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N. MÜNEVVER PINAR

ÖZDEN İNCEOĞLU

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Pollen Morphology of Turkish *Chenopodium* L. (*Chenopodiaceae*)

N. Münevver PINAR, Özden INCEOĞLU

Ankara Üniversitesi, Fen Fakültesi, Biyoloji Bölümü 06100 Tandoğan, Ankara-TURKEY

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Abstract: Pollen grains of 12 species of the genus *Chenopodium* L. (*Chenopodiaceae*), of which morphological separation is problematical, have been examined in detail comparatively by using light microscopy (LM), scanning (SEM) and transmission electron microscopy (TEM). Pollen description of each taxon has been given. Pollen grains of *Chenopodium* L. species examined are radially symmetrical, isopolar, pantopolyporate and spheroidal. Their exine structure is similar. In the genus, five pollen types have been defined, mainly on the basis of pollen size.

Key Words: *Chenopodium*, *Chenopodiaceae*, pollen morphology.

Türkiye Sirken Türlerinin (*Chenopodium* L.) Polen Morfolojisi (*Chenopodiaceae*)

Özet: Bu çalışmada, dış morfolojik özelliklerine göre tanımlanmasında zorluk çekilen *Chenopodium* L. (*Chenopodiaceae*) cinsinin 12 türünün pollen morfolojileri ışık, taramalı ve geçermeli elektron mikroskoplarında karşılaştırılmalı olarak incelenmiş. Her taksonun ayrı ayrı palinolojik tanımları yapılmıştır. Polenler radyal simetrikli, isopolar, pantopolyporate ve sferoiddir. Ekzin yapıları birbirlerine benzemektedir. Polen çaplarının büyüklüklerine göre *Chenopodium* L. cinsi içinde 5 polen tip görülmüştür.

Anahtar Sözcükler: *Chenopodium*, *Chenopodiaceae*, polen morfolojisi.

Introduction

According to Aellen (1), in Turkey there are 14 species, 2 subspecies and 2 varieties of *Chenopodium* L. (*Chenopodiaceae*). The species of the genus are currently identified on the basis of mainly seed structure and leaf characters. But difficulties are still encountered in the separation of some taxa.

The pollen morphology of *Chenopodium* has received considerable attention from several research workers. The first palynological study on the *Chenopodium* pollen was done by Erdtman (2) who described briefly the pollen *C. glaucum* L. Mc Andrews and Swanson (3) gave only the C/D ratio and pore number in 35 species under LM. Tsukoda (4) made comparison between the fossil and modern representatives of *C. album* L., *C. ambrioides* L., *C. capitatum* (L.) Ascherson, *C. hybridum* L. and *C. murale* L. by SEM while Uotila (5) studied 21 *Chenopodium* L. species in detail by LM and SEM. The exine ultrastructure in *C. album* was shown by Skavarla and Nowicke (6).

The main aims of this study are to contribute to an understanding of the detailed pollen morphology of some *Chenopodium* L. species by light and electron microscopes.

Materials and Methods

Polliniferous material was taken from Ankara University Herbarium (ANK). The collections are listed under "Specimens investigated", following the sequence of Aellen (1).

For LM study, the pollen slides were prepared according to the technique of Wodehouse (W) (7) and Erdtman (E) (8). A Leitz-Wetzlar microscope was used for examination (ocular X16, objective X100). Measurements were taken statistically. In order to estimate the pore number, the method by Mc Andrews and Swanson (3), based on the ratio of distance between centers of adjacent pores (C) and the diameter of the diameter of the grain (D) was followed. Dimensions and morphological variation in pollen of *Chenopodium* are

given in Table 1. photographs were taken with a Leitz Phan-Photo microscope. Only photographs of selected representatives of pollen types are given.

For TEM study, acetolysed pollen grains were fixed in O_3O_4 , stained with uranyl acetate and embedded in araldite. Ultrathin sections were post-stained with lead citrate and uranylacetate. For SEM study, unacetolysed pollen grains were transferred to stubs and covered with gold. A jeol 100 CXII electron microscope was employed for both TEM and SEM studies.

Terminology follows that of Faegri and Iversen (9).

Specimens Investigated

<i>C. botrys</i>	KONYA	H. Ocakverdi 1412 ANK
<i>C. foliosum</i>	KONYA	M. Vural 1077 ANK
<i>C. chenopodium</i>	İZMİR	Y. Gemici 25116 ANK
<i>C. murale</i>	MUĞLA	Khan, Prance, Ratelliffe 142 ANK
<i>C. opulifolium</i>	AMASYA	P. Uotilo 19897 ANK
<i>C. vulvaria</i>	İSTANBUL	P. Uotilo 19897 ANK
<i>C. sosnowskyi</i>	ANKARA	B. Kasaplıgil 15 ANK
<i>C. urbicum</i>	ÇORUM	P. Motila 19927 ANK
<i>C. polyspermum</i>	ANKARA	P. Aellen 119 ANK
<i>C. album</i>	BOLU	Butter, Bothmer 2551 ANK
<i>C. glaucum</i>	BURSA	B. Kasaplıgil ANK
<i>C. ambrosoides</i>	MUĞLA	P. Uotilo 30590 ANK

Results

Pollen descriptions

Chenopodium botrys L.

Pollen grains radial symmetrical, isopolar, pantopolyporate, spheroidal, pollen diameter (D) 20.4 μ m (E) Pores 1.7 μ m (W) in diameter and circular. Operculum 1.3 μ m (E) wide; 0.5 μ m high, 4-5 conical spinules on operculum. Distance between the centers of the centers of the adjacent pores (C) μ m. C/D 0.2067. Pore number 84.

Ornamentation scabrate; 139 spinules per 100 μ m²; tectal spinules conical, 0.1 μ m high, 0.1 μ m wide.

Exine 1.2 μ m (W), 1.4 μ m (E) thick; ektexine 1.33 μ m thick; tectum subtectate, 0.56 μ m thick; columellae 0.7 μ m high, 0.24 μ m wide; foot layer continuous, 0.07 μ m thick; endexine irregular, 0.07 μ m thick.

Intine 0.25 μ m (W) thick (Ex/Int \approx 3/1).

C. foliosum (Moench) Aschers

Pollen grains radial symmetrical, isopolar, pantopolyporate, spheroidal, pollen diameter (D) 21.3 μ m (W), 21.7 μ m (E). Pores 1.9 μ m (W), 2 μ m (E) in diameter and circular. Operculum 1.8 μ m (E) wide; 0.43 μ m high, 4-5 conical spinules on operculum. Distance between the centers of the adjacent pores (C) 5.3 μ m. C/D 0.2448. Pore number 60.

Ornamentation scabrate; 75 spinules per 100 μ m²; tectal spinules conical, 0.3 μ m high, 0.37 μ m wide.

Table 1. Dimensions and morphological variation in pollen of *Chenopodium*

TAXA	Pollen Dimension (D)		Pit		C	Op. diameter	Exine		Intine		C/D	Por number
	(μ m)	(μ m)	(μ m)	(μ m)			(μ m)	(μ m)	(μ m)	(μ m)		
	E	W	E	W	E	E	W	E	W			
<i>Chenopodium botrys</i>	20.8	20.4	1.7	1.7	4.3	1.3	1.4	1.2	0.25	0.2067	84	
<i>C. foliosum</i>	21.7	21.3	2	1.9	5.3	1.8	1.5	1.25	0.5	0.2448	60	
<i>C. chenopodioides</i>	16.1	15.4	2.5	2.2	4.3	2.5	1.4	1.4	0.3	0.2692	49	
<i>C. murale</i>	20.8	20.5	2.1	2.2	4.4	2.1	1.76	1.6	0.4	0.2125	79	
<i>C. opulifolium</i>	31.6	28.4	2.5	2.3	5.8	2.3	1.9	2.1	0.5	0.1835	107	
<i>C. vulvaria</i>	25	24.3	3.1	2.9	7.3	2.8	1.5	1.6	0.54	0.2920	41	
<i>C. sosnowskyi</i>	26.5	26.5	2.5	2.5	5.8	2.3	1.76	1.9	0.3	0.2190	75	
<i>C. urbicum</i>	18.7	18	2	1.9	3.9	2	1.79	1.4	0.4	0.2083	83	
<i>C. polyspermum</i>	16	16	2.5	2.5	5.1	2.4	1.5	1.5	0.25	0.3167	35	
<i>C. album</i>	25.3	25.3	2	2	4.6	1.9	1.9	1.9	0.4	0.1818	107	
<i>C. glaucum</i>	18.5	18	1.25	1.25	3.19	1.12	1.12	1.2	0.4	0.1724	121	
<i>C. amrosioides</i>	21.1	21.1	1.4	1.3	4	1.3	1.3	1.2	0.4	0.1886	101	

Exine 1.25 μm (W), 1.5 (E) thick; extexine 1.42 μm thick; tectum subtectate, 0.67 μm thick; columellae 0.69 μm high, 0.32 μm wide; foot layer continuous, 0.1 μm thick; endexine irregular, 0.08 μm thick.

Intine 0.5 μm (W) (Ex/Int \approx 3/1).

C. ambrosioides L.

Pollen grains radial symmetrical, isopolar, pantoplyporate, spheroidal, pollen diameter (D) 21.1 μm (W) (E). Pores 1.3 μm (W), 1.4 μm (E) in diameter and circular. Operculum 1.3 μm (E) wide; 0.2 μm high, 3-4 conical spinules on operculum. Distance between the centers of the adjacent pores (C) 4 μm . C/D 0.1886. Pore number 101.

Ornamentation scabrate; 75 spinules per 100 μm^2 ; tectal spinules conical, 0.3 μm high, 0.4 μm wide.

Exine 1.2 μm (W), 1.3 (E) thick; extexine 1.23 μm thick; tectum subtectate, 0.58 μm thick; columellae 0.59 μm high, 0.42 μm wide; foot layer continuous, 0.05 μm thick; endexine irregular, 0.07 μm thick.

Intine 0.4 μm (W) (Ex/Int \approx 3/1).

C. glaucum L. (Fig. 5-8)

Pollen grains radial symmetrical, isopolar, pantoplyporate, spheroidal, pollen diameter (D) 18 μm (W) 18.5 μm (E). Pores 1.25 μm (W) (E) in diameter and circular. Operculum 1.12 μm (E) wide; 0.2 μm high, 3-4 conical spinules on operculum. Distance between the centers of the adjacent pores (C) 3.19 μm . C/D 0.1724. Pore number 121.

Ornamentation scabrate; 104 spinules per 100 μm^2 ; tectal spinules conical, 0.24 μm high, 0.25 μm wide.

Exine 1.2 μm (W), 1.28 μm (E) thick. Extexine 1.2 μm thick; tectum subtectate, 0.52 μm thick; columellae 0.63 μm high, 0.28 μm wide; foot layer continuous 0.045 μm thick; endexine irregular, 0.08 μm thick.

Intine 0.4 μm (W) thick (Ex/Int \approx 3/1).

C. chenopodioides (L.) Aellen (Fig 1-4)

Pollen grains radial symmetrical, isopolar, pantoplyporate, spheroidal, pollen diameter (D) 15.4 μm (W) 16.1 μm (E). Pores 2.2 μm (W), 2.5 μm (E) in diameter and circular. Operculum 2.5 μm (E) wide; 0.2 μm high, 12-15 conical spinules on operculum. Distance between the centers of the adjacent pores (C) 4.3 μm . C/D 0.2692. Pore number 49.

Ornamentation scabrate; 94 spinules per 100 μm^2 ; tectal spinules conical, 0.28 μm high, 0.4 μm wide.

Exine 1.4 μm (W) (E) thick. Extexine 1.36 μm thick; tectum subtectate, 0.6 μm thick; columellae 0.69 μm high, 0.22 μm wide; foot layer continuous 0.07 μm thick; endexine irregular, 0.07 μm thick.

Intine 0.3 μm (W) thick (Ex/Int \approx 5/1).

C. murale L. (Fig 9-13)

Pollen grains radial symmetrical, isopolar, pantoplyporate, spheroidal, pollen diameter (D) 20.5 μm (W) 20.8 μm (E). Pores 2.2 μm (W), 2.1 μm (E) in diameter and circular. Operculum 2.1 μm (E) wide; 0.2

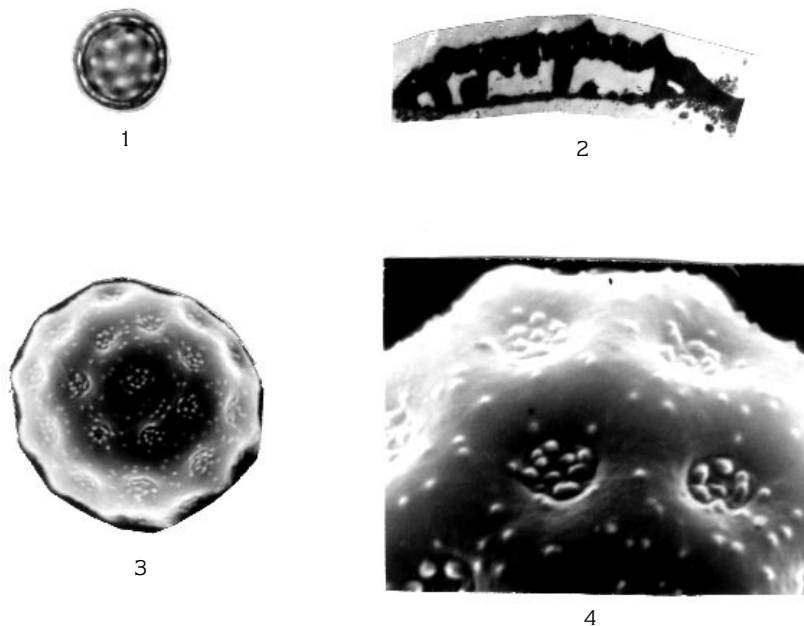


Figure 1-4. *C. polyspermum* type pollen showing *C. chenopodioides* pollen grains 1. Pollen grains in LMx1000 2. Exine structure, TEMx10000 3. Pores and ornamentation, SEMx3000 4. Pores and opercula SEMx10000.

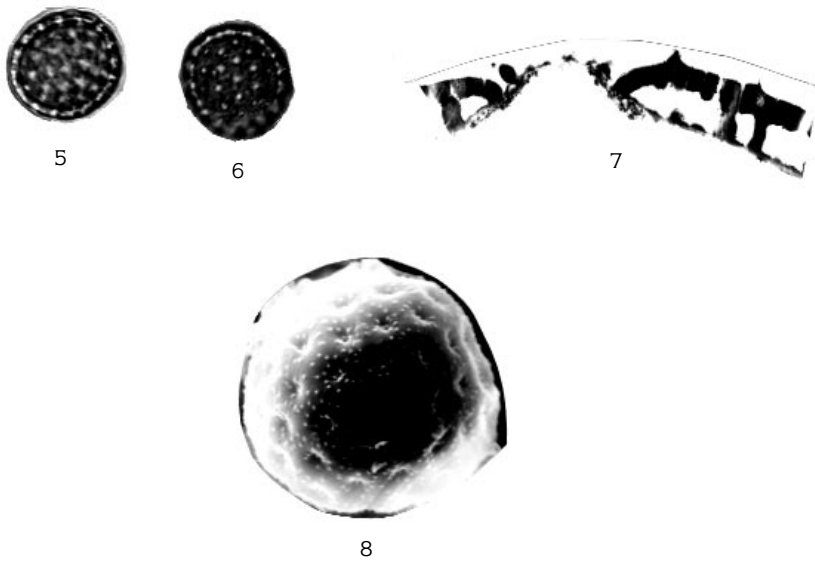


Figure 5-8. *C. urbicum* type pollen showing *C. glaucum* pollen grains 5-6. Pollen grains in LMx1000 7. Exine structure, TEMx10000 8. Pores and ornamentation, SEMx3000.

μm high, 5-6 conical spinules on operculum. Distance between the centers of the adjacent pores (C) $4.4 \mu\text{m}$. C/D 0.2125. Pore number 79.

Ornamentation scabrate; 105 spinules per $100 \mu\text{m}^2$; tectal spinules conical, $0.2 \mu\text{m}$ high, $0.3 \mu\text{m}$ wide.

Exine $1.6 \mu\text{m}$ (W), $1.76 \mu\text{m}$ (E) thick; ektexine $1.66 \mu\text{m}$ thick; tectum subtectate, $0.61 \mu\text{m}$ thick; columellae $0.95 \mu\text{m}$ high, $0.31 \mu\text{m}$ wide; foot layer continuous $0.095 \mu\text{m}$ thick; endexine irregular, $0.1 \mu\text{m}$ thick.

Intine $0.4 \mu\text{m}$ (W) thick (Ex/Int \approx 4/1).

C. opulifolium Schrad. (Fig 19-23)

Pollen grains radial symmetrical, isopolar, pantopolyporate, spheroidal, pollen diameter (D) $28.4 \mu\text{m}$ (W) $31.6 \mu\text{m}$ (E). Pores $2.3 \mu\text{m}$ (W), $2.5 \mu\text{m}$ (E) in diameter and circular. Operculum $2.3 \mu\text{m}$ (E) wide; $0.3 \mu\text{m}$ high, 4-6 conical spinules on operculum. Distance between the centers of the adjacent pores (C) $5.8 \mu\text{m}$. C/D 0.1835. Pore number 107.

Ornamentation scabrate; 130 spinules per $100 \mu\text{m}^2$; tectal spinules conical, $0.1 \mu\text{m}$ high, $0.15 \mu\text{m}$ wide.

Exine $2.1 \mu\text{m}$ (W), $1.9 \mu\text{m}$ (E) thick; ektexine $1.57 \mu\text{m}$ thick; tectum subtectate, $0.7 \mu\text{m}$ thick; columellae

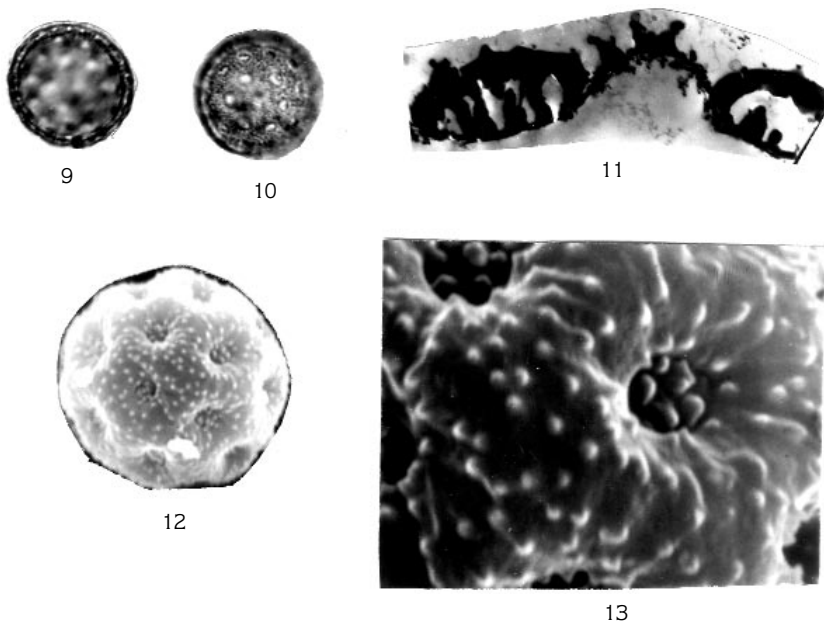


Figure 9-13. *C. murale* type pollen showing *C. murale* pollen grains 9-10. Pollen grains in LMx1000 11. Exine structure, TEMx10000 12. Pore and ornamentation, SEMx3000 13. Pores and opercula SEMx10000.

0.72 μm high, 0.25 μm wide; foot layer continuous 0.095 μm thick; endexine irregular, 0.33 μm thick.

Intine 0.5 μm (W) thick (Ex/Int \approx 4/1).

C. vulvaria L.

Pollen grains radial symmetrical, isopolar, pantoporporate, spheroidal, pollen diameter (D) 24.3 μm (W) 25 μm (E). Pores 2.9 μm (W), 3.1 μm (E) in diameter and circular. Operculum 2.8 μm (E) wide; 0.15 μm high, 6-7 conical spinules on operculum. Distance between the centers of the adjacent pores (C) 7.3 μm . C/D 0.2920. Pore number 41.

Ornamentation scabrate; 84 spinules per 100 μm^2 ; tectal spinules conical, 0.1 μm high, 0.12 μm wide.

Exine 1.6 μm (W), 1.15 μm (E) thick; ectexine 1.43 μm thick; tectum subtectate, 0.65 μm thick; columellae 0.7 μm high, 0.27 μm wide; foot layer continuous 0.045 μm thick; endexine irregular, 0.07 μm thick.

Intine 0.54 μm (W) thick (Ex/Int \approx 3/1).

C. sosnowskyi Kapeller

Pollen grains radial symmetrical, isopolar, pantoporporate, spheroidal, pollen diameter (D) 26.5 μm (W) (E). Pores 2.5 μm (W) (E) in diameter and circular. Operculum 2.3 μm (E) wide; 0.15 μm high, 6-7 conical spinules on operculum. Distance between the centers of the adjacent pores (C) 5.8 μm . C/D 0.2190. Pore number 75.

Ornamentation scabrate; 149 spinules per 100 μm^2 ; tectal spinules conical, 0.12 μm high, 0.19 μm wide.

Exine 1.9 μm (W), 1.76 μm (E) thick; ectexine 1.64 μm thick; tectum subtectate, 0.69 μm thick; columellae 0.85 μm high, 0.2 μm wide; foot layer continuous 0.045 μm thick; endexine irregular, 0.12 μm thick.

Intine 0.3 μm (W) thick (Ex/Int \approx 6/1).

C. urbicum L.

Pollen grains radial symmetrical, isopolar, pantoporporate, spheroidal, pollen diameter (D) 18 μm (W) 18.7 μm (E). Pores 1.9 μm (W), 2 μm (E) in diameter and circular. Operculum 2 μm (E) wide; 0.35 μm high, 10-12 conical spinules on operculum. Distance between the centers of the adjacent pores (C) 3.9 μm . C/D 0.2083. Pore number 83.

Ornamentation scabrate; 82 spinules per 100 μm^2 ; tectal spinules conical, 0.17 μm high, 0.2 μm wide.

Exine 1.4 μm (W), 1.79 μm (E) thick; ectexine 1.49 μm thick; tectum subtectate, 0.7 μm thick; columellae 0.69 μm high, 0.28 μm wide; foot layer continuous, 0.11 μm thick; endexine irregular, 0.3 μm thick.

Intine 0.4 μm (W) thick (Ex/Int \approx 4/1).

C. polyspermum L.

Pollen grains radial symmetrical, isopolar, pantoporporate, spheroidal, pollen diameter (D) 16 μm (W) (E). Pores 2.5 μm (E) in diameter and circular.

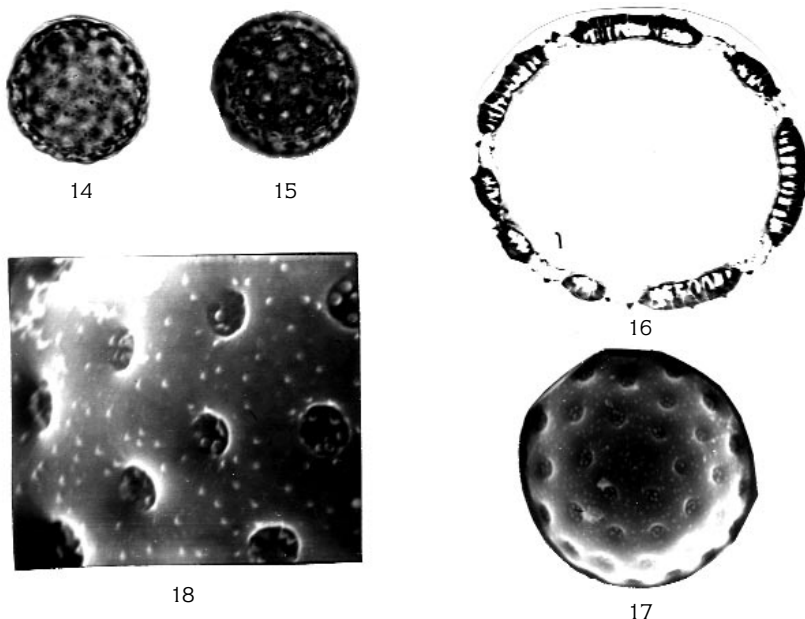


Figure 14-18. *C. vulvaria* type pollen showing *C. album* pollen grains 14-15. Pollen grains in LMx1000 16. Exine structure. TEMx3900 17. Pore and ornamentation. Semx3000 18. Pores and opercula SEMx10000.

Operculum 2.4 μm (E) wide; 0.4 μm high 5-6 conical spinules on operculum. Distance between the centers of the adjacent pores (C) 5.1 μm . C/D 0.3167. Pore number 35.

Ornamentation scabrate; 84 spinules per 100 μm^2 ; tectal spinules conical, 0.1 μm high, 0.12 μm wide.

Exine 1.5 μm (W) (E) thick. Ektexine 1.43 μm thick; tectum subtectate, 0.63 μm thick; columellae 0.69 μm high, 0.38 μm wide; foot layer continuous 0.07 μm thick; endexine irregular, 0.07 μm thick.

Intine 0.25 μm (W) thick (Ex/Int \approx 6/1).

C. album L. (Fig 14-18)

Pollen grains radial symmetrical, isopolar, pantopolporate, spheroidal, pollen diameter (D) 25.3 μm (W) (E). Pores 2 μm (W) (E) in diameter and circular. Operculum 1.9 μm (E) wide; 0.3 μm high, 7-9 conical spinules on operculum. Distance between the centers of the adjacent pores (C) 4.6 μm . C/D 0.1818. Pore number 107.

Ornamentation scabrate; 85 spinules per 100 μm^2 ; tectal spinules conical, 0.25 μm high 0.3 μm wide.

Exine 1.9 μm (W) (E) thick; ektexine 1.54 μm thick; tectum subtectate, 0.65 μm thick; columellae 0.8 μm high, 0.25 μm wide; foot layer continuous 0.095 μm thick; endexine irregular, 0.36 μm thick.

Intine 0.4 μm (W) thick. (Ex/Int \approx 5/1)

Discussion and Conclusion

Pollen grains of *Chenopodium* species examined are radially symmetrical, isopolar, pantopolporate and spheroidal. Their exine structure is similar under LM and TEM. Ektexine overlying endexine is thick. Tectum is discontinuous and it is as thick as the columellae layer. Foot layer is very thin. Endexine is as thick as foot layer and is discontinuous (Fig 2, 7, 11, 16 and 21).

Especially the number of pores and the C/D ratio on periporate pollen have been used as diagnostic character for taxonomic and pollen analytical purposes in the genus *Chenopodium* (3). The C/D ratio is used by Mc Andrews & Swanson (3) when they studied 74 North American sampled of 35 *Chenopodium* species. They found variations in the C/D ratio of the *Chenopodium* samples collected from different localities. Uotila (6) pointed out the importance of the C/D ratio and pore number in the *Chenopodium* species. We also gave variation in C/D ratio corresponding pore number according to Mc Andrews & Swanson and pollen size in Fig 24. The figure shows no correlation between pore number and pollen size of the species examined for the present study. Though the majority of the species have pollen 16-27 μm indiameter, there is a tendency of *C. opulifolium* to have larger pollen grains.

This research suggests that there are significant differences in pollen size and pore number within *Chenopodium* species.

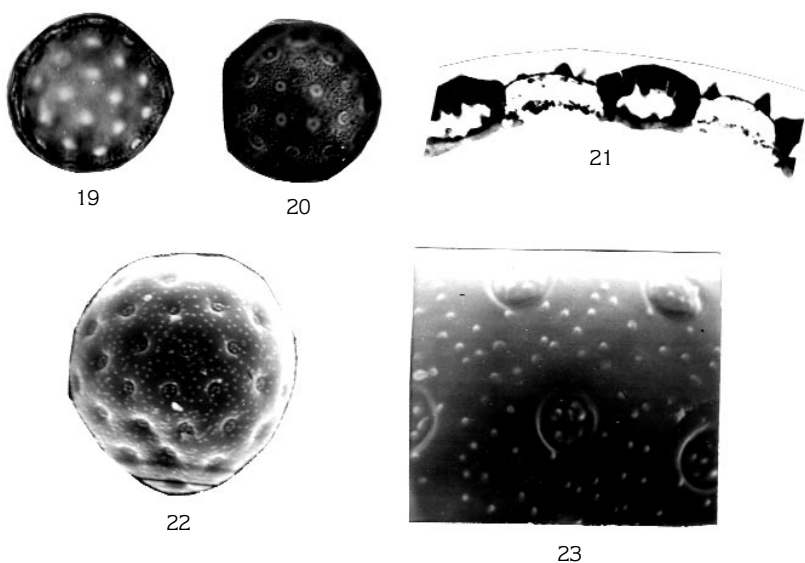


Figure 19-23. *C. opulifolium* type pollen showing *C. opulifolium* pollen grains 19-20. Pollen grains in LMx1000 21. Exine structure, TEMx10000 22. Pores and ornamentation, SEMx3000 23. Pores and opercula SEMx10000.

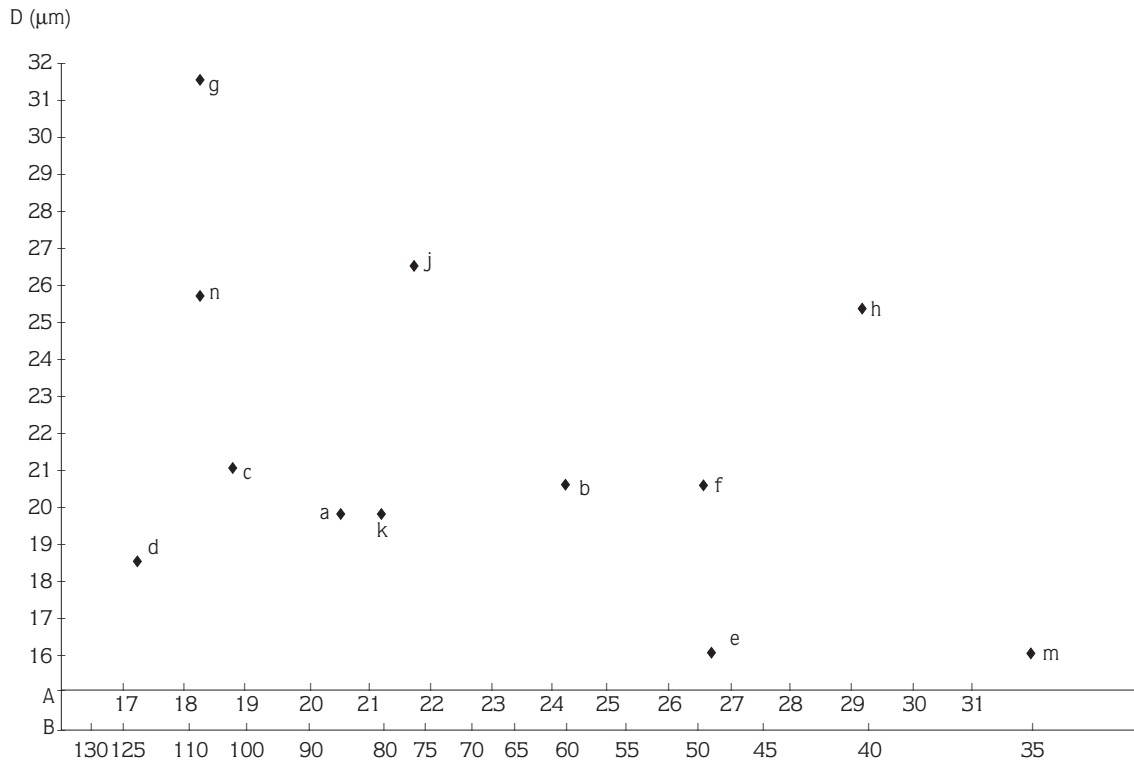


Figure 24. Variation in pollen size and C/D ratio (pore number) of *Chenopodium*. Vertical axis, diameter in μm . Horizontal axis, upper (A) C/D ratio, lower (B) corresponding pore number according to McAndrews & Swanson (1967).
 a. *C. botrys* b. *C. foliosum* c. *C. ambrosioides* d. *C. glaucum* e. *C. chenopodioides* f. *C. murale* g. *C. opulifolium* h. *C. vulgaria* j. *C. sosnowskyi* k. *C. urbicum* m. *C. polyspermum* n. *C. album*.

Chenopodium species have been divided into five pollen types, firstly on the basis of pollen diameter. The species placed in these types have been then evaluated with respect to their pore number.

1. *C. polyspermum* type: Pollen grains, ranging from 14-16 μm in diameter, belong here; *C. polyspermum* and *C. chenopodioides*. These two taxa can be distinguished from each other on the basis of pore number being 35 in the former and 49 in the latter.

2. *C. urbicum* type: Pollen grains, ranging from 18-19 μm in diameter, belong here; *C. urbicum* and *C. glaucum*. These two taxa can be distinguished from each other on the basis of number, being 83 in the former and 121 in the latter.

3. *C. murale* type: Pollen grains ranging from 20-22 μm in diameter are placed in this type including *C.*

murale, *C. botrys*, *C. foliosum* and *C. ambrosioides*, with 79, 84, 60 and 101 pores respectively. Since the number of pores is distinctively different, pollen grains of these species can be separated easily.

4. *C. vulvaria* type: Pollen grains ranging from 25-27 μm in diameter are placed in this type, including *C. vulvaria*, *C. sosnowskyi* and *C. album* with 41, 75 and 107 pores respectively.

5. *C. opulifolium* type: Pollen grains of *C. opulifolium* which are 30 μm in diameter belong here.

In conclusion, our research reveals that in the genus *Chenopodium*, only certain types can be separated palynologically. However, in this study, Turkish *Chenopodium* pollen morphology was described in detail.

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