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A palynological study of the genus *Mentha* L. (Lamiaceae)

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The pollen morphology and exine structure of 10 *Mentha* L. species were investigated using light microscopy and scanning electron microscopy. The pollen grains of all 11 species were hexazonocolpate with granular membranes and a circular amb, varying in shape from prolate-spheroidal to suboblate. Different colpus shapes were recognized in *M.* × *dumetorum*. The exine was bireticulate in section *Pulegium*, and reticulate in section *Menthae*. A correlation was found between pollen size and chromosome number. The results indicate that the pollen characters of the genus *Mentha* are valuable for taxonomic applications and may be useful for classification. © 2008 Uludag University. Journal compilation © 2008 The Linnean Society of London, *Botanical Journal of the Linnean Society*, 2008, **157**, 141–154.

ADDITIONAL KEYWORDS: light microscopy – pollen morphology – scanning electron microscopy – Turkey – Labiate.

INTRODUCTION

The genus *Mentha* L. (mint), comprising *c.* 25 species of herbaceous perennial (rarely annual) plants, is a member of the subfamily Nepetoideae, tribe Mentheae. Mints are distributed chiefly in the temperate regions of the Old and New World, where they are widespread and abundant (Shishkin, 1976; Harley & Brington, 1977; Kokkini, 1991). The genus *Mentha* is grouped into five sections and is characterized by the following characters: flowers hermaphrodite or female, on the same or different plants, usually in dense, many-flowered verticillasters, sometimes forming a long spike-like inflorescence or a terminal head. Calyx actinomorphic or weakly two-lipped, tubular or campanulate, 10–13-veined, with five(four) subequal or rarely unequal teeth. Corolla weakly two-lipped, with four subequal lobes, the upper lobe wider and usually emarginate; tube shorter than the calyx. Stamens about equal, divergent or ascending under the upper lip of the corolla, exerted (except in *M. pulegium*, some hybrids, and female flowers). Style branches subequal, nutlets smooth, reticulate or tuberculate (Tutin & Heywood, 1972).

Mints were already grown in antiquity for the extraction of essential oil and for medicinal use, and they attained a wide distribution in the Middle Ages. Their prolonged cultivation has contributed to the formation of many hybrid forms; these are mostly propagated vegetatively, by means of rootstock division, stem cuttings, and even leaf cuttings. The species widely occurring in cultivation include *M.* × *piperita* L., *M. spicata* L., *M. arvensis* L., and a few others. Most of the cultivated mints are of hybrid origin. The pollen morphology of 11 taxa, four of which are hybrids, was investigated in this study. They belong to two sections: section *Pulegium* is represented only by *M. pulegium* L. ($2n = 20$), and section *Menthae* consists of ten taxa: *M. aquatica* L. ($2n = 96$), *M.* × *dumetorum* Schultes ($2n = 60$), *M. longifolia* (L.) Hudson ssp. *longifolia* ($2n = 24$), *M. longifolia* (L.) Hudson ssp. *typhoides* (Briq.) Harley var. *typhoides* ($2n = 24$), *M.* × *piperita* L. ($2n = 72$), *M.* × *rotundifolia* (L.) Huds. ($2n = 24$), *M. spicata* L. ssp. *spicata* L. ($2n = 48$), *M. spicata* ssp. *tomentosa* (Briq.) Harley ($2n = 48$), *M. suaveolens* Ehrh. ($2n = 24$), and

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Table 1. Pollen morphological data (mean values, standard deviations, and variations) of *Mentha* species

Taxon	P	E	P/E	Pollen shape
M. aquatica	39.58 ± 3.01 (34.18–43.48)	39.56 ± 2.62 (32.56–44.72)	1.00	Spheroidal
M. × *dumetorum*	42.33 ± 3.19 (38.05–48.12)	41.27 ± 3.30 (36.98–48.40)	1.03	Prolate-spheroidal
M. longifolia ssp. *longifolia*	30.11 ± 2.04 (26.42–32.71)	30.82 ± 2.33 (26.01–34.66)	0.98	Oblate-spheroidal
M. longifolia ssp. *typhoides* var. *typhoides*	31.02 ± 1.36 (29.11–33.99)	34.05 ± 3.44 (30.81–41.01)	0.91	Oblate-spheroidal
M. × *piperita*	26.97 ± 2.43 (23.61–31.50)	29.35 ± 2.96 (25.10–36.61)	0.92	Oblate-spheroidal
M. pulegium	23.47 ± 1.76 (20.53–26.78)	25.14 ± 1.64 (22.65–28.84)	0.97	Oblate-spheroidal
M. × *rotundifolia*	23.67 ± 2.59 (20.87–29.74)	24.27 ± 3.01 (17.32–30.02)	0.98	Oblate-spheroidal
M. spicata ssp. *spicata*	30.01 ± 2.87 (27.35–34.70)	31.08 ± 1.55 (28.76–34.62)	0.97	Oblate-spheroidal
M. spicata ssp. *tomentosa*	29.02 ± 1.63 (26.85–31.10)	31.67 ± 3.70 (28.00–38.93)	0.92	Oblate-spheroidal
M. suaveolens	21.53 ± 4.66 (17.46–26.61)	20.16 ± 0.44 (19.65–20.45)	0.87	Suboblate
M. × *villosa-nervata*	26.90 ± 1.40 (25.88–28.84)	25.72 ± 3.79 (19.83–28.38)	1.13	Prolate-spheroidal

E, equatorial axis; P, polar axis. All measurements in μm.

M. × *villosa-nervata* Opiz ($2n = 36$) (chromosome count references: Davis, 1982; Tarimcilar & Kaynak, 2004). Most of the *Mentha* species are characterized by large morphological variations, as reflected by the large number of names at different taxonomic ranks attributed by taxonomists to mints during the past 200 years. Furthermore, intra- and interspecific hybridization occurs commonly when the species of section *Menthae* meet sympatrically with each other, leading to the complex variation patterns that characterize most wild populations.

Investigations of pollen morphology in the Lamiaceae have been essential as an aid to classification within this family (Erdtman, 1945; Harley *et al.*, 1992; Abu-Asab & Cantıno, 1994). Pollen morphological studies for the Lamiaceae have been carried out by several authors (for example, Erdtman, 1945; Abu-Asab & Cantıno, 1992, 1994; Harley, 1992; Wagstaff, 1992), but only a few studies have been conducted on the genus *Mentha*. Jancic & Polic (1989) studied the pollen morphology of five *Mentha* species. Gocmen, Tarımcılar & Kaynak (1997) studied six *Mentha* species from Turkey. Perveen & Qaiser (2003) investigated the pollen morphology of the three *Mentha* species from Pakistan. In addition, pollen grains of three *Mentha* species appear on the web pages of Paldat (a palynological database) (Ulrich, 2000).

The objectives of this paper were to provide a detailed account of the pollen morphology of *Mentha* as a whole by light microscopy (LM) and scanning electron microscopy (SEM), and to determine the extent to which these palynological data can be used as a taxonomic character in the genus. This paper presents a detailed account of the pollen morphology of 11 taxa of *Mentha* collected from Turkey.

MATERIAL AND METHODS

Pollen for examination by LM was prepared according to the Wodehouse method (Wodehouse, 1935). Pollen grains of the 11 recognized taxa of *Mentha*, *M. aquatica*, *M.* × *dumetorum*, *M. longifolia* ssp. *longifolia*, *M. longifolia* ssp. *typhoides* var. *typhoides*, *M.* × *piperita*, *M. pulegium*, *M.* × *rotundifolia*, *M. spicata* ssp. *spicata*, *M. spicata* ssp. *tomentosa*, *M. suaveolens*, and *M.* × *villosa-nervata*, were mostly taken from herbarium material housed at the herbarium of Uludag University (BULU). The polar axis (P), equatorial axis (E), colpus length (Clg) and width (Clt), apocolpium diameter, and mesocolpium, exine, and intine thickness were measured on the pollen grains. Measurements and light micrographs were taken with an Olympus BX 51 microscope. The measured pollen diameters were based on at least 20 samples and other characters on approximately 10 samples under the light microscope (× 1000). The details are given in Table 1. The collections examined are listed in the Appendix.

For SEM, pollen grains were transferred directly to a double-sided tape-affixed stub and micrographs were obtained using an XL-30 ESEM-FEG/PHILIPS microscope. All of the measurements were performed using CARNOY 2.0. Analysis of variance (ANOVA) and Scheffe's range test were applied for statistical evaluation (Sokal & Rohlf, 1981).

In general, the pollen terminology follows Faegri & Iversen (1975), Harley *et al.* (1992), and Punt *et al.* (1994).

RESULTS AND DISCUSSION

The pollen grains are monads, six-zonocolpate (very rarely intermixed with eight or four colpate grains) or

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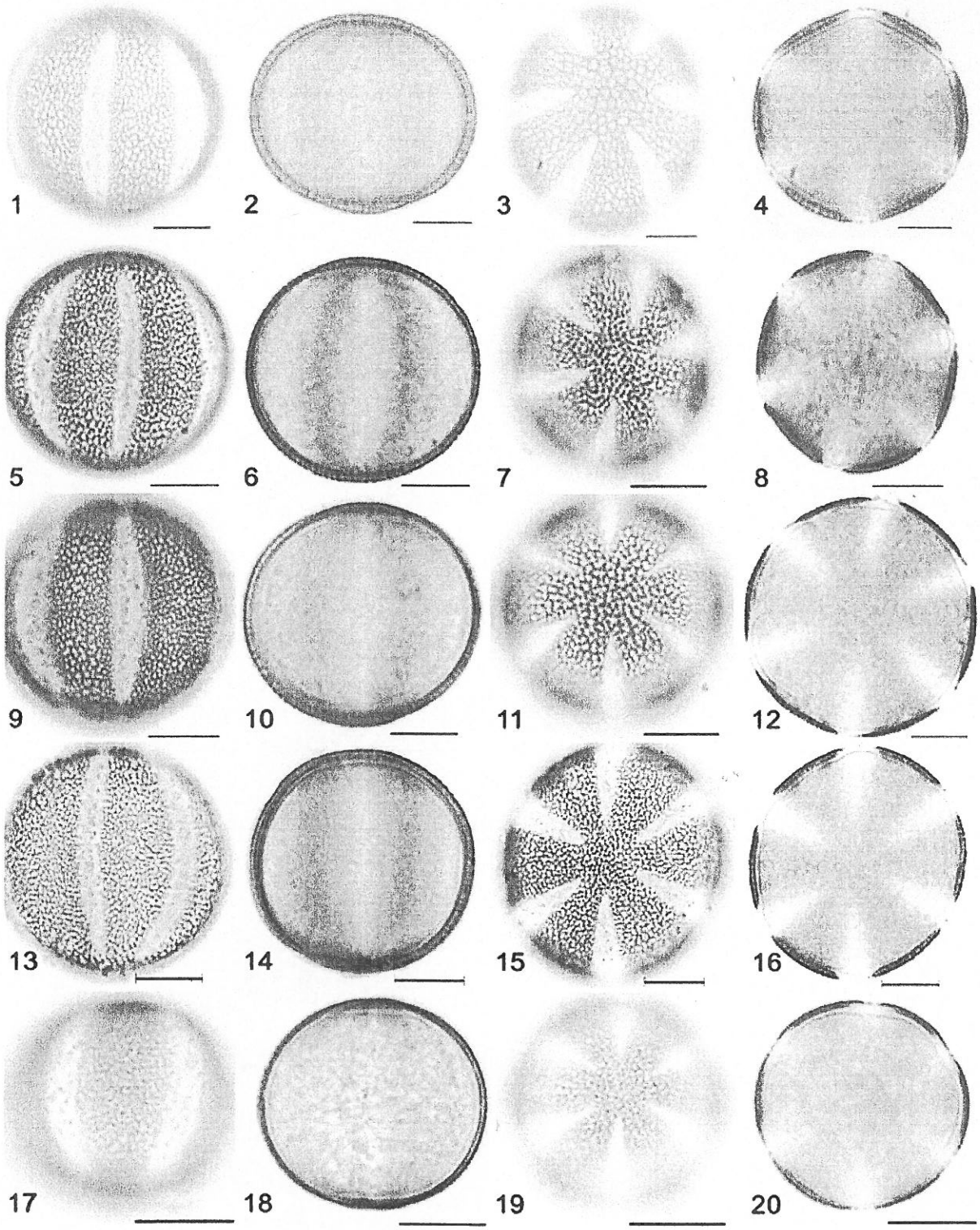

Figures 1–20. Light micrographs of pollen grains of *Mentha*. Figs 1–5. *M. aquatica*. Figs 6–8. *M. longifolia* ssp. *longifolia*. Figs 9–12. *M. longifolia* ssp. *typhoides* var. *typhoides*. Figs 13–16. *M.* × *piperita*. Figs 17–20. *M. pulegium*. Figs 1, 5, 9, 13, 17. Equatorial view and high focus. Figs 2, 6, 10, 14, 18. Equatorial view and low focus. Figs 3, 7, 11, 15, 19. Polar view and high focus. Figs 4, 8, 12, 16, 20. Polar view and low focus. Scale bars, 10 μm.

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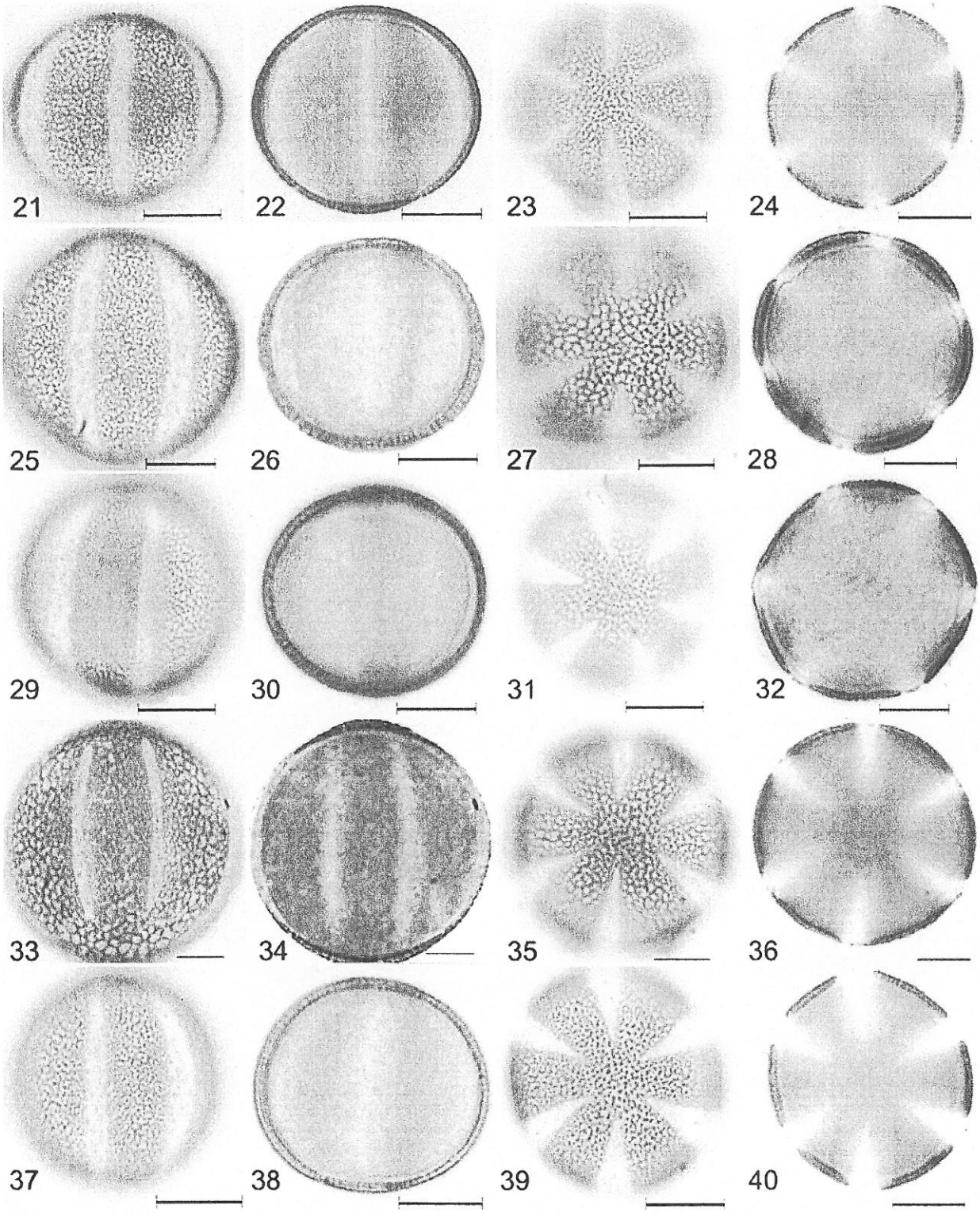

Figures 21–40. Light micrographs of pollen grains of *Mentha*. Figs 21–24. *M.* × *rotundifolia*. Figs 25–28. *M. spicata* ssp. *spicata*. Figs 29–32. *M. spicata* ssp. *tomentosa*. Figs 33–36. *M. suaveolens*. Figs 37–40. *M.* × *villosa-nervata*. Figs 21, 25, 29, 33, 37. Equatorial view and high focus. Figs 22, 26, 30, 34, 38. Equatorial view and low focus. Figs 23, 27, 31, 35, 39. Polar view and high focus. Figs 24, 28, 32, 36, 40. Polar view and low focus. Scale bars, 10 μm.

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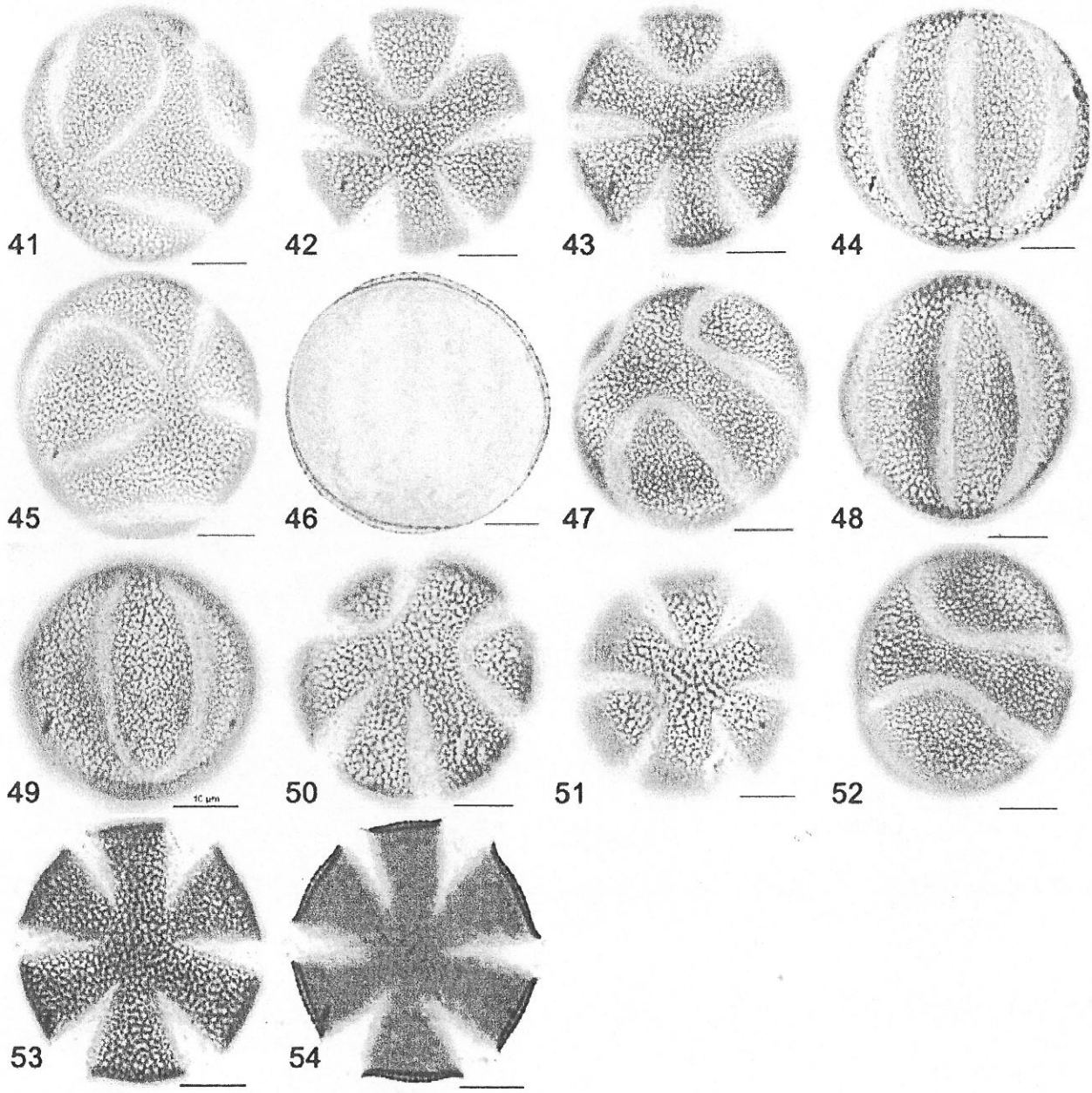

Figures 41–54. Light micrographs of pollen grains of *Mentha* × *dumetorum*. Figs 41, 45, 47, 49, 52. Colpus shape. Figs 42, 43, 50, 51, 53. Polar view and high focus. Figs 44, 48. Equatorial view and high focus. Fig. 46. Equatorial view and low focus. Fig. 54. Polar view and low focus. Scale bars, 10 µm.

heterosyncolpate, prolate-spheroidal to suboblate, with a polar axis of 21.53–42.33 µm and an equatorial diameter of 20.16–41.27 µm. Of the species investigated, the largest pollen grains, on average, were observed in *M.* × *dumetorum* and the smallest pollen grains, on average, were observed in *M. suaveolens*. The amb shape is circular (Figs 4, 8, 12, 16, 20, 24, 28, 32, 36, 40). It is noteworthy, however, that the shape of Lamiaceae pollen is often affected by the state of hydration and/or fixation (Sebsebe & Harley, 1992). The pollen grains in this group frequently undergo a dramatic shape change as a result of colpal membrane loss during acetolysis. As a result of hot acid treatment, oblate or suboblate grains frequently become subprolate or prolate, because in the absence of the colpal membranes the intercolpal areas of

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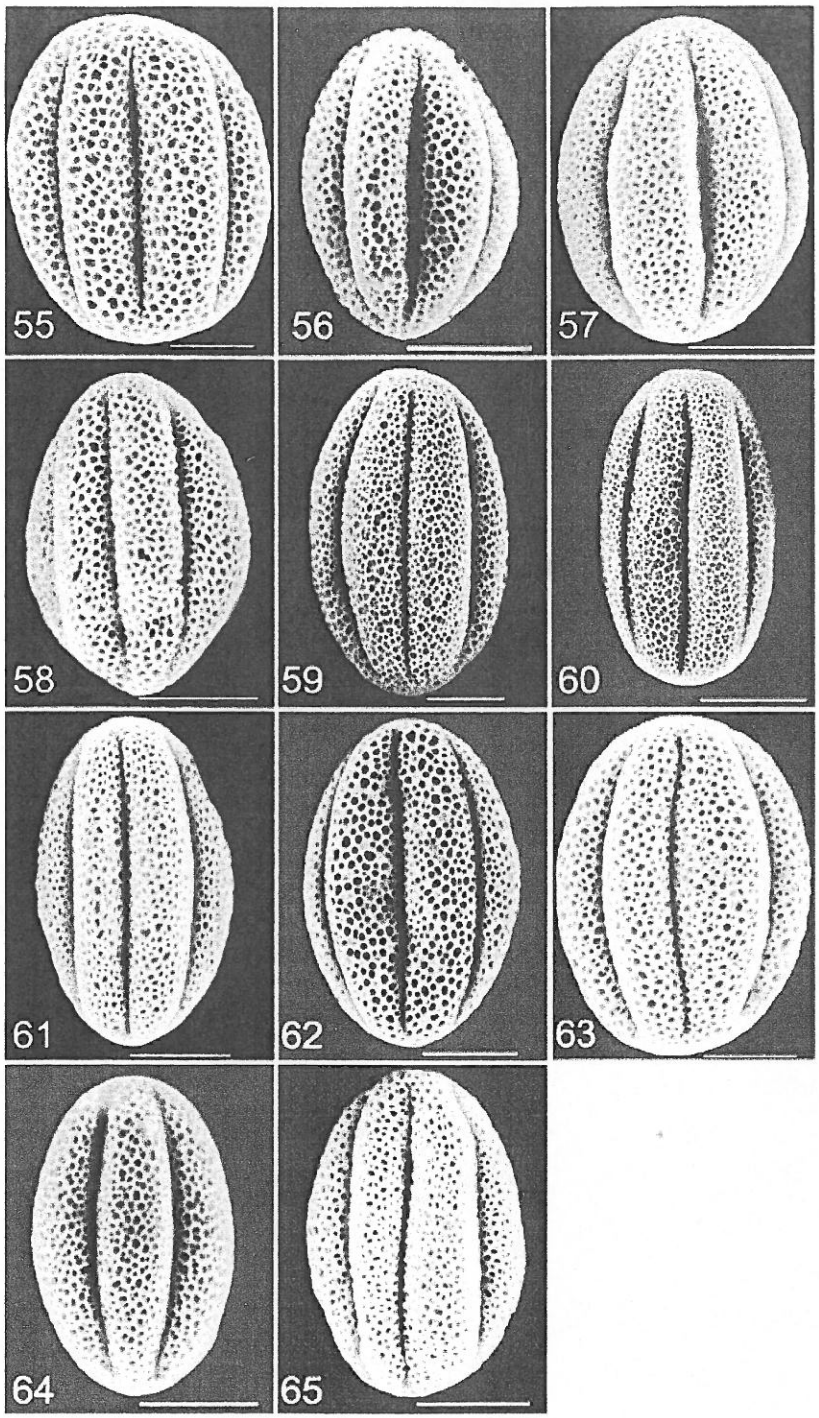

Figures 55–65. Scanning electron micrographs of pollen grains of *Mentha* (equatorial view). Fig. 55. *M. aquatica*. Fig. 56. *M.* × *dumetorum*. Fig. 57. *M. longifolia* ssp. *longifolia*. Fig. 58. *M. longifolia* ssp. *typhoides* var. *typhoides*. Fig. 59. *M.* × *piperita*. Fig. 60. *M. pulegium*. Fig. 61. *M.* × *rotundifolia*. Fig. 62. *M. spicata* ssp. *spicata*. Fig. 63. *M. spicata* ssp. *tomentosa*. Fig. 64. *M. suaveolens*. Fig. 65. *M.* × *villosa-nervata*. Scale bars, 10 μm.

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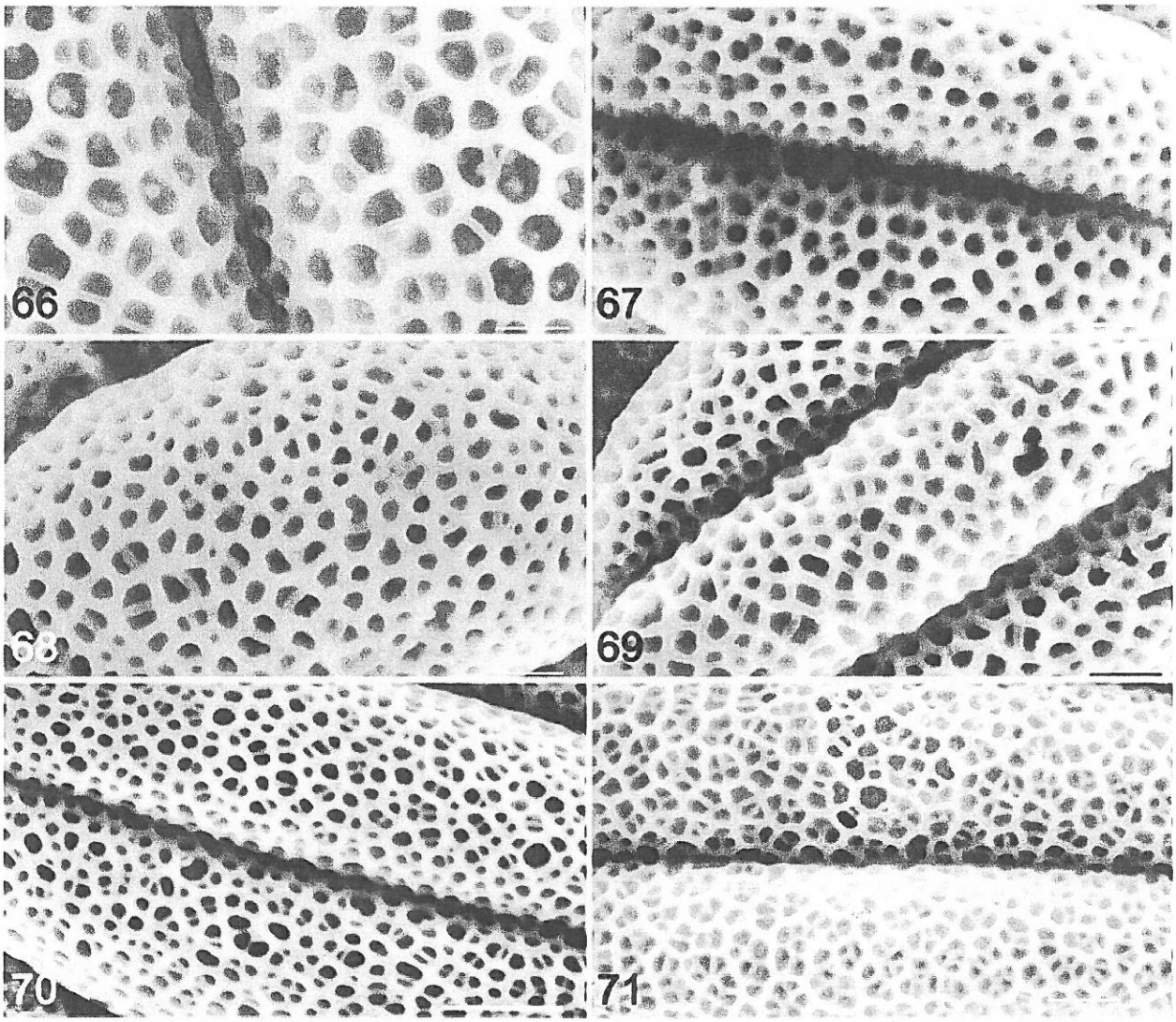

Figures 66–71. Scanning electron micrographs of pollen grains of *Mentha* (surface details, mesocolpium, and colpus margin). Fig. 66. *M. aquatica*. Fig. 67. *M.* × *dumetorum*. Fig. 68. *M. longifolia* ssp. *longifolia*. Fig. 69. *M. longifolia* ssp. *typhoides* var. *typhoides*. Fig. 70. *M.* × *piperita*. Fig. 71. *M. pulegium*. Scale bars: Fig. 70, 5 μm; remainder, 2 μm.

the tectum tend to close in (Harley, 1992). In order to retain the natural form of the pollen grains, the Wodehouse method was used in our study.

The exine sculpture is bireticulate (section *Pulegium*) or reticulate (section *Menthae*) (the terminology follows Harley *et al.*, 1992). In the bireticulate ornamentation, which only distinctly occurs in *M. pulegium*, the muri of the primary reticulum are shallow and usually rounded or occasionally more or less polygonal (Figs 66, 70, 71, 74, 76), and the lumina size is small, the secondary reticulum is finely reticulate, with the number of perforations not exceeding six per larger lumen of the primary reticulum, or the secondary reticulum is more or less absent. In the reticulate ornamentation, some of the reticulum is subdivided into a few smaller units. The average diameter of the small perforations is less than 1.50 μm. The exine thickness is 0.75–1.56 μm, and the intine thickness is 0.68–1.13 μm.

Cantino, Harley & Wagstaff (1992) placed the genus *Mentha* into the subfamily Nepetoideae, tribe Mentheae. Based on a study of 128 species of this tribe, Wagstaff (1992) produced a phylogenetic interpretation of pollen morphology. Our results are a confirmation of the concept of the genus position used until now. Hexazonocolpate pollen probably represents a synapomorphy in this order comprising the subfamily Nepetoideae (Cantino & Sanders, 1986; Abu-Asab &

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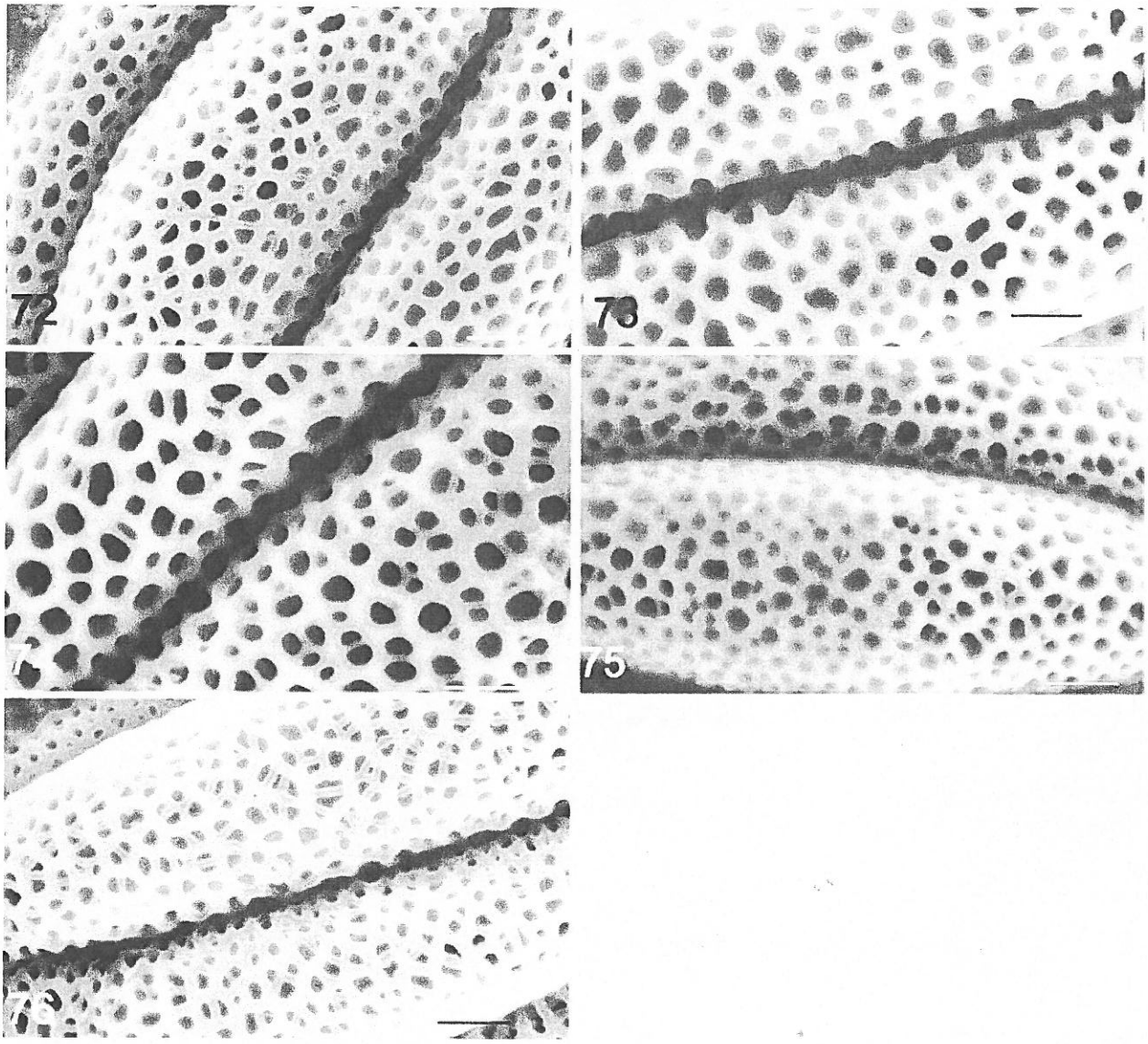

Figures 72–76. Scanning micrographs of pollen grains of *Mentha* (surface details, mesocolpium, and colpus margin). Fig. 72. *M.* × *rotundifolia*. Fig. 73. *M. spicata* ssp. *spicata*. Fig. 74. *M. spicata* ssp. *tomentosa*. Fig. 75. *M. suaveolens*. Fig. 76. *M.* × *villosa-nervata*. Scale bars, 2 μm.

Cantıno, 1992, 1994); furthermore, pollen with a tectate-perforate to reticulate exine structure and a surface ornamented with a network of supratectal ridges surrounding polygonal lumina is hypothesized to be a plesiomorphic condition within the subfamily Nepetoideae, where it occurs, for example, in the tribe Mentheae: *Perilla* L., *Elshohzia* Willd., *Perillula* Maxim., *Hyssopus* L., *Monardella* Benth., and *Satureja mimoloides* Briq. (Wagstaff, 1992). It is characteristic of *Mentha* pollen that it has two different exine structures and a surface ornamentation characterized by the partial reduction of the tectum. Representative pollen grains are illustrated in LM and SEM (Figs 1–76). The tendency towards reduction of the tectum is characteristic of many other genera and species in the tribe Mentheae [for example, *Origanum* L. (Husain & Heywood, 1982), *Thymbra* L. (Morales-Valverde, 1987), *Micromeria* L. (Morales-Valverde, 1990), and *Nepeta* L. (Celenk, 2006)], and is generally interpreted as an evolutionary trend.

The ectocolpi are distributed symmetrically, elongated, usually shallow, and narrowing at the poles, except in *M.* × *dumetorum*. In all the investigated species, the colpus membrane is finely or coarsely

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Table 2. Pollen morphological data (mean values, standard deviations, and variations) of *Mentha* species

Taxon	Clg	Clt	Mesocolpium thickness	Apocolpium diameter	Exine thickness	Intine thickness
M. aquatica	32.29 ± 2.04 (25.74–34.26)	5.43 ± 0.97 (3.03–7.14)	11.61 ± 1.11 (8.98–13.1)	14.32 ± 1.46 (11.27–16.39)	1.52 ± 0.30	1.05 ± 0.20
M. × *dumetorum*	32.08 ± 1.89 (29.05–35.35)	4.76 ± 1.35 (2.78–10.36)	13.16 ± 2.07 (10.17–17.96)	6.65 ± 1.55 (7.41–16.43)	1.56 ± 0.32	1.05 ± 0.22
M. longifolia ssp. *longifolia*	24.73 ± 2.31 (19.47–27.79)	4.60 ± 0.76 (3.15–6.63)	10.00 ± 1.67 (7.13–12.94)	10.61 ± 1.29 (8.99–13.33)	1.23 ± 0.27	1.00 ± 0.22
M. longifolia ssp. *typhoides* var. *typhoides*	24.32 ± 2.40 (21.32–28.66)	4.50 ± 1.00 (3.90–7.55)	12.29 ± 1.93 (9.19–15.93)	11.94 ± 0.46 (11.22–12.53)	1.40 ± 0.40	1.13 ± 0.26
M. × *piperita*	19.78 ± 3.62 (16.06–27.71)	4.02 ± 0.58 (3.14–5.08)	9.40 ± 4.82 (7.58–11.68)	10.22 ± 0.82 (8.87–11.32)	1.27 ± 0.19	0.81 ± 0.17
M. pulegium	22.25 ± 1.11 (16.83–23.04)	4.89 ± 2.14 (3.30–9.83)	7.65 ± 1.33 (6.07–9.73)	7.00 ± 0.48 (5.47–7.54)	0.75 ± 0.10	0.68 ± 0.08
M. × *rotundifolia*	20.95 ± 2.94 (16.01–25.51)	3.69 ± 0.86 (2.14–6.23)	8.54 ± 0.95 (6.91–11.43)	9.49 ± 1.07 (8.30–11.30)	1.16 ± 0.16	0.77 ± 0.18
M. spicata ssp. *spicata*	24.51 ± 3.64 (21.51–30.17)	3.65 ± 0.78 (2.61–5.34)	10.99 ± 1.63 (8.28–13.17)	11.35 ± 0.66 (10.26–12.27)	1.43 ± 0.29	1.12 ± 0.33
M. spicata ssp. *tomentosa*	25.21 ± 6.44 (15.21–32.48)	3.68 ± 1.04 (1.98–5.13)	10.42 ± 2.55 (9.43–10.77)	12.06 ± 1.83 (9.87–10.64)	1.23 ± 0.24	1.08 ± 0.23
M. suaveolens	18.19 ± 0.77 (17.24–24.43)	3.11 ± 1.40 (1.16–5.02)	6.17 ± 1.04 (4.85–7.43)	9.85 ± 1.19 (8.09–11.12)	1.18 ± 0.29	0.87 ± 0.11
M. × *villosa-nervata*	21.14 ± 3.20 (15.10–25.85)	4.07 ± 0.71 (2.94–5.74)	8.79 ± 1.67 (9.50–10.16)	8.77 ± 1.19 (9.59–11.15)	1.29 ± 0.34	0.85 ± 0.13

Clg, colpus length; Clt, colpus width. All measurements in μm.

Table 3. Pollen morphological data of *Mentha* L. species

Taxon	MN	Mesh diameter (μm)	Sculpture
M. aquatica	1–3	0.40–1.40	Reticulate
M. × *dumetorum*	3–4	0.20–1.85	Reticulate
M. longifolia ssp. *longifolia*	3–5	0.20–0.85	Reticulate
M. longifolia ssp. *typhoides* var. *typhoides*	2–5	0.20–0.90	Reticulate
M. × *piperita*	1–5	0.10–1.40	Reticulate
M. pulegium	4–7	0.20–0.80	Bireticulate
M. × *rotundifolia*	2–6	0.10–1.20	Reticulate
M. spicata ssp. *spicata*	1–3	0.20–1.20	Reticulate
M. spicata ssp. *tomentosa*	1–3	0.25–1.20	Reticulate
M. suaveolens	4–5	0.15–0.85	Reticulate
M. × *villosa-nervata*	4–7	0.15–0.80	Reticulate

MN, mesh number in 2 μm^2.

granular, visible in LM (for example, Figs 1, 5, 9, 13, 17, 21, 25, 29, 33, 37, 42). The range of colpus length of all the studied taxa is 18.19–32.29 μm (Table 1). The length of the colpus is not correlated with the whole pollen size. The range of colpus width of all the studied taxa is 3.11–5.43 μm (Table 1). In *M.* × *dumetorum*, different colpus shapes were recognized (Figs 41–54). The colpi of pollen grains in *M.* × *dumetorum* varied from *c.* 40% for heterosyncolpate to *c.* 60% for hexacolpate. In half (*c.* 50%) of the hexacolpate pollen grains, the colpi present a round amb with three large and three slightly smaller mesocolpia (Figs 44, 48, 51, 53), like many hexacolpate Lamiaceae pollen grains, as discussed by Pozhidaev (1992).

The ranges of the mesocolpial area and apocolpium diameter of the studied taxa are 6.17–13.16 μm and 6.65–14.32 μm, respectively. All palynological data

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Table 4. Results of analysis of variance (ANOVA) for the characters studied in *Mentha* L. pollen grains

	Polar axis			Equatorial axis		
Analysed level	*F*-ratio	d.f.	s.l.	*F*-ratio	d.f.	s.l.
Amongst all taxa	171.26	10	*	112.40	10	*
		237			248	
Amongst ploidy levels	78.00	2	*	53.43	2	*
($2n$ = 20, 24, 36, 48–96)		245			256	

d.f., degrees of freedom; s.l., significance level.
*Significant at 0.005.

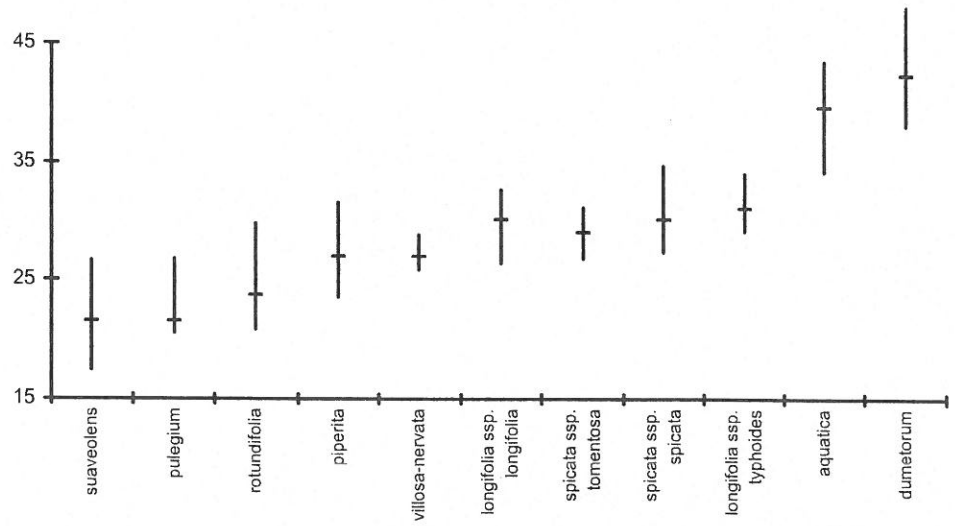

Figure 77. Maximum, minimum, and average size of polar axis (P) of *Mentha* species.

of the investigated *Mentha* species are given in Tables 1–3.

The genus *Mentha* is taxonomically complex and characterized by a high level of reticulate evolution. Only a few, frequently overlapping, characters are of value in taxonomy. Pollen data were evaluated statistically to ascertain the value of pollen characters in the taxonomy of *Mentha* (Tables 4 and 5). The results of ANOVA and Scheffe's range tests allow the selection of homogeneous groups within the data set analysed. Results from ANOVA tests show statistically significant differences both amongst samples of the same species and amongst samples with different chromosome numbers. Scheffe's test clearly shows that there are three different groups on the basis of polar axis size and two different groups on the basis of equatorial diameter in the data set studied, and, furthermore, that these groups correspond to chromosome number (Tables 4 and 5). With an increase in chromosome number, the tendency to larger pollen grains is obvious. The smallest pollen grains are found in *M. suaveolens* (section *Menthae*), with a chromosome number of $2n = 24$. This species is part of an individual ploidy line with a basic chromosome number of $x = 12$. The largest pollen grains are found in *M.* × *dumetorum* (tetraploid with $2n = 60$) (Figs 77, 78). The tendency to larger pollen grains with an increase in chromosome number has also been described in the genus *Thymus* L. (Lamiaceae) by Martonfi (1997).

The pollen grain sizes obtained were compared with a few previously published data. Jancic & Polic (1989) reported the following pollen sizes: *M. aquatica*, P = 37.71, 35.29 μm, E = 27.90, 26.57 μm; *M. spicata* ssp. *tomentosa*, P = 36.96, 38.84 μm, E = 25.96, 28.87 μm; *M. pulegium*, P = 30.79 μm, E = 17.82 μm. Perveen & Qaiser (2003) reported the following pollen sizes: *M. longifolia*, P = 29.11 μm, E = 28.29 μm; *M. spicata*, P = 27.50 μm, E = 25.70 μm. Gocmen *et al.* (1997) provided brief pollen data of six *Mentha* taxa

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Table 5. Mean and results of Scheffe's test for P and E in *Mentha* L. pollen grains

2*n*	Taxon	Polar axis (mean in μm)	Scheffe's test ($P < 0.05$)					2*n*	Taxon	Equatorial axis (mean in μm)	Scheffe's test ($P < 0.05$)					
24	*M. suaveolens*	21.53	1					24	*M. suaveolens*	20.16	1					
20	*M. pulegium*	23.47	1	2				24	*M.* × *rotundifolia*	24.27	1	2				
24	*M.* × *rotundifolia*	23.66	1	2				20	*M. pulegium*	25.14	1	2	3			
36	*M.* × *villosa-nervata*	26.90		2	3			36	*M.* × *villosa-nervata*	25.72		2	3			
72	*M.* × *piperita*	26.97		2	3			72	*M.* × *piperita*	29.35			3	4		
48	*M. spicata* ssp. *tomentosa*	29.02			3			24	*M. longifolia* ssp. *longifolia*	30.82				4		
48	*M. spicata* ssp. *spicata*	30.01			3			48	*M. spicata* ssp. *spicata*	31.08				4		
24	*M. longifolia* ssp. *longifolia*	30.11			3			48	*M. spicata* ssp. *tomentosa*	31.67				4		
24	*M. longifolia* ssp. *typhoides* var. *typhoides*	31.02			3			24	*M. longifoiai* ssp. *typhoides* var. *typhoides*	34.05				4		
96	*M. aquatica*	39.58				4		96	*M. aquatica*	39.56						5
60	*M.* × *dumetorum*	42.33				4		60	*M.* × *dumetorum*	41.27						5
	Chromosome number								Chromosome number							
	2*n* = 20–24	26.97	I						2*n* = 20–24	28.65		I				
	2*n* = 36–48	29.61		II					2*n* = 36–48	31.08		I				
	2*n* = 60–96	36.18			III				2*n* = 60–96	36.04			II			

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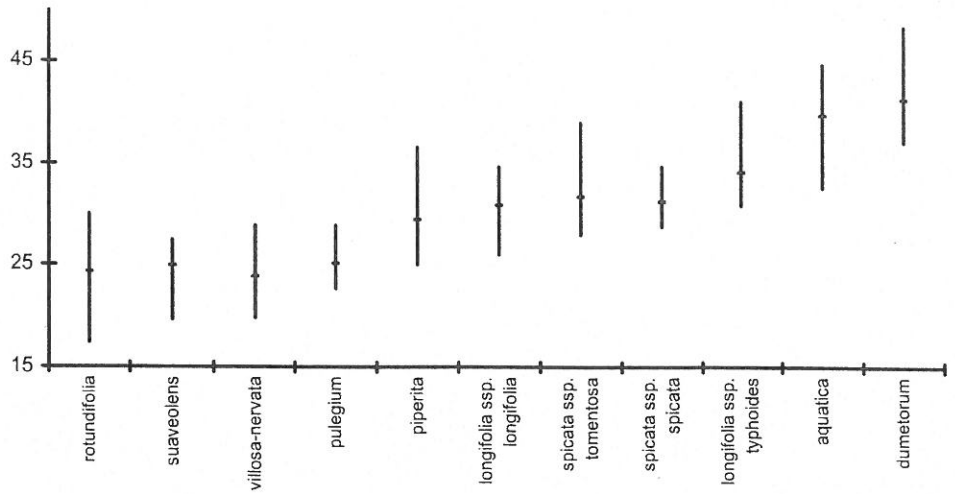

Figure 78. Maximum, minimum, and average size of equatorial axis (E) of *Mentha* species.

using LM. Most of the taxa investigated by Gocmen *et al.* (1997) had more or less similar pollen morphologies to those examined by us, except for the differences in size, ratio of the polar axis to equatorial diameter, and sculpture types. The values are a little different from those given in the present paper. It is possible that the slight variation is a result of differences in preparation.

The genus *Mentha* has been considered to be most closely related to *Lycopus* L. in the tribe Mentheae (Briquet, 1896; Henderson, 1962). As already concluded in earlier studies, the pollen morphology in *Mentha* and *Lycopus* is very homogeneous. Moon & Hong (2003) stated that the grains have no clearly defined supratectal reticulum, and do not provide much useful information for the intergeneric delimitation within the tribe Mentheae. According to the present results, the pollen morphology in *Mentha* may be helpful in elucidating the intergeneric relationships between the genus and relatives in the subtribe Mentheae.

In conclusion, the relationship between the ploidy level or chromosome number and pollen size at the species level in the studied taxa has been demonstrated statistically: in section *Menthae*, except for *M. longifolia* and *M. piperita*, higher ploidy levels correspond to an increase in pollen grain size. Studies so far in the genus *Mentha* indicate that additional sources of potentially very useful characters are available from the pollen morphology. As with any morphological study, the more complete the data, the more convincing the subsequent analyses regarding phylogeny and relationships.

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APPENDIX

SPECIMENS EXAMINED

Taxon	Locality (from Turkey)
Mentha aquatica	1. A1: Kirklareli; Babaeski, Mimar Sinan bridge, streambed, 60 m, 23.viii.2003, G. Tarimcilar 2. Balikesir; Balya way-out, Balikesir to Ivrindi crossroads, 40 km below Balikesir, watery places, 280 m, 26.viii.2004, G. Tarimcilar
Mentha × *dumetorum*	A1: Kirklareli; Babaeski, Mimar Sinan bridge, streambed, 60 m, 23.viii.2003, G. Tarimcilar
Mentha longifolia ssp. *longifolia*	A1: Kirkpinar, 4 km above İnece, waterway sides, 160 m, *Typha* sp., 23.viii.2003, G. Tarimcilar
Mentha longifolia ssp. *typhoides* var. *typhoides*	Balikesir; Balya way-out, Balikesir to İvrindi crossroads, 40 km below Balikesir, watery places, 280 m, 26.viii.2004, G. Tarimcilar
Mentha × *piperita*	Istanbul, Sile-Omerli, dam way, road side, grassland, 15.viii.2005 G. Tarimcilar

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APPENDIX *Continued*

Taxon	Locality (from Turkey)
Mentha pulegium	A2: Istanbul; Catalca, 15.ix.2003, H. Malyer B2: Balikesir; Bandirma, Manyas Kus cenneti, lake sides, 190 m, 27.viii.2004, G. Tarimcilar
Mentha × *rotundifolia*	B2: Balikesir; Bandirma to Erdek, Duzler way-out, grassland, 130 m, 27.viii.2004, G. Tarimcilar
Mentha spicata ssp. *spicata*	A1: Kirklareli; 22 km below Kirklareli, Urunlu village, stream sides, 120 m, 23.viii.2003, G. Tarimcilar
Mentha spicata ssp. *tomentosa*	A1: Edirne; Edirne to Istanbul, 15 km below Ogulpasa village, damp places, 70 m, 23.viii.2003, G. Tarimcilar B1: Canakkale; Bayramic, 2 km below Cırpıcılar, stream sides, *Juncus* sp., 350 m, 26.viii.2004, G. Tarimcilar
Mentha suaveolens	A2: Bursa; Gorukle, Uludag University, campus, 155 m, 30.viii.1992, G. Tarimcilar
Mentha × *villosa-nervata*	A1: Canakkale; Saros bay, Kocacesme village, streambed that dries up in summer, 35 m, 25.viii.2004, G. Tarimcilar A1: Canakkale; Lapseki to Beycayiri, Sahinli village, road sides, dry places, 220 m, 25.viii.2004, G. Tarimcilar

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