of the pollen grain in response to external conditions (Hesse et al., 2009).

With scanning electron microscopy, the exine pattern in the mesocolpium was shown to be micro-echinate-punctate in all the taxa within the tribe. It is widely accepted that elaborate exine surface patterns or pollen wall structures are associated with animal pollination (Chaloner, 1986; Hesse, 2000; Punt, 1986).

CONCLUSION

This study provided pollen data for a total of 88 specimens from 21 taxa belonging to the tribe *Nigelleae*, describing the characteristics of almost all the taxa worldwide. We also described some intergeneric and intrageneric pollen variations in the tribe. In some species of the tribe, variability in the aperture form was recorded in single pollen sacs.

AUTHORS' CONTRIBUTIONS

The authors contributed in the following manner to the investigation of the subject. SI, EOD: pollen morphological studies, photographing, text writing and editing; ZUA: material collections in Turkey, taxonomic studies, evaluation of multivariate data analyses; AAD: field work and herbarium visits in Eurasia for extensive material collections, taxonomic studies, revision, and evaluation of multivariate data analyses. The authors declare that there are no conflicts of interest.

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POLLEN MORPHOLOGY IN THE TRIBE *NIGELLEAE* (RANUNCULACEAE): A WORLDWIDE PALYNOLOGICAL INVESTIGATION INTO THE SPECIES

S1. Specimens investigated

S2. TABLE 1. Pollen morphological characters for each specimen studied. P polar axis, E equatorial axis, M mean, SD ± standard deviation, V ranges, TRZC trizonocolpate, NONTR non-trizonocolpate, OB-SPH oblate-spheroidal, P-SPH prolate-spheroidal, SP subprolate, Clt colpus width, ECH echinate, MECH micro-echinate, MECH-PU micro-echinate-punctate.

S3. UPGMA cluster analysis derived from pollen type and shape, the mean polar and equatorial axes, apocolpium index, the mean length of colpus based on Gower's coefficient. Bootstrap support values are indicated on the branches.

S1

Tribe ***Nigelleae*** Schröd.

Komarofia Kuntze

K. integrifolia (Regel) Lemos Pereira

Iran Horasan: Djeneran et Kujan, *K. H. Rechinger* 4704 (HUB)**;** between Chamanbid and Bojnurd; FUMH 28909 (HUB). **Afghanistan:** Nordost-Afghanistan, Gipfelregion eines Kalk-Limonit-Berges bei Dschebel-Seradsch, 1730 m, *A. Gilli* 827.

K. bucharica sensu lato (s. l.) - **Tajikistan:** 526 (E-photo!), W Herbarium no.14384.

Garidella L.

G. nigellastrum L.

Turkey B4 Kırşehir: Ömerhacı Village, 990 m, gypsiferous slopes, *B. Mutlu* 5061 (HUB)**; C5 Mersin:** Mut, Çamlıca Village, Near Akseki, 307 m, *A. A. Dönmez* (*AAD*) 15965 (HUB); **C6 Antakya:** Osmaniye, 2 km from Toprakkale to İskenderun, stony slopes, 58 m, *AAD* 15977 (HUB); **C8 Siirt:** 5 km from Siirt to Eruh, *AAD* 11174-*B. Mutlu* (HUB). **Cyprus Gazimagusa:** 3 km from Turnalar Village to Kantar, openings in *Juniperus-Pistacia* scrub, 165 m, *AAD* 15928 (HUB); 5 km from Büyükkonuk Village to Kalıca, in *Ceratonia siliqua* orchard, 137 m, *AAD* 15934 (HUB); **Güzelyurt:** Lefke, Cengizköy, clayey soil, 62 m, *AAD* 15948 (HUB). **Syria Aleppo:** Afrin, Questal Jindu Barsa Mountain, limestone slopes, in *Sarcopoterium* scrub, *AAD* 15453 (HUB).

G. unguicularis Lam.

Turkey C6 Kahramanmaraş: Ahır Mountain, near Küçükgöl, 1400-1700 m, *Z. Aytaç* 4867-*H. Duman* (HUB); **C8 Diyarbakır:** Çermik, around Sinek Village, *A. Güner* 6488 (HUB). **Syria Damascus:** Das, crop field margine, rocky slopes, *AAD* 15437-*B. A. Sawman* (HUB)**; Damascus:** Bloudan, slopes of Yunnan Mountain, 1740 m, *AAD* 15440 (HUB); **Aleppo:** Afrin, Questal Jindu, Barsa Mountain, limestone slopes, in *Sarcopoterium* scrub, 623 m, *AAD* 15454.

Nigella L.

Sect. ***Erobathos*** DC.

N. damascena L.

Greece: Nomos Kikladon, 50-70 m, *A. Tsopra* (HUB). **Turkey A1 Edirne:** Enez, 2 km to Enez, *Quercus* forest, 150 m, *AAD* 8718 (HUB). **A3 Düzce:** Akçakoca, *A. D. Koca* 1918 (HUB).

N. elata Boiss.

Turkey A3 Bolu: 14 km from Kıbrıscık to Bolu, roadside, in openings of *Juniperus excelsa* scrub, *AAD* 17617-*Z.Uğurlu* (HUB); **B2 Balıkesir:** 15 km to Saruhan, in *Quercus* scrub, 399 m, *AAD* 14994 (HUB); **C3 Isparta:** Eğirdir, Yukarıgökdere, in *Quercus* forest, 1700 m, *H.Peşmen-A.Güner* 1805 (HUB).

Sect. Nigellaria DC.

N. gallica Jord.

Portugal Vale de Rio: Coimbra, *J. Paiva*, (COI) Herbarium No 8231; *K.H. Rechinger* 1373 (COI). **Spain Ustpyranen:** Lerida Segre-Tal öst. Seo de Urgel, 6 km O Martinet, ca. 1050 m, silicate, *F. Krendl* 766, (W) Herbarium No 01215.

N. papillosa G.López subsp. ***atlantica*** (Murb.) Amich ex G.López

Portugal Arrodores de Lias: ma estada Moura Serpa, *A.Q.Fernandez et al.*, 8688 (COI). **Tunisia Scttat:** 2 km W of Kasba-de-Boulaouane, SW of Boulaouane an der StraBe von Sidi-Bennour nach Scttat, 240 m, Acker, Wegrand, *D. Podlech* 53897 (W).

N. arvensis L. **var. *arvensis***

Greece Ikaria: 3 km NW of Ag. Kşrikos, 500-800 m, *R.v.Bothmer & A. Strid* 21809 (W) Herbarium No: 21775. **Kasos:** roadside, near the harbor village of Ophris, 20 m, *R.V. Bothmer sn* (W); **Piraeus:** Andikithira, *K. H. Rechinger* (recorded as *Strid*) 24423 (W); **Paros:** Island, Nausa Town, seashore, 15 m, *AAD* 15460-*T. Karamplians* (HUB). **Paros:** Island, near Vukakos beach, crop field margin, in *Quercus* scrub, limestone, 12 m, *AAD* 15462 (HUB)**;** **Pyreaus:** 157 m, *AAD* 15474 (HUB)**;** **Crete**: Khania, stable sand and dunes, c.1.5 km N from the Monastery of Au. Christokalatitis, 1-2 m, *A.Strid* 4042 (W). **Turkey A1 Edirne:** Enez, around Gülçavuş Village, in *Pinus* forest openings, 25 m, *AAD* 14996-*B. Mutlu* (HUB)**;** Enez, from Edirne to Havsa, between Havsa and Karakasım, steppe, 96 m, *AAD* 15001-*B. Mutlu***; A1 Kırklareli:** Pınarhisar, 2 km to Sergen, 362 m, *AAD* 15005-B. Mutlu**; B5 Yozgat:** *P. H. Davis-T. Ekim* 68596 (HUB); **C3 Isparta:** Gönen, near Subaşı, *Quercus* scrub, 1227 m, *AAD* 14990. **Lebanon Bekaa Valley:** Hermal, dry *Artemisia* steppes, 698 m, *AAD* 17014 (HUB).

N. arvensis L. **var. *aristata*** s. l.

Greece Siros: Island, Kini Village, around Saint Varvara Monastry, dry *Sarcopoterium-Pistacia-Corydothymus* phrygana, limestone, 176 m, *AAD* 15459 (HUB); **Rhodes:** 2 km S of Faliraki Village, in *Pistacia*-Olive scrub openings, 5 m, *AAD* 15468-*T.Karamplians* (HUB);Around Kalithera mare Resort Faliraki road, *Pistacia* scrub, *AAD* 15469 - *T. Karamplians* (HUB). **Turkey A1 Edirne:** Keşan, around Mecidiye Military Zone, dunes, 1 m, *AAD* 7203 (HUB); **A4 Ankara:** between Irmak and Kalecik, 10 km to Kalecik, steppe, 700 m, *AAD* 3536- *H. Şağban-A. Kahraman* (HUB); **B3 Afyon:** Çay, Karamuk Lake, around Koçbey Village, steppe, 1050 m, *AAD* 2920 (HUB); **B4 Kırıkkale:** Delice, 2 km to Ortakışla, in crop fields openings, gypsiferous slopes, 633 m, *AAD* 14847 (HUB)**;** **B5 Niğde:** Ulukışla, near Ahmet Şükrü Farm, gypsiferous slopes, steppe, 1478 m, *AAD* 15955-*Z. Uğurlu* (HUB); **B6 Sivas:** Malatya road, around the junction of Altınyayla, crop field margin, transition to steppe, 1432 m, *AAD* 14977 (HUB)**;** **B7 Sivas:** Divriği, Karasar Passage, steppe slopes, *AAD* 12398-*I. A. Shehbaz-M. Menke* (HUB)**;** **C5 Mersin:** 1 km from Bozyazı to Silifke, Tosaklar Village, in *Quercus-Pistacia* scrub openings, 1 m, *AAD* 16164-*Z.Uğurlu* (HUB); **C5 Hatay:** Samandağ coast, near the entrance of Asi River, beach, 0 m, *AAD* 16975-*G. Zare* (HUB). **Syria Swedaa:** Tel Hadid, Thali Village, 871 m, *AAD* 15445 (HUB); from Silamiya to Rsafa, near Iterya Village, *AAD* 15449 (HUB); **Teltemur:** Desert, 40 km from Rakkat, *AAD* 15451 (HUB); Desert 40 km from Rakkato Teltemur, 393 m, *AAD* 15452 (HUB).

N. koyuncui Dönmez & Uğurlu

Turkey A5 Sinop: Boyabat, 1.4 km to Gökçeağaçsakızı, 442 m, *AAD* 17223-*Z. Uğurlu* (HUB).

N. segetalis M.Bieb.

Turkey A4 Çankırı: Korgun, Aktaş Village, roadside, 1282 m, *AAD* 14403 (HUB); **A5 Sivas:** Suşehri, from Suşehri to Gölova, 1 km to Karayakup Village, crop field margin, 1375 m, *AAD* 14860 (HUB); **A8 Erzurum:** Gümüşhane road, 1 km to Pınarkapan Village, gypsiferous stony slopes, 1680 m, *AAD* 12342-*I.A. Shehbaz-M. Menke* (HUB); **A9 Iğdır:** Tuzluca, Turabi Village, Aras Valley, 1006 m, *AAD* 11411-*B. Mutlu* (HUB); **B5 Nevşehir:** Sulusaray, 1100 m, eroded slopes, *M.Vural et al.* (HUB); **B8 Muş:** Yaygın, Nadaslı Village, burnt crop fields, 1275 m, *AAD* 14952 (HUB); **B9 Ağrı:** Doğubeyazıt, *AAD* 15502.

N. sativa L.

Turkey B3 Isparta: Şarkikaraağaç, 1150 m, *B. Mutlu* 1780 (HUB); **C2 Denizli:** Altınyayla, *AAD* 10915-*E. Oybak Dönmez* (HUB); **C4 Konya:** Ermenek, *H. Sümbül* 2953 (HUB).

N. turcica Dönmez & Mutlu

Turkey A9 Iğdır: Tuzluca, 1 km to Turabi Village, 1006 m, AAD 10833-*B. Mutlu* (HUB); **B9 Ağrı:** Doğubeyazıt, *AAD* 15499 (HUB).

N. stellaris Boiss.

Turkey C4 İçel: Ermenek-Mut road, 200 m, *M. Koyuncu* 4191-*G. Sezik-F. İzgü* (AEF); **C6 K.Maraş:** Süleymanlı, 800 m, *B.Yıldız* 2652 (HUB).

N. fumariifolia Kotschy

Greece Rhodes: Paros, South of Ventia, *Runemark et al.* 41441 (E! photo). **Cyprus:** Iter Cyprinum, *Sintenis et Rigo* (1880) *sn*, Nu mountosis supra Lefkoniko, (COI).

Sect. Nigellastrum (Fabricus) DC.

N. orientalis L.

Turkey B8 Bitlis: Hizan, Tatik Plain, 1850 m, *AAD* 8047 (HUB); **C6 Kahramanmaraş:** Süleymanlı, Okkayası, 1200 m, *B. Yıldız* 1847 (HUB). **Syria Swedaa:** 20 km from Azraa to Swedaa, 776 m, *AAD* 15444 (HUB).

N. oxypetala Boiss. var. ***oxypetala***

Turkey A8 Erzurum: Gümüşhane road, 1 km to Pınarkapan Village, gypsiferous slopes, 1680 m, *AAD* 12341-*I.A.Shehbaz-M.Menke* (HUB); **B8 Bingöl:** Yolçatı, 2 km from Yolçatı to Solhan, 1170 m, *AAD* 14961 (HUB); **C9 Şırnak:** 26 km from the junction of Uludere road to Beytüşşebab, 1520 m, *AAD* 11242 (HUB); **C9 Şırnak:** Uludere, Taşdelen Village, *AAD* 15486 (HUB). **Syria Damascus:** Das, from Surgaya to Bloudan, around the city, *AAD* 15439 (HUB)**; Swedaa:** Shaf Village, crop field margin, volcanic rocky fields, 1524 m, *AAD* 15447 (HUB). **Lebanon Bekaa:** Yammounek, crop field margin, 1393 m, *AAD* 17026 (HUB).

N. oxypetala Boiss. var. ***latisecta*** s. l.

Turkey A5 Sivas: Suşehri, Suşehri to Gölova road, 1 km to Karayakup Village, crop field margin, 1375 m, *AAD* 14857 (HUB).

N. oxypetala Boiss. var. ***lancifolia*** s. l.

Turkey B4 Niğde: Ulukışla, 5 km from Ulukışla to Ereğli, crop field, 1480 m, *AAD* 15960 (HUB).

N. ciliaris DC**.**

Syria Swedaa: 20 km from Azraa to Swedaa, volcanic area, red soil, 776 m, *AAD* 15443 (HUB); Plantae Syriae borealis, Mounts Nussiry, Qin Hala Kırin, 770 m, June 1910, *M. Haradjian* 3511 (W!).

S2

Taxa	Specimen	Pollen type	P (µm)			E (µm)		
			M	SD	V	M	SD	V
Komaroffia								
K. integrifolia	Iran: *K. H. Rechinger* 4704	TRZC & NONTR	31.09	±2.10	27-36	29.79	±2.45	23-35
	Iran: FUMH 28909	TRZC & NONTR	29.55	±0.95	25-35	29.08	±0.89	23.75-33.75
	Afghanistan: *A. Gilli* 827	TRZC & NONTR	35.58	±0.68	31.25-38.75	30.65	±0.53	27.5-35
K. bucharica	Tajikistan: W 14384	TRZC	37.69	±3.6	32.5-48	36.98	±3.64	32.5-49
Garidella								
G. nigellastrum	Turkey B4 Kırşehir: *B. Mutlu* 5061	TRZC	31.35	±0.5	30-32.5	25.6	±0.47	22.5-27.5
	Turkey C5 Mersin: *AAD* 15965	TRZC	29.05	±0.39	27.5-31.25	26.08	±0.40	23.75-27.5
	Turkey C6 Antakya: *AAD* 15977	TRZC	29.3	±0.70	26.25-35	24.75	±0.45	22.5-28.75
	Turkey C8 Siirt: *AAD* 11174-*B. Mutlu*	TRZC	31.25	±0.5	30-32.5	23.6	±0.5	22.5-25
	Cyprus: *AAD* 15928	TRZC & NONTR	29.2	±0.64	25-32.5	25.83	±0.61	22.5-30
	Cyprus: *AAD* 15934	TRZC	29.38	±0.64	25-35	23.63	±0.69	21.25-30
	Cyprus: *AAD* 15948	TRZC	27.63	±0.80	25-32.5	22.43	±0.82	20-28.75
	Syria: *AAD* 15453	TRZC	31.9	±0.72	27.5-36.25	26.35	±0.90	22.5-32.5
G. unguicularis	Turkey C6 K.Maraş: *Z. Aytaç* 4867-*H. Duman*	TRZC & NONTR	30.6	±0.55	27.5-32.5	25.35	±0.49	22.5-27.5
	Turkey C8 Diyarbakır: *A. Güner* 6488	TRZC	30.75	±0.58	27.5-32.5	23.65	±0.50	22.5-25
	Syria: *AAD* 15437-*B.A. Sawman*	TRZC	30.78	±0.6	28.75-33.75	27.1	±0.58	23.75-30
	Syria: *AAD* 15440	TRZC & NONTR	28.4	±0.53	26.25-31.25	26.93	±0.54	23.75-31.25
	Syria: *AAD* 15454	TRZC	30.23	±0.82	26.25-35	23.1	±0.54	20-25
Nigella								
Sect. *Erobathos*								
Nigella damascena	Greece: *A. Tsopra*	TRZC	44.73	±1.30	37.5-53.75	44.05	±1.44	36.25-53.75
	Turkey A1 Edirne: *AAD* 8718	TRZC & NONTR	38.8	±0.57	35-41.25	41.55	±0.61	37.5-45
	Turkey A3 Düzce: *Aslı Doğru Koca* 1918	TRZC & NONTR	44.5	±1.30	37.5-52.5	46.25	±1.3	40-52.5
N. elata	Turkey A3 Bolu: *AAD* 17617-*Z. Uğurlu*	TRZC	38.3	±0.89	33.75-42.5	38.55	±0.78	35-42.5
	Turkey B2 Balıkesir: *AAD* 14994	TRZC & NONTR	37.8	±0.49	35-40	37.7	±0.70	32.5-41.25
	Turkey C3 Isparta: *H. Peşmen-A. Güner* 1805	TRZC & NONTR	37.9	±1.03	32.5-45	38.3	±0.99	32.5-42.5
Sect. *Nigellaria*								
N. gallica	Portugal: *J. Paiva*, COI 8231	TRZC & NONTR	44.83	±0.55	41.25-47.5	39.53	±0.44	37.5-42.5
	Portugal: *K. H. Rechninger* 1373	TRZC & NONTR	41.88	±0.65	38.75-45	42.53	±0.74	37.5-46.25
	Spain: *F. Krendl* 766	TRZC & NONTR	41.3	±0.87	37.5-47.5	42.48	±0.67	38.75-47.5

Taxa	Specimen	Pollen Type	P (µm)			E (µm)		
			M	SD	V	M	SD	V
N. papillosa	Portugal: *A.Q. Fernandez et al.* 8688	TRZC	45.43	±1.06	40-50	39.73	±0.67	35-42.5
subsp. *atlantica*	Tunisia: *D. Podlech* 53897	TRZC	39.35	±0.55	37.5-42.5	39.98	±0.38	37.5-42.5
N. arvensis	Greece: *R.v. Bothmer & A. Strid* 21809	TRZC	40.18	±0.90	35-45	40.03	±0.80	36.25-43.75
var. *arvensis*	Greece: *R.V. Bothmer sn*	TRZC	40.08	±0.96	33.75-45	39.58	±1.02	33.75-43.75
	Greece: *K. H. Rechinger* (recorded as *Strid*) 24423	TRZC	35.95	±0.70	32.5-41.25	37.1	±0.53	33.75-40
	Greece: *AAD* 15460-*T. Karamplians*	TRZC & NONTR	34.43	±0.38	32.5-37.5	36.3	±0.40	33.75-38.75
	Greece: *AAD* 15462	TRZC	34.55	±0.71	31.25-40	35.43	±0.73	31.25-41.25
	Greece: *AAD* 15474	TRZC	33.38	±0.72	30-38.75	34.73	±0.63	31.25-37.5
	Greece: *A. Strid* 4042	TRZC & NONTR	35.43	±0.70	32.5-38.75	37.55	±0.54	33.75-40
	Turkey A1 Edirne: *AAD* 14996-*B. Mutlu*	TRZC	35.33	±0.71	31.25-40	34.95	±0.91	28.75-40
	Turkey A1 Edirne: *AAD* 15001-*B. Mutlu*	TRZC	34.93	±0.50	32.5-37.5	35.25	±0.75	30-38.75
	Turkey A1 Kırklareli: *AAD* 15005- *B. Mutlu*	TRZC	33.03	±0.45	31.25-35	33.7	±0.61	30-36.25
	Turkey B5 Yozgat: *P.H. Davis-T. Ekim* 68596	TRZC	37.3	±0.72	35-40	38.9	±0.76	35-42.5
	Turkey C3 Isparta: *AAD* 14990	TRZC	34.55	±0.38	32.5-35.25	35.07	±0.43	32.5-37.5
	Lebanon: *AAD* 17014	TRZC	35.88	±2.24	25-51.25	31.75	±2.67	25-50
Nigella arvensis	Greece: *AAD* 15459	TRZC	33.45	±0.47	31.25-37.5	34.73	±0.46	32.5-37.5
var. *aristata*	Greece: *AAD* 15468-*T. Karamplians*	TRZC	34.05	±0.5	31.25-36.25	35.48	±0.55	31.25-37.5
	Greece: *AAD* 15469-*T. Karamplians*	TRZC & NONTR	36.4	±0.56	33.75-40	37.65	±0.55	33.75-40
	Turkey A1 Edirne: *AAD* 7203	TRZC	36.88	±0.80	32.5-40	37.08	±0.86	32.5-41.25
	Turkey A4 Ankara: *AAD 3536-H. Şağban-A. Kahraman*	TRZC & NONTR	35.28	±0.52	32.5-37.5	36.4	±0.61	32.5-40
	Turkey B3 Afyon: *AAD* 2920	TRZC	36.6	±0.59	35-40	38.1	±0.59	35-42.5
	Turkey B4 Kırıkkale: *AAD* 14847	TRZC	34.8	±0.72	32.5-40	36.13	±0.61	33.75-40
	Turkey B5 Niğde: *AAD* 15955-*Z. Uğurlu*	TRZC	34.9	±0.96	30-41.25	36.6	±1.04	31.25-42.5
	Turkey B6 Sivas: *AAD* 14977	TRZC & NONTR	38.55	±0.45	36.25-40	39.57	±0.46	35-42.5
	Turkey B7 Sivas: *AAD* 12398-*I.A. Shehbaz-M. Menke*	TRZC	37.68	±0.57	35-41.25	38.25	±0.68	35-41.25
	Turkey C5 Mersin: *AAD* 16164-*Z. Uğurlu*	TRZC & NONTR	37.23	±0.53	35-40	38.5	±0.49	36.25-41.25
	Turkey C5 Hatay: *AAD* 16975-*G. Zare*	TRZC	39.23	±0.55	36.25-42.5	39.85	±0.6	36.25-42.5
	Syria: *AAD* 15445	TRZC & NONTR	37.58	±0.51	35-40	37.63	±0.42	35-40
	Syria: *AAD* 15449	TRZC & NONTR	35.28	±0.57	31.25-38.75	36.53	±0.54	33.75-40
	Syria: *AAD* 15451	TRZC & NONTR	35.78	±0.71	32.5-40	36.6	±0.67	32.5-40
	Syria: *AAD* 15452	TRZC & NONTR	38.4	±1.13	33.75-46.25	38.6	±1.05	33.75-45
Nigella koyuncui	Turkey A5 Sinop: *AAD* 17223-*Z. Uğurlu*	TRZC	36.03	±0.80	32.5-40	37.75	±0.70	35-41.25

Taxa	Specimen	Pollen Type	P (µm)			E (µm)		
			M	SD	V	M	SD	V
N. segetalis	Turkey A4 Çankırı: *AAD* 14403	TRZC	37.48	±0.55	35-41.25	38.38	±0.55	36.25-42.5
	Turkey A5 Sivas: *AAD* 14860	TRZC & NONTR	34.00	±0.59	32.5-40	34.90	±0.60	32.5-40
	Turkey A8 Erzurum: *AAD* 12342-*I.A. Shehbaz- M. Menke*	TRZC & NONTR	34.45	±0.48	32.5-36.25	36.85	±0.46	35-38.75
	Turkey A9 Iğdır: *AAD* 11411-*B. Mutlu*	TRZC	34.37	±0.73	30-37.5	35.22	±0.89	31.25-40
	Turkey B5 Nevşehir: *M. Vural et al*.	TRZC	36.2	±0.76	32.5-40	36.5	±0.75	32.5-40
	Turkey B8 Muş: *AAD* 14952	TRZC & NONTR	34.85	±0.81	30-40	35.6	±0.74	32.5-40
	Turkey B9 Ağrı: *AAD* 15502	TRZC & NONTR	33.58	±1.06	30-41.25	33.85	±0.94	30-41.25
N. sativa	Turkey B3 Isparta: *B. Mutlu* 1780	TRZC & NONTR	37.1	±0.95	31.25-45	39.25	±0.85	35-45
	Turkey C2 Denizli: *AAD* 10915-*E. Oybak* Dönmez	TRZC	36.7	±0.76	35-40	41.5	±0.90	37.5-47.5
	Turkey C4 Konya: *H. Sümbül* 2953	TRZC	43.4	±1.64	37.5-52.5	45.53	±1.6	40-55
N. turcica	Turkey A9 Iğdır: *AAD* 10833-*B. Mutlu*	TRZC & NONTR	41.15	±1.01	37.5-45	45.1	±0.72	42.5-47.5
	Turkey B9 Ağrı: *AAD* 15499	TRZC & NONTR	38.28	±1.11	30-43.75	42.1	±1.10	36.25-47.5
N. stellaris	Turkey C4 İçel: *M. Koyuncu* 4191-*G. Sezik-F. İzgü*	TRZC	42.25	±0.88	40-50	44.35	±1.10	40-52.5
	Turkey C6 K.Maraş: *B. Yıldız* 2652	TRZC	45.73	±1.09	42.5-51.25	46.95	±1.02	42.5-52.5
N. fumariifolia	Greece Rhodes: *Runemark et al*. 41441	TRZC	38.43	±1.04	32.5-45	36.05	±1.09	32.5-42.5
	Cyprus: *Sintenis et Rigo* 1880	TRZC	41.7	±0.85	37.5-47.5	32.73	±0.7	27.5-35
Sect. *Nigellastrum*								
N. orientalis	Turkey B8 Bitlis: *AAD* 8047	TRZC & NONTR	43.95	±0.64	40-47.5	45.8	±0.65	42.5-47.5
	Turkey C6 K. Maraş: *B. Yıldız* 1847	TRZC	38.4	±0.68	35-42.5	42.25	±0.61	38.75-45
	Syria: *AAD* 15444	TRZC & NONTR	38.2	±0.93	35-45	41.7	±0.89	37.5-45
N. oxypetala var. *oxypetala*	Turkey A8 Erzurum: *AAD* 12341-*I. A. Shehbaz-M. Menke*	TRZC	40.58	±0.74	36.25-45	42.55	±0.74	38.75-48.75
	Turkey B8 Bingöl: *AAD* 14961	TRZC & NONTR	43.5	±0.68	40-46.25	45.87	±0.65	42.5-50
	Turkey C9 Şırnak: *AAD* 11242	TRZC & NONTR	45.8	±0.62	42.5-48.75	46.67	±0.61	45-50
	Turkey C9 Şırnak: *AAD* 15486	TRZC	43.55	±1.18	37.5-51.25	45.85	±0.98	41.25-52.5
	Syria: *AAD* 15439	TRZC	35.1	±0.83	32.5-41.25	37.73	±0.84	35-42.5
	Syria: *AAD* 15447	TRZC & NONTR	37.7	±0.43	35-40	40.8	±0.36	38.75-42.5
	Lebanon: *AAD* 17026	TRZC & NONTR	40.35	±1.46	32.5-50	41.13	±1.48	35-53.75
Nigella oxypetala var. *latisecta*	Turkey A5 Sivas: *AAD* 14857	TRZC & NONTR	43.47	±0.54	40-46.25	44.75	±0.45	42.5-47.5
Nigella oxypetala var. *lancifolia*	Turkey B4 Niğde: *AAD* 15960	TRZC & NONTR	38.28	±1.01	32.5-43.75	40.6	±0.98	35-46.25
N. ciliaris	Syria: *AAD* 15443	TRZC & NONTR	38.35	±1.6	30-47.5	40	±2.02	27.5-50
	Syria: *M. Haradjian* 3511	TRZC & NONTR	43.33	±0.52	41.25-47.5	43.68	±0.55	41.25-46.25

Taxa	Specimen	Shape	Apocolpium Index	Clt (µm)
Komaroffia				
K. integrifolia	Iran: *K. H. Rechinger* 4704	P-SPH	0.25	5-7.6-14
	Iran: FUMH 28909	P-SPH	0.26	6-7.3-10
	Afghanistan: *A. Gilli* 827	SP	0.23	5-7.4-12
K. bucharica	Tajikistan: W 14384	P-SPH	0.26	7-9.4-10
Garidella				
G. nigellastrum	Turkey B4 Kırşehir: *B. Mutlu* 5061	SP	0.30	7.5-9.7-10
	Turkey C5 Mersin: *AAD* 15965	P-SPH	0.32	9-9.4-10
	Turkey C6 Antakya: *AAD* 15977	SP	0.24	7-8.3-10
	Turkey C8 Siirt: *AAD* 11174-*B. Mutlu*	SP	0.30	7.5-8.75-10
	Cyprus: *AAD* 15928	SP	0.26	6-7.3-8
	Cyprus: *AAD* 15934	SP	0.36	7-7.1-8
	Cyprus: *AAD* 15948	SP	0.30	6-7.1-9
	Syria: *AAD* 15453	SP	0.26	7-7.8-9
G. unguicularis	Turkey C6 K.Maraş: *Z. Aytaç* 4867-*H. Duman*	SP	0.27	7.5-8.75-10
	Turkey C8 Diyarbakır: *A. Güner 6488*	SP	0.29	7.5-9.25-10
	Syria: *AAD* 15437-*B.A. Sawman*	SP	0.29	7-8.3-10
	Syria: *AAD* 15440	P-SPH	0.29	7-7.9-10
	Syria: *AAD* 15454	SP	0.31	7-8.4-10
Nigella **Sect.** *Erobathos*				
N. damascena	Greece: *A. Tsopra*	P-SPH	0.24	7-9.3-12
	Turkey A1 Edirne: *AAD* 8718	OB-SPH	0.24	10-11.12-12.5
	Turkey A3 Düzce: *Aslı Doğru Koca* 1918	OB-SPH	0.41	10-12.4-14
N. elata	Turkey A3 Bolu: *AAD* 17617-*Z. Uğurlu*	OB-SPH	0.34	8-9.66-13
	Turkey B2 Balıkesir: *AAD* 14994	OB-SPH	0.33	10-11.37-12.5
	Turkey C3 Isparta: *H. Peşmen-A. Güner* 1805	OB-SPH	0.32	7.5-9.5-12.5
Sect. *Nigellaria*				
N. gallica	Portugal: *J. Paiva*, COI 8231	P-SPH	0.23	8-10.1-12
	Portugal: *K.H. Rechninger* 1373	OB-SPH	0.20	9-10.5-12
	Spain: *F. Krendl* 766	OB-SPH	0.24	8-10.55-13

Taxa	Specimen	Shape	Apocolpium Index	Clt (µm)
N. papillosa subsp. *atlantica*	Portugal: *A.Q. Fernandez et al.* 8688	P-SPH	0.26	8-9.33-10
	Tunisia: *D. Podlech* 53897	OB-SPH	0.31	11-11.44-12
N. arvensis var. *arvensis*	Greece: *R.v. Bothmer & A. Strid* 21809	OB-SPH	0.25	9-9.6-11
	Greece: *R.V. Bothmer sn*	P-SPH	0.31	6-8.9-12
	Greece: *K. H. Rechinger* (recorded as *Strid*) 24423	OB-SPH	0.29	10-10.44-11
	Greece: *AAD* 15460- *T. Karamplians*	OB-SPH	0.24	10-11.2-12
	Greece: *AAD* 15462	OB-SPH	0.21	10-10.3-11
	Greece: *AAD* 15474	OB-SPH	0.31	10-11.40-13
	Greece: *A. Strid* 4042	OB-SPH	0.31	9-10-11
	Turkey A1 Edirne: *AAD 14996-B. Mutlu*	P-SPH	0.31	9-11.3-13
	Turkey A1 Edirne: *AAD* 15001-*B. Mutlu*	OB-SPH	0.30	11-11.6-12
	Turkey A1 Kırklareli: *AAD* 15005- *B. Mutlu*	OB-SPH	0.32	8-10-12
	Turkey B5 Yozgat: *P. H. Davis-T. Ekim* 68596	OB-SPH	0.33	10-11.75-12.5
	Turkey C3 Isparta: *AAD* 14990	OB-SPH	0.33	7.5-8.25-10
	Lebanon: *AAD* 17014	P-SPH	0.31	1-1.88-3
N. arvensis var. *aristata*	Greece: *AAD* 15459	OB-SPH	0.32	6-9.5-11
	Greece: *AAD* 15468-*T. Karamplians*	OB-SPH	0.25	9-10.2-11
	Greece: *AAD* 15469-*T. Karamplians*	OB-SPH	0.30	11-12.5-14
	Turkey A1 Edirne: *AAD* 7203	OB-SPH	0.29	8-10.2-12
	Turkey A4 Ankara: *AAD* 3536-*H. Şağban-A. Kahraman*	OB-SPH	0.25	11-11.9-13
	Turkey B3 Afyon: *AAD* 2920	OB-SPH	0.30	10-12-12.5
	Turkey B4 Kırıkkale: *AAD* 14847	OB-SPH	0.27	9-10.5-11
	Turkey B5 Niğde: *AAD* 15955-*Z. Uğurlu*	OB-SPH	0.31	9-10.9-12
	Turkey B6 Sivas: *AAD* 14977	OB-SPH	0.23	12.5-13.5-15
	Turkey B7 Sivas: *AAD* 12398-*I. A. Shehbaz-M. Menke*	OB-SPH	0.28	12-12.7-14
	Turkey C5 Mersin: *AAD* 16164-*Z. Uğurlu*	OB-SPH	0.25	10-10.5-11
	Turkey C5 Hatay: *AAD* 16975-*G. Zare*	OB-SPH	0.35	10-11-12
	Syria: *AAD* 15445	OB-SPH	0.27	10-11.1-12
	Syria: *AAD* 15449	OB-SPH	0.26	10-11-12
	Syria: *AAD* 15451	OB-SPH	0.30	8-8.6-10
	Syria: *AAD* 15452	OB-SPH	0.22	8-10-12
N. koyuncui	Turkey A5 Sinop: *AAD* 17223-*Z. Uğurlu*	OB-SPH	0.27	7-10.8-14

Taxa	Specimen	Shape	Apocolpium Index	Clt (µm)
N. segetalis	Turkey A4 Çankırı: *AAD* 14403	OB-SPH	0.21	10-11.7-14
	Turkey A5 Sivas: *AAD* 14860	OB-SPH	0.28	7.5-10-12.5
	Turkey A8 Erzurum: *AAD* 12342-*I. A. Shehbaz- M. Menke*	OB-SPH	0.25	11.25-12.25-13.75
	Turkey A9 Iğdır: *AAD* 11411-*B. Mutlu*	OB-SPH	0.27	10-12.12-13.75
	Turkey B5 Nevşehir: *M. Vural et al.*	OB-SPH	0.34	10-11.25-12.5
	Turkey B8 Muş: *AAD* 14952	OB-SPH	0.22	9-11-14
	Turkey B9 Ağrı: *AAD* 15502	OB-SPH	0.24	8-9.2-10
N. sativa	Turkey B3 Isparta: *B. Mutlu* 1780	OB-SPH	0.24	7-8-10
	Turkey C2 Denizli: *AAD* 10915-*E. Oybak Dönmez*	OB-SPH	0.27	10-12-12.5
	Turkey C4 Konya: *H. Sümbül* 2953	OB-SPH	0.25	10-11.5-13
N. turcica	Turkey A9 Iğdır: *AAD* 10833-*B.Mutlu*	OB-SPH	0.24	10-10.75-12.5
	Turkey B9 Ağrı: *AAD* 15499	OB-SPH	0.26	11-12.6-15
N. stellaris	Turkey C4 İçel: *M. Koyuncu* 4191-*G. Sezik-F. İzgü*	OB-SPH	0.28	10-11-12.5
	Turkey C6 K.Maraş: *B. Yıldız* 2652	OB-SPH	0.30	9-10.6-12
N. fumarifolia	Greece Rhodes: *Runemark et al.* 41441	P-SPH	0.23	7-8.8-10
	Cyprus: *Sintenis et Rigo*	SP	0.29	2-2.3-3
Sect. *Nigellastrum*				
N. orientalis	Turkey B8 Bitlis: *AAD* 8047	OB-SPH	0.23	12.5-12.75-15
	Turkey C6 K. Maraş: *B. Yıldız* 1847	OB-SPH	0.22	9-10.7-12
	Syria: *AAD* 15444	OB-SPH	0.26	9-12.6-15
N. oxypetala var. *oxypetala*	Turkey A8 Erzurum: *AAD* 12341-*I.A. Shehbaz* & *M. Menke*	OB-SPH	0.27	11-12.4-13
	Turkey B8 Bingöl: *AAD* 14961	OB-SPH	0.26	10-13.12-16.25
	Turkey C9 Şırnak: *AAD* 11242	OB-SPH	0.25	12.5-14-15
	Turkey C9 Şırnak: *AAD* 15486	OB-SPH	0.31	10-11.5-13
	Syria: *AAD* 15439	OB-SPH	0.20	8-10.1-12
	Syria: *AAD* 15447	OB-SPH	0.19	10-12.9-15
	Lebanon: *AAD* 17026	OB-SPH	0.19	9-10-12
N. oxypetala var. *latisecta*	Turkey A5 Sivas: *AAD* 14857	OB-SPH	0.24	11.25-12.62-15
N. oxypetala var. *lancifolia*	Turkey B4 Niğde: *AAD* 15960	OB-SPH	0.29	11-12.5-16
N. ciliaris	Syria: *AAD* 15443	OB-SPH	0.30	8-12.1-15
	Syria: *M. Haradjian* 3511	OB-SPH	0.22	8-9.44-10

Taxa	Specimen	Exine thickness (µm)					
		Sexine			Nexine		
		Polar area	Mesocolpium	Margo	Polar area	Mesocolpium	Margo
Komaroffia							
K. integrifolia	Iran: *K. H. Rechinger* 4704	1.5	1.5	1.5	1	0.50	0.50
	Iran: FUMH 28909	1.5-1.95-2	1-1.45-2	0.9-0.98-1	0.9-0.99-1	0.9-0.92-1	0.9-0.92-1
	Afghanistan: *A. Gilli* 827	2.75	2	1.75	0.50	0.50	1
K. bucharica	Tajikistan: W 14384	1.75	1.50	1.50	0.75	0.50	0.50
Garidella							
G. nigellastrum	Turkey B4 Kırşehir: *B. Mutlu* 5061	1.5-1.74-2	1.5	0.8-0.91-1	0.90	0.9-0.93-1	0.9-0.93-1
	Turkey C5 Mersin: *AAD* 15965	2-2.05-2.5	1.9-2.18-2.5	1-1.10-1.5	0.9-0.95-1	0.7-0.75-0.8	0.7-0.75-0.8
	Turkey C6 Antakya: *AAD* 15977	1.5-1.95-2	2-2.2-2.5	1-1.05-1.5	0.9-0.92-1	0.9-0.97-1	0.9-0.98-1
	Turkey C8 Siirt: *AAD* 11174-*B. Mutlu*	1.5-1.61-2	1.5-1.55-2	0.9-0.99-1	0.9-0.99-1	0.9-0.98-1	0.9-0.98-1
	Cyprus: *AAD* 15928	1.8-1.98-2	1.8-1.95-2	1-1.10-1.5	0.9-0.96-1	0.5-0.75-1	0.5-0.76-1
	Cyprus: *AAD* 15934	1.8-1.96-2	1.7-1.79-1.8	0.7-0.97-1	0.9-0.95-1	0.9-0.97-1	0.9-0.99-1
	Cyprus: *AAD* 15948	1.5-1.85-2	1.5-1.9-2	0.9-1.09-1.5	0.9-0.94-1	0.9-0.97-1	0.9-0.98-1
	Syria: *AAD* 15453	1.5-1.95-2	1.7-1.87-2	0.8-0.96-1	0.9-0.96-1	0.7-0.89-1	0.7-0.89-1
G. unguicularis	Turkey C6 K.Maraş: *Z. Aytaç* 4867-*H. Duman*	1.5-1.6-2	1.5-1.7-2.5	0.9-0.96-1.5	0.9	0.9-0.97-1	0.9-0.96-1
	Turkey C8 Diyarbakır: *A. Güner* 6488	1.5-1.6-2	1.5-2.1-2.5	1-1.05-1.5	0.9	0.9-0.97-1	0.9-0.97-1
	Syria: *AAD* 15437-*B.A. Sawman*	1.5-2.05-2.5	2-2.3-2.5	1-1.2-1.5	0.9-0.95-1	0.9-0.98-1	1
	Syria: *AAD* 15440	2-2.05-2.5	2-2.1-2.5	0.9-0.99-1	0.9-0.94-1	0.9-0.97-1	0.9-0.97-1
	Syria: *AAD* 15454	2-2.1-2.5	2-2.05-2.5	0.9-0.99-1	0.9-0.93-1	0.9-0.98-1	0.9-0.99-1
Nigella **Sect.** *Erobathos*							
N. damascena	Greece: *A. Tsopra*	2	1.50	1.50	1	0.5	0.75
	Turkey A1 Edirne: *AAD* 8718	2.5-2.9-3	2.5-2.95-3	1.5-1.95-2	0.9-0.97-1	0.9-0.95-1	1-1.30-1.5
	Turkey A3 Düzce: *Aslı Doğru Koca* 1918	2.5-2.7-3	2.5-2.65-3	1.5-1.8-2	1	0.7-0.91-1	0.8-1.33-1.5
N. elata	Turkey A3 Bolu: *AAD* 17617-*Z. Uğurlu*	2	1.75	1	0.5	0.5	0.5
	Turkey B2 Balıkesir: *AAD* 14994	2-2.7-3	2.5	1-1.15-1.5	0.9-0.98-1	0.8-0.97-1	1-1.35-1.5
	Turkey C3 Isparta: *H. Peşmen-A. Güner* 1805	2-2.4-2.5	2-2.45-2.5	1	0.8-0.9-1	0.8-0.95-1	1-1.15-1.5
Sect. *Nigellaria*							
N. gallica	Portugal: *J. Paiva*, COI 8231	3	2	1.75	0.75	0.50	0.50
	Portugal: *K. H. Rechninger* 1373	2.25	2	2	0.75	0.50	0.50
	Spain: *F. Krendl* 766	2.25	1.75	1.75	0.75	1	0.50

Taxa	Specimen	Exine thickness (µm)					
		Sexine			Nexine		
		Polar area	Mesocolpium	Margo	Polar area	Mesocolpium	Margo
N. papillosa	Portugal: *A.Q. Fernandez et al.* 8688	2.25	1.75	2	0.75	0.50	0.75
subsp. *atlantica*	Tunisia: *D. Podlech* 53897	2.25	1.75	2	0.75	0.50	0.75
N. arvensis	Greece: *R.v. Bothmer* & *A. Strid* 21809 (W)	2	2	1.75	0.75	0.75	1
var. *arvensis*	Greece: *R.V. Bothmer sn*	2.5	1.5	1	0.5	1	1
	Greece: *K. H. Rechinger* (recorded as *Strid*) 24423	2	1	1	1	1	1
	Greece: *AAD* 15460-*T. Karamplians*	3-3.05-3.5	2.5-2.8-3	1.5-1.65-2	0.9-0.98-1	0.9-0.97-1	1-1.05-1.5
	Greece: *AAD* 15462	3-3.1-3.5	2.5-2.8-3	1.5-1.6-2	0.9-0.99-1	0.7-0.84-1	0.9-1.03-1.5
	Greece: *AAD* 15474	3-3.2-3.5	2-2.63-3.5	1-1.7-2	0.8-0.9-1	0.5-0.73-1	0.5-0.73-1
	Greece: *A. Strid 4042*	2	1.50	1	0.50	0.50	0.50
	Turkey A1 Edirne: *AAD* 14996-*B. Mutlu*	2.5-2.9-3.5	2.5-2.6-3	1-1.35-1.5	0.9-0.98-1	0.9-0.97-1	1-1.2-1.5
	Turkey A1 Edirne: *AAD* 15001-*B. Mutlu*	3-3.05-3.5	2.5-2.85-3	1.5-1.65-2	0.9-0.93-1	0.8-0.98-1	1-1.3-1.5
	Turkey A1 Kırklareli: *AAD* 15005- *B. Mutlu*	2.5-2.85-3	2.5-2.6-3	1-1.45-1.5	0.9-0.98-1	0.8-0.96-1	1
	Turkey B5 Yozgat: *P.H. Davis-T. Ekim* 68596	2.5	2.5	1	0.8-0.91-1	0.8-0.93-1	0.9-0.97-1
	Turkey C3 Isparta: *AAD* 14990	2.5-2.6-3	2.5-2.7-3	1-1.15-1.5	0.9-0.96-1	0.8-0.98-1	1-1.45-1.5
	Lebanon: *AAD* 17014	3	1.5	2	1	1	1
N. arvensis	Greece: *AAD* 15459	2.5-3-3.5	2.5-2.7-3	1.5-1.65-2	0.9-0.98-1	0.7-0.77-0.9	0.9-0.95-1
var. *aristata*	Greece: *AAD* 15468-*T. Karamplians*	3	2.5-3-3.5	1.5-1.8-2	0.9-0.99-1	0.9-0.96-1	0.9-1.04-1.5
	Greece: *AAD* 15469-*T. Karamplians*	3-3.45-3.5	2.5-2.95-3	1.5-1.65-2	0.9-0.97-1	0.9-0.98-1	1-1.20-1.5
	Turkey A1 Edirne: *AAD* 7203	2.5-3.05-3.5	2.5-3-3.5	1.5-1.85-2	0.9-0.97-1	0.9-0.97-1	1-1.35-1.5
	Turkey A4 Ankara: *AAD 3536-H. Şağban-A.Kahraman*	2.5-2.7-3	2.5-2.55-3	1.5-1.75-2	0.8-0.88-1	0.8-0.95-1	1
	Turkey B3 Afyon: *AAD* 2920	2.5-2.85-3	2.5-2.65-3	1-1.20-2	0.8-0.92-1	0.8-0.88-1	1-1.05-1.5
	Turkey B4 Kırıkkale: *AAD* 14847	2.5-2.8-3	2.5-2.8-3	1.5-1.55-2	0.9-0.99-1	0.7-0.94-1	1-1.30-1.5
	Turkey B5 Niğde: *AAD* 15955-*Z. Uğurlu*	2.5-2.85-3	2.5	1.5-1.7-2	0.9-0.99-1	0.8-0.95-1	1-1.15-1.5
	Turkey B6 Sivas: *AAD* 14977	2.5-2.9-3.5	2-2.5-3	1-1.05-1.5	0.9-0.98-1	0.9-0.99-1	1.5
	Turkey B7 Sivas: *AAD* 12398-*I.A. Shehbaz-M. Menke*	3-3.35-3.5	2.5-2.75-3	1.5-1.6-2	0.9-0.97-1	0.9-0.95-1	1-1.10-1.5
	Turkey C5 Mersin: *AAD* 16164-*Z. Uğurlu*	2.5-2.7-3	2.5-2.8-3	1-1.5-2	0.9-0.97-1	0.9-0.98-1	1-1.13-1.5
	Turkey C5 Hatay: *AAD* 16975-*G. Zare*	2.5-3-3.5	2-2.75-3.5	1-1.5-2	0.8-0.9-1	0.7-0.85-1	1-1.25-1.5
	Syria: *AAD* 15445	2.5-3.35-4	2.5-2.95-3	1.5-1.65-2	0.9-0.98-1	0.7-0.94-1	1-1.15-1.5
	Syria: *AAD* 15449	3	2-2.35-3	1-1.45-2	0.9-0.99-1	0.5-0.96-1.5	0.5-1.03-1.5
	Syria: *AAD* 15451	3-3.1-3.5	2.5-2.6-3	1-1.5-2	0.9-0.97-1	0.8-0.92-1	1
	Syria: *AAD* 15452	2.5-3-3.5	2-2.7-3	1-1.4-1.5	0.9-0.95-1	0.8-0.91-1	1-1.15-1.5
N. koyuncui	Turkey A5 Sinop: *AAD* 17223-*Z. Uğurlu*	2	1.50	1	1	0.50	1

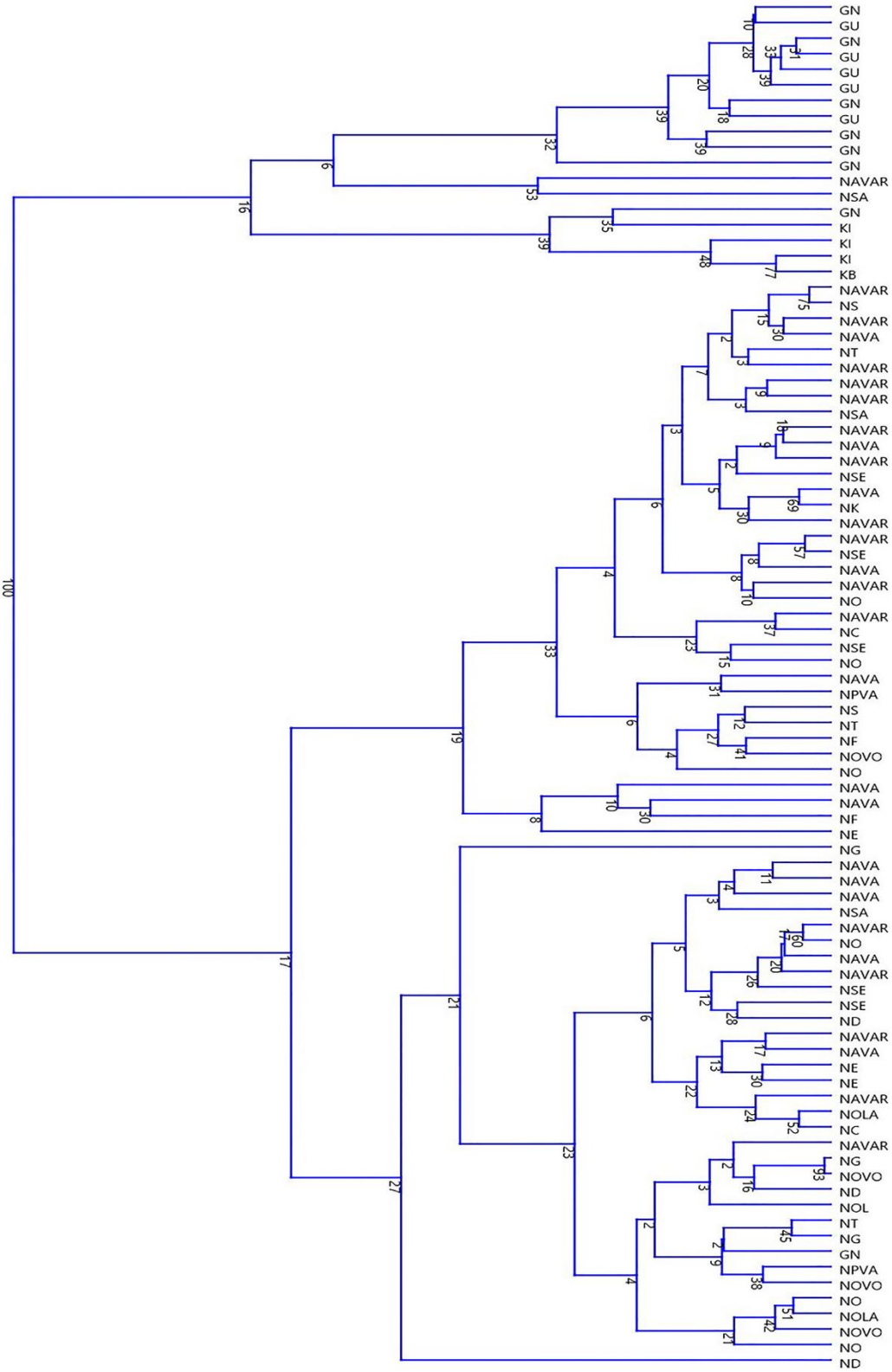
Taxa	Specimen	Exine thickness (µm)					
		Sexine			Nexine		
		Polar area	Mesocolpium	Margo	Polar area	Mesocolpium	Margo
N. segetalis	Turkey A4 Çankırı: *AAD* 14403	2.5-2.9-3	2-2.5-3	1-1.5-2	0.9-0.99-1	0.7-0.92-1	1-1.25-1.5
	Turkey A5 Sivas: *AAD* 14860	2-2.5-3	2-2.1-2.5	1-1.10-1.5	0.9-0.97-1	0.9-0.99-1	1-1.15-1.5
	Turkey A8 Erzurum: *AAD* 12342-*I.A. Shehbaz- M. Menke*	2-2.6-3	2.5-2.65-3	1-1.35-1.5	0.7-0.85-1	0.9-0.96-1	1
	Turkey A9 Iğdır: *AAD* 11411-*B. Mutlu*	2-2.5-3	2-2.4-2.5	1-1.10-1.5	0.8-0.88-1	0.8-0.93-1	0.8-1.03-1.5
	Turkey B5 Nevşehir: *M. Vural et al*. (HUB)	2-2.55-3	2-2.25-2.5	1-1.20-1.5	0.9-0.92-1	0.9-0.96-1	1-1.05-1.5
	Turkey B8 Muş: *AAD* 14952	2.5-2.85-3	2.5-2.8-3	1.5-1.75-2	0.9-0.99-1	0.7-0.93-1	1-1.2-1.5
	Turkey B9 Ağrı: *AAD* 15502	2.5-2.95-3	2.5-2.8-3	1.5-1.7-2	0.9-0.96-1	0.8-0.94-1	1-1.25-1.5
N. sativa	Turkey B3 Isparta: *B. Mutlu* 1780 (HUB)	3	2.5-2.85-3	1-1.10-1.5	0.8-0.93-1	0.8-0.93-1	0.8-0.91-1
	Turkey C2 Denizli: *AAD* 10915-*E. Oybak* Dönmez	2.5-2.75-3.5	2.5	1-1.10-1.5	0.9-0.92-1	0.9-0.97-1	1-1.10-1.5
	Turkey C4 Konya: *H. Sümbül* 2953	3	2.75	1	1	0.50	1
N. turcica	Turkey A9 Iğdır: *AAD* 10833-*B. Mutlu*	3-3.35-4	3.5-4.2-5	1-1.20-1.5	0.9-0.94-1	0.9-0.98-1	1-1.10-1.5
	Turkey B9 Ağrı: *AAD* 15499	2.5-2.9-3.5	2.5-2.8-3	1.5-1.6-2	0.9-0.95-1	0.9-0.96-1	1-1.4-2
N. stellaris	Turkey C4 İçel: *M. Koyuncu* 4191-*G. Sezik-F. İzgü*	2.5-2.85-3	2-2.35-2.5	1-1.10-1.5	0.9-0.94-1	0.9-0.97-1	1-1.3-1.5
	Turkey C6 K.Maraş: *B. Yıldız* 2652 (HUB)	3	2	2	0.75	0.75	0.50
N. fumarifolia	Greece Rhodes: *Runemark et al*. 41441	2.25	2	2	0.75	0.50	0.50
	Cyprus: *Sintenis et Rigo* 1880	2	1.75	2	1	0.75	0.50
Sect. *Nigellastrum*							
N. orientalis	Turkey B8 Bitlis: *AAD* 8047	2.5-2.65-3	3-3.6-4	1.5-1.7-2	1	1-1.05-1.5	1-1.15-1.5
	Turkey C6 K. Maraş: *B. Yıldız* 1847	2.50	1.75	1.5	0.5	0.75	0.5
	Syria: *AAD* 15444	2.5-2.85-3	2-2.6-3	1.5-1.9-2	0.9-0.94-1	0.5-0.68-0.8	0.7-0.96-1.5
N. oxypetala var. *oxypetala*	Turkey A8 Erzurum: *AAD* 12341-*I. A. Shehbaz-M. Menke*	3-3.05-3.5	3-3.30-3.5	1-1.55-2	0.9-0.98-1	0.8-1.12-1.5	1-1.3-1.5
	Turkey B8 Bingöl: *AAD* 14961	3-3.45-4	3.5-4.40-5	1-1.55-2	0.9-0.96-1	0.9-1.19-1.5	1-1.6-2
	Turkey C9 Şırnak: *AAD* 11242	3.5-3.95-4	3.5-4.2-5	1.5-1.85-2	1	0.9-0.98-1	1-1.25-1.5
	Turkey C9 Şırnak: *AAD* 15486	3.5-3.7-4	4-4.45-5	1-2.15-3	0.9-0.98-1	0.8-0.94-1	1-1.38-1.5
	Syria: *AAD* 15439	2.5-2.65-3	3-3.75-4.5	1-1.4-2	1	0.8-1.01-1.5	1-1.15-1.5
	Syria: *AAD* 15447	2.5-3-4	2.5-3.2-4	1-1.15-1.5	1-1.05-1.5	1-1.35-1.5	1-1.5-2
	Lebanon: *AAD* 17026	2.5	3	1.5	0.75	1	1
N. oxypetala var. *latisecta*	Turkey A5 Sivas: *AAD* 14857	3-3.30-4	3-3.35-4	1-1.5-2	1	1	1-1.35-1.5
N. oxypetala var. *lancifolia*	Turkey B4 Niğde: *AAD* 15960	2.5-2.95-4	2.5-3.05-4	1.5-1.85-2	0.9-0.99-1	0.9-0.99-1	1
N. ciliaris	Syria: *AAD* 15443	2.5-3.05-3.5	2.5-2.85-3.5	1-1.75-2	0.9-0.99-1	0.9-0.99-1	1-1.25-1.5
	Syria: *M. Haradjian* 3511	2.5	1.75	1.75	0.50	0.75	0.50

Taxa	Specimen	Exine Pattern				Intine thickness (µm)
		Mesocolpium and Polar area		Colpus membrane		
		LM	SEM	LM	SEM	
Komaroffia						
K. integrifolia	Iran: *K. H. Rechinger* 4704	MECH	MECH-PU	MECH	MECH	<1
	Iran: FUMH 28909	MECH	MECH-PU	MECH	MECH	<1
	Afghanistan: *A. Gilli* 827	MECH	MECH-PU	MECH	MECH	<1
K. bucharica	Tajikistan: W 14384	MECH	MECH-PU	MECH	MECH	<1
Garidella						
G. nigellastrum	Turkey B4 Kırşehir: *B. Mutlu* 5061	MECH	MECH-PU	MECH	ECH	≤1
	Turkey C5 Mersin: *AAD* 15965	MECH	MECH-PU	MECH	ECH	<1
	Turkey C6 Antakya: *AAD* 15977	MECH	MECH-PU	MECH	ECH	<1
	Turkey C8 Siirt: *AAD* 11174-*B. Mutlu*	MECH	MECH-PU	MECH	ECH	≤1
	Cyprus: *AAD* 15928	MECH	MECH-PU	MECH	ECH	<1
	Cyprus: *AAD* 15934	MECH	MECH-PU	MECH	ECH	<1
	Cyprus: *AAD* 15948	MECH	MECH-PU	MECH	ECH	<1
	Syria: *AAD* 15453	MECH	MECH-PU	MECH	ECH	<1
G. unguicularis	Turkey C6 K.Maraş: *Z. Aytaç* 4867-*H. Duman*	MECH	MECH-PU	MECH	ECH	<1
	Turkey C8 Diyarbakır: *A. Güner* 6488	MECH	MECH-PU	MECH	ECH	<1
	Syria: *AAD* 15437-*B.A. Sawman*	MECH	MECH-PU	MECH	ECH	<1
	Syria: *AAD* 15440	MECH	MECH-PU	MECH	ECH	<1
	Syria: *AAD* 15454	MECH	MECH-PU	MECH	ECH	<1
Nigella						
Sect. *Erobathos*						
N. damascena	Greece: *A. Tsopra*	MECH	MECH-PU	MECH	MECH	<1
	Turkey A1 Edirne: *AAD* 8718	MECH	MECH-PU	MECH	MECH	≤1
	Turkey A3 Düzce: *Aslı Doğru Koca* 1918	MECH	MECH-PU	MECH	MECH	≤1
N. elata	Turkey A3 Bolu: *AAD* 17617-*Z. Uğurlu*	MECH	MECH-PU	MECH	MECH	<1
	Turkey B2 Balıkesir: *AAD* 14994	MECH	MECH-PU	MECH	MECH	<1
	Turkey C3 Isparta: *H. Peşmen*-*A. Güner* 1805	MECH	MECH-PU	MECH	MECH	<1
Sect. *Nigellaria*						
N. gallica	Portugal: *J. Paiva*, COI 8231	MECH	MECH-PU	MECH	MECH	<1
	Portugal: *K. H. Rechninger* 1373	MECH	MECH-PU	MECH	MECH	<1
	Spain: *F. Krendl* 766	MECH	MECH-PU	MECH	MECH	<1

Taxa	Specimen	Exine Pattern				Intine thickness (µm)
		Mesocolpium and Polar area		Colpus membrane		
		LM	SEM	LM	SEM	
N. papillosa	Portugal: *A.Q. Fernandez* et al. 8688	MECH	MECH-PU	MECH	MECH	≤1
subsp. *atlantica*	Tunisia: *D. Podlech* 53897	MECH	MECH-PU	MECH	MECH	≤1
N. arvensis	Greece: *R.v. Bothmer* & *A. Strid* 21809	MECH	MECH-PU	MECH	MECH	<1
var. *arvensis*	Greece: *R.V. Bothmer sn*	MECH	MECH-PU	MECH	MECH	<1
	Greece: *K. H. Rechinger* (recorded as *Strid*) 24423	MECH	MECH-PU	MECH	MECH	<1
	Greece: *AAD* 15460-*T. Karamplians*	MECH	MECH-PU	MECH	MECH	<1
	Greece: *AAD* 15462	MECH	MECH-PU	MECH	MECH	<1
	Greece: *AAD* 15474	MECH	MECH-PU	MECH	MECH	≤1
	Greece: *A. Strid* 4042	MECH	MECH-PU	MECH	MECH	<1
	Turkey A1 Edirne: *AAD* 14996-*B. Mutlu*	MECH	MECH-PU	MECH	MECH	<1
	Turkey A1 Edirne: *AAD* 15001-*B. Mutlu*	MECH	MECH-PU	MECH	MECH	<1
	Turkey A1 Kırklareli: *AAD* 15005- *B. Mutlu*	MECH	MECH-PU	MECH	MECH	<1
	Turkey B5 Yozgat: *P.H. Davis-T. Ekim* 68596	MECH	MECH-PU	MECH	MECH	<1
	Turkey C3 Isparta: *AAD* 14990	MECH	MECH-PU	MECH	MECH	<1
	Lebanon: *AAD* 17014	MECH	MECH-PU	MECH	MECH	<1
N. arvensis	Greece: *AAD* 15459	MECH	MECH-PU	MECH	MECH	<1
var. *aristata*	Greece: *AAD* 15468-*T. Karamplians*	MECH	MECH-PU	MECH	MECH	<1
	Greece: *AAD* 15469-*T. Karamplians*	MECH	MECH-PU	MECH	MECH	<1
	Turkey A1 Edirne: *AAD* 7203	MECH	MECH-PU	MECH	MECH	<1
	Turkey A4 Ankara: *AAD 3536-H. Şağban-A. Kahraman*	MECH	MECH-PU	MECH	MECH	<1
	Turkey B3 Afyon: *AAD* 2920	MECH	MECH-PU	MECH	MECH	<1
	Turkey B4 Kırıkkale: *AAD* 14847	MECH	MECH-PU	MECH	MECH	<1
	Turkey B5 Niğde: *AAD* 15955-*Z. Uğurlu*	MECH	MECH-PU	MECH	MECH	<1
	Turkey B6 Sivas: *AAD* 14977	MECH	MECH-PU	MECH	MECH	<1
	Turkey B7 Sivas: *AAD* 12398-*I.A. Shehbaz-M. Menke*	MECH	MECH-PU	MECH	MECH	<1
	Turkey C5 Mersin: *AAD* 16164-*Z. Uğurlu*	MECH	MECH-PU	MECH	MECH	<1
	Turkey C5 Hatay: *AAD* 16975-*G. Zare*	MECH	MECH-PU	MECH	MECH	<1
	Syria: *AAD* 15445	MECH	MECH-PU	MECH	MECH	<1
	Syria: *AAD* 15449	MECH	MECH-PU	MECH	MECH	≤1
	Syria: *AAD* 15451	MECH	MECH-PU	MECH	MECH	<1
	Syria: *AAD* 15452	MECH	MECH-PU	MECH	MECH	<1
N. koyuncui	Turkey A5 Sinop: *AAD* 17223-*Z. Uğurlu*	MECH	MECH-PU	MECH	MECH	<1

Taxa	Specimen	Exine Pattern				Intine thickness (µm)
		Mesocolpium and Polar area		Colpus membrane		
		LM	SEM	LM	SEM	
N. segetalis	Turkey A4 Çankırı: *AAD* 14403	MECH	MECH-PU	MECH	MECH	<1
	Turkey A5 Sivas: *AAD* 14860	MECH	MECH-PU	MECH	MECH	≤1
	Turkey A8 Erzurum: *AAD* 12342-*I.A. Shehbaz- M. Menke*	MECH	MECH-PU	MECH	MECH	<1
	Turkey A9 Iğdır: *AAD* 11411-*B. Mutlu*	MECH	MECH-PU	MECH	MECH	<1
	Turkey B5 Nevşehir: *M. Vural et al*.	MECH	MECH-PU	MECH	MECH	<1
	Turkey B8 Muş: *AAD* 14952	MECH	MECH-PU	MECH	MECH	≤1
	Turkey B9 Ağrı: *AAD* 15502	MECH	MECH-PU	MECH	MECH	≤1
N. sativa	Turkey B3 Isparta: *B. Mutlu* 1780	MECH	MECH-PU	MECH	MECH	<1
	Turkey C2 Denizli: *AAD* 10915-*E. Oybak* Dönmez	MECH	MECH-PU	MECH	MECH	<1
	Turkey C4 Konya: *H. Sümbül* 2953	MECH	MECH-PU	MECH	MECH	<1
N. turcica	Turkey A9 Iğdır: *AAD* 10833-*B. Mutlu*	MECH	MECH-PU	MECH	MECH	<1
	Turkey B9 Ağrı: *AAD* 15499	MECH	MECH-PU	MECH	MECH	<1
N. stellaris	Turkey C4 İçel: *M. Koyuncu* 4191-*G. Sezik-F. İzgü*	MECH	MECH-PU	MECH	MECH	<1
	Turkey C6 K.Maraş: *B. Yıldız* 2652	MECH	MECH-PU	MECH	MECH	≤1
N. fumarifolia	Greece Rhodes: *Runemark et al*. 41441	MECH	MECH-PU	MECH	MECH	<1
	Cyprus: *Sintenis et Rigo* 1880	MECH	MECH-PU	MECH	MECH	<1
Sect. *Nigellastrum*						
N. orientalis	Turkey B8 Bitlis: *AAD* 8047	MECH	MECH-PU	MECH	MECH	<1
	Turkey C6 K. Maraş: *B. Yıldız* 1847	MECH	MECH-PU	MECH	MECH	<1
	Syria: *AAD* 15444	MECH	MECH-PU	MECH	MECH	<1
N. oxypetala var. *oxypetala*	Turkey A8 Erzurum: *AAD* 12341-*I. A. Shehbaz-M. Menke*	MECH	MECH-PU	MECH	MECH	≤1
	Turkey B8 Bingöl: *AAD* 14961	MECH	MECH-PU	MECH	MECH	≤1
	Turkey C9 Şırnak: *AAD* 11242	MECH	MECH-PU	MECH	MECH	<1
	Turkey C9 Şırnak: *AAD* 15486	MECH	MECH-PU	MECH	MECH	≤1
	Syria: *AAD* 15439	MECH	MECH-PU	MECH	MECH	≤1
	Syria: *AAD* 15447	MECH	MECH-PU	MECH	MECH	<1
	Lebanon: *AAD* 17026	MECH	MECH-PU	MECH	MECH	≤1
N. oxypetala var. *latisecta*	Turkey A5 Sivas: *AAD* 14857	MECH	MECH-PU	MECH	MECH	<1
N. oxypetala var. *lancifolia*	Turkey B4 Niğde: *AAD* 15960	MECH	MECH-PU	MECH	MECH	<1
N. ciliaris	Syria: *AAD* 15443	MECH	MECH-PU	MECH	MECH	<1
	Syria: *M. Haradjian* 3511	MECH	MECH-PU	MECH	MECH	<1

S3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