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Pollen Morphology of *Artemisia* L. and Its Systematic Significance

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Abstract: The pollen of 57 species representing 7 sections of *Artemisia* was examined by light microscope and scanning microscope for the purpose to elucidate the systematic relationships of the genus. The examination indicates that the pollen grains present high concordance which is characterized by the globular or the approximate shape, 3-lobed circular from polar view while granular or ellipse sphere from tropical plate with tricolporate structure. The exine of pollen has an obvious double structure of inner and outer layers (including the tectum and columnar layers) where the outer is thicker than the inner and the sculpture of exine degenerates into small spinules easily distinguishable from other genera of the Compositae. Based on exine sculpture, the pollen grains of *Artemisia* can be divided into two types: Myriantha type and Mongolica type, which possesses 4 subtypes according to the distribution forms of spinule: (1) Sacrorum subtype, (2) Oligocarpa subtype, (3) Lavandulaefolia subtype, (4) Anomale subtype.

Key words: *Artemisia*; Compositae; pollen morphology; systematic significance

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0 Introduction

The morphological researches on the pollen grain of *Artemisia* can be oddly seen in overseas reports (Woodhouse^[1,2], Erdtman^[3,4], Ikuse^[5], Skavarla and Larson^[6], Singh and Joshi^[7], Praglowski^[8], Rowley^[9] *et al*). Researchers in China, also reported 8 species of pollen morphology of *Artemisia*^[10], and Lin yourun^[11] observed the representative plants belong to 7 sections of 2 subgenus of *Artemisia* L. in China by light microscope (LM). Ye Shi-tai *et al*^[12] observed 9 species of *Artemisia* L. in China. Chen Song-po *et al*^[13] observed pollen morphology of *Artemisia* L. in China under light and electron microscope.

Pollen of *Artemisia* L. is small in size but large in amount and pollinated by wind. What's more, some of the species are allergen in air. The studies on the morphology of pollen of *Artemisia* L. therefore has a practical value in medical science. Our this research mainly focuses on the morphological characteristics of pollen including the structure of its exine, the differences of the structure and sculpture of pollen exine to investigate the basis of classification and the relation between of *Artemisia* L. and its alliance.

1 Materials and Methods

1.1 Materials

(1) The materials for light microscope(LM) observation and photography are prepared by Erdtman's

acetolysis^[1] in advance of observation, measurement and picturing. 20 pollens from each species are measured and determined with average value manifested by maximum and minimum variation range, items including length of polar and tropical axis, thickness of exine and width of colpus.

(2) The acetolyzed pollens for the photography and observation of scanning electron microscope are washed by distilled water and placed in 50% ethanol, then sucked and located on bronze desk, determined dry they are coated with gold covering through ionic spraying and observed and photographed afterward.

1.2 Methods

Most of the materials are obtained from the specimen department of South China Institute of Botany (IB-SC) except for only a small part from the collected wild pollen, including 57 species of 7 sections of *Artemisia* L. in China (see Table 1).

2 Morphological Characteristics of Pollen of *Artemisia* L.

2.1 Observation under Light Microscope

The pollens appear globular or approximately round (subprolate or suboblate), a 3-lobed circular while observed from polar view and round or oblong from equatorial view, with 16.25-36.5 μm of polar axis length and 17.5-36.5 μm of tropical axis length. Pollens possesses tricolporate of which the middle is wider and both ends are narrow in average of 1.8-7.0 μm of colpus width. The porus are apparent and oblong, nearly round or transversely long in shape, its margin being almost regular, irregular or ruminant. The exine of pollens has an obvious two-layer structure: the outer layer and the inner layer. The outer is composed of a thinner tectum and a thicker columnar layers, the full thickness being 2.88-6.25 μm . The exine sculpture is actually the degenerative spinules whose features granular or granular reticulate appearance made up of respectively psilate, ruffles and rugulate with spinules three types.

2.2 Observation under Scanning Electronic Microscope

A spinule structure appears on every pollen surface and granular sculpture covers the tectum layer. We categorize the pollen of *Artemisia* L. into two types four subtype according to the shape and the arrangement of spinules and the sculpture among the interspinules, which

will be detailed discussed in the part of conclusion (Fig. 1, Fig. 2).

2.3 The Pollen Morphological Description of *Artemisia* L.

The 57 species of pollen from 7 sections of *Artemisia* observed above can be catalogued into two types and four sub-types, based on their sculpture in the exine (see Table 2).

(1) Myriantha type (Myr-type): characterized by multi-ruminant and outward extending base, mostly densely and minorly loosely arranged spinules connected by the stretching bases.

(2) Mongolica type (Mon-type): characterized by independent either densely or loosely arranged spinules without outward extending base connected by granular or smooth inter space. This type covers four subtype.

Sacrorum subtype (S-subtype): characterized by loosely arranged spinular with granular inter space.

Oligocarpa subtype (O-subtype): characterized by loosely arranged spinules and almost or slightly sinuate inter space.

Lavandulaefolia subtype (L-subtype): characterized by densely arranged spinules with granular inter space.

Anomale subtype (A-subtype): characterized by densely arranged spinules and slightly sinuate inter space.

3 Discussion and Conclusion

(1) The pollen morphological features of *Artemisia* L. present high concordance which is characterized by the globular or the approximate shape, 3-lobed circular from polar view while granular or ellipse sphere from tropical plate with tricolporate structure. According to the NPC system initiated by Erdtman in which "N" stands for the number of aperture, "P" for the position and "C" for the character, the NPC of *Artemisia* L. is defined to 345^[1]. The exine of pollen has an obvious double structure of inner and outer layers (including the tectum and columnar layers) where the outer is thicker than the inner and the sculpture of exine degenerates into small spinules easily distinguishable from other genera of the Compositae.

(2) It is very hard to distinguish among different species and sections only by their pollen's morphology, since *Artemisia* L. share high concordance. But there are also exceptions that pollen of *A. aurate* Komar. displays small volume of grain, loosely arranged sharp spinules on

Table 1 List of pollen materials for this study (Source: IBSC)

Species	Section	Locality	No. of specimen
<i>A. sieversiana</i> (Sie)	Absinthium	Gongliu, Xinjiang	Y. R. Lin 74363
<i>A. sericea</i> (Ser)	Absinthium	Gongliu, Xinjiang	Y. R. Lin 74435
<i>A. obtusiloba</i> (Obt)	Absinthium	Xinjiang	Xinjiang 07
<i>A. minor</i> (Min)	Absinthium	Mazongshan, Gansu	Gansu 15050
<i>A. polybotryoidea</i> (Pol)	Abrotanum	Antai, Xinjiang	G. L. Zhu 7281
<i>A. aksaiensis</i> (Aks)	Abrotanum	Akesai, Gansu	Gansu, 1563
<i>A. maximowicziana</i> (Max)	Abrotanum	Genhe, Neimenggu	S. E. Liu 8820
<i>A. indica</i> (Ind)	Artemisia	Donghu, Wuhan	Y. R. Lin 83021
<i>A. abaensis</i> (Aba)	Artemisia	Songpan, Sichuan	Aba 117
<i>A. campbellii</i> (Cam)	Artemisia	Zhongdian, Yunnan	J. S. Yang 83417
<i>A. imponens</i> (Imp)	Artemisia	Aba, Sichuan	Z. C. Zuo 830317
<i>A. selengensis</i> (Sel)	Artemisia	Fengxian, Shannxi	Z. Y. Zhang 202
<i>A. occidentalis-sichuanensis</i> (Occ)	Viscidpubes	Aba, Sichuan	S. Y. Zhao 103
<i>A. erlangshanensis</i> (Erl)	Viscidpubes	Hanyuan, Sichuan	H. C. Zhou 499
<i>A. myriantha</i> (Myr)	Viscidpubes	Kunming, Yunnan	Y. R. Lin 78241
<i>A. sphaerocephala</i> (Sph)	Dracunculus	Yimeng, Neimenggu	Q. R. Wu 152
<i>A. ordosica</i> (Ord)	Dracunculus	Yimeng, Neimenggu	Y. Q. Ma 57
<i>A. marschalliana</i> (Mar)	Dracunculus	Haba River, Xinjiang	Y. R. Lin 741209
<i>A. wellbyi</i> (Wel)	Dracunculus	Dingri, Tibet	Qingzang 4097
<i>A. nanschanica</i> (Nan)	Latilobus	Tibet	Tibet Team 3691
<i>A. xerophytica</i> (Xer)	Absinthium	Mingqin, Gansu	S. kun 490
<i>A. younghusbandii</i> (You)	Absinthium	Lasa, Tibet	B. S. Zhong 6111
<i>A. stracheyi</i> (Str)	Absinthium	Pulan, Tibet	Qingzang 76538
<i>A. anethifolia</i> (Ane)	Absinthium	Taiyuan, Shanxi	B. L. Li 01
<i>A. fauriei</i> (Fau)	Absinthium	Hebei	Unknown
<i>A. sacrorum</i> (Sac)	Abrotanum	Anda, Heilongjiang	S. E. Liu 6596
<i>A. succulenta</i> (Suc)	Abrotanum	Artai, Xinjiang	T. Y. Zhou 652188
<i>A. robusta</i> (Rob)	Artemisia	Kunming, Yunnan	N. H. Xia 40
<i>A. phyllobotrys</i> (Phy)	Artemisia	Angjiu, Qinghai	Z. C. Zuo 80466
<i>A. vaxans</i> (Yac)	Artemisia	Langcazi, Tibet	Qingzang 7699
<i>A. tanutica</i> (Tan)	Artemisia	Huangzhong, Qinghai	Y. R. Lin 80006
<i>A. flaccida</i> (Fla)	Albibracteata	Paomasha, Sichuan	L. Jiang 90024
<i>A. songarica</i> (Son)	Dracunculus	Mingqin, Gansu	X. D. Wang 491
<i>A. waltonii</i> (Wal)	Dracunculus	Naidong, Tibet	L. R. Xu 04
<i>A. gyangzeensis</i> (Gya)	Dracunculus	Lasa, Tibet	Z. C. Ni, unknown
<i>A. scoparia</i> (Sco)	Dracunculus	Meixian, Shannxi	X. M. Zhang 777
<i>A. pewzowi</i> (Pew)	Dracunculus	Xinjiang	Y. R. Lin 741036
<i>A. blepharotripis</i> (Ble)	Dracunculus	Bameng, Neimenggu	Unknown
<i>A. desertorum</i> (Des)	Latilobus	Sichuan	Biology Ins. 10204
<i>A. duthreuil-de-rhinsi</i> (Dut)	Latilobus	Sichuan	Sichuan 9576
<i>A. japonica</i> (Jap)	Latilobus	Yunnan	M. K. Li 0442
<i>A. aurata</i> (Aur)	Artemisia	Hailaer, Neimenggu	Z. Wang 2134
<i>A. dracunculus</i> (Dra)	Dracunculus	Artai, Xinjiang	T. Y. Zhou 652201
<i>A. oligocarpa</i> (Oli)	Dracunculus	Taiwan	S. Suzuki 2417
<i>A. shangnanensis</i> (Sha)	Abrotanum	Shangnan, Shannxi	S. B. He 626
<i>A. annua</i> (Ann)	Abrotanum	Hongyuan, Sichuan	SY. Zhao 88002
<i>A. argyi</i> (Arg)	Artemisia	Wushan, Sichuan	G. H. Yang 65659
<i>A. lavandulaefolia</i> (Lav)	Artemisia	Kunming, Yunnan	Y. R. Lin 782469
<i>A. calophylla</i> (Cal)	Artemisia	Luding, Sichuan	L. Jiang 90026
<i>A. velutina</i> (Vel)	Artemisia	Miyi, Sichuan	S. Y. Zhao 221
<i>A. mongolica</i> (Mon)	Artemisia	Hailaer, Neimenggu	S. E. Liu 8086
<i>A. somai</i> var. <i>batakensis</i> (Bat)	Artemisia	Taiwan	S. Suzuki s. n
<i>A. dubia</i> (Dub)	Latilobus	Huzhu, Qinghai	Y. R. Lin 80314
<i>A. conaensis</i> (Con)	Latilobus	Sichuan	W. K. Hu 2324
<i>A. chingii</i> (Chi)	Viscidpubes	Wengyuan	X. Q. Liu 24910
<i>A. anomala</i> (Ano)	Albibracteata	Jiangxi	Jiangxi 3765
<i>A. edgeworthii</i> (Edg)	dracunculus	Tibet	Z. C. Ni, unknown

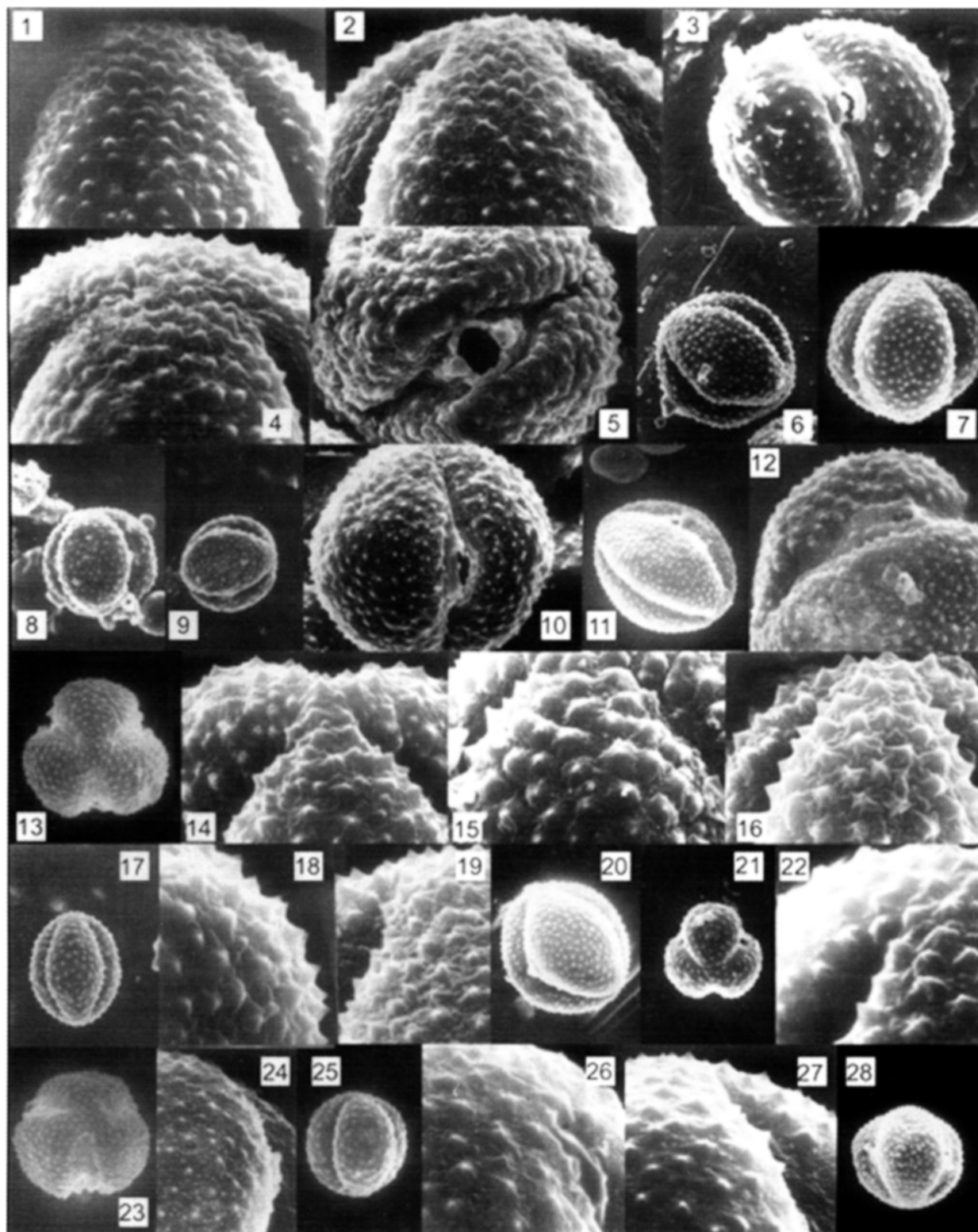


Fig. 1 Pollen morphology of *Artemisia* L. and Its systematic significance[1]

1. *A. sieversiana*($\times 5\ 000$); 2. *A. sericea*($\times 5\ 000$); 3. *A. obtusiloba*($\times 1\ 800$); 4. *A. minor*($\times 5\ 000$); 5. *A. polybotryi*($\times 2\ 000$); 6. *A. aksuensis*($\times 850$); 7. *A. maximowicziana*($\times 1\ 200$); 8. *A. indica* ($\times 1\ 000$); 9. *A. abaensis*($\times 750$); 10. *A. campbellii*($\times 1\ 800$); 11. *A. imponens*($\times 1\ 200$); 12. *A. selengensis* ($\times 2\ 500$); 13. *A. occidentalis-sichuanensis*($\times 1\ 100$); 14. *A. erlangshanensis*($\times 5\ 000$); 15. *A. myriantha*($\times 5\ 000$); 16. *A. sphaerocephala*($\times 5\ 000$); 17. *A. ordosica*($\times 850$); 18. *A. marschalliana*($\times 5\ 000$); 19. *A. wellbyi* ($\times 5\ 000$); 20. *A. nanshanica*($\times 1\ 000$); 21. *A. xerophytica*($\times 850$); 22. *A. younghusbandii* ($\times 5\ 000$); 23. *A. stracheyi*($\times 1\ 000$); 24. *A. anethi folia*($\times 5\ 000$); 25. *A. fauriei*($\times 900$); 26. *A. sacrorum* ($\times 5\ 000$); 27. *A. succulenta*($\times 5\ 000$); 28. *A. robusta*($\times 900$)

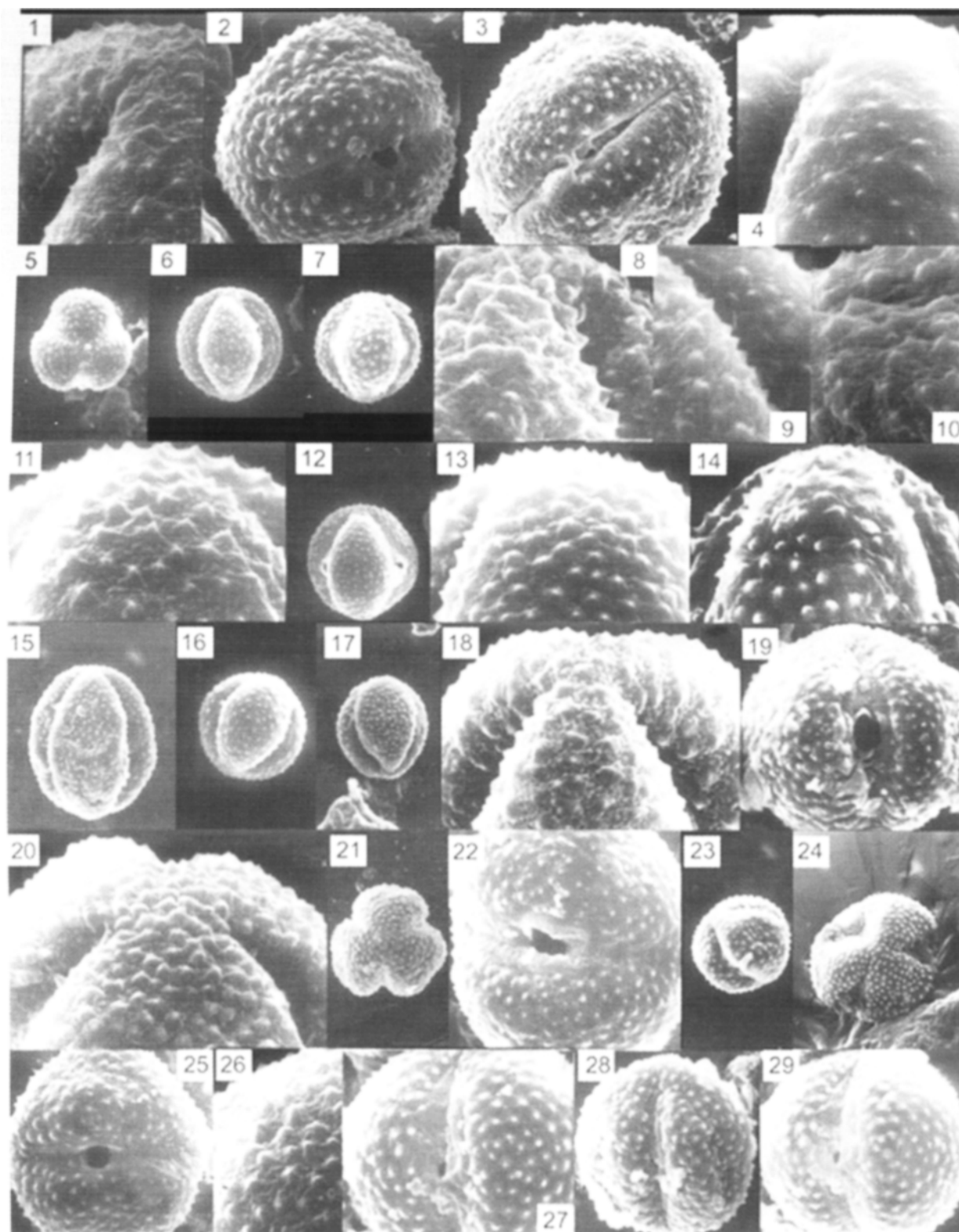


Fig. 2 Pollen morphology of *Artemisia* L. and its systematic significance(II)

1. *A. phyllobotrys*($\times 5\ 000$); 2. *A. vaxans*($\times 2\ 000$); 3. *A. tanutica*($\times 2\ 200$); 4. *A. flaccida*($\times 5\ 000$); 5. *A. songarica*($\times 900$);
 6. *A. waltonii*($\times 900$); 7. *A. gyangzeensis*($\times 900$); 8. *A. scoparia*($\times 5\ 000$); 9. *A. pewzowi*($\times 5\ 000$); 10. *A. blepharotwipis*($\times 5\ 000$);
 11. *A. desertorum*($\times 5\ 000$); 12. *A. duthreuil-de-rhinsi*($\times 1\ 000$); 13. *A. japonica*($\times 5\ 000$); 14. *A. aurata*($\times 5\ 000$); 15. *A. dracunculus*
 ($\times 800$); 16. *A. oligocarpa*($\times 900$); 17. *A. shangnanensis*($\times 900$); 18. *A. annua*($\times 5\ 000$); 19. *A. argyi*($\times 2\ 500$); 20. *A. lavandulaefolia*
 ($\times 5\ 000$); 21. *A. calophylla*($\times 950$); 22. *A. velutina*($\times 1\ 900$); 23. *A. mongolica*($\times 1\ 000$); 24. *A. somai* var. *Batakensis*($\times 700$); 25. *A. dubia*
 ($\times 1\ 600$); 26. *A. conaensis*($\times 5\ 000$); 27. *A. chingii*($\times 2\ 200$); 28. *A. anomala*($\times 2\ 200$); 29. *A. edgeworthii*($\times 2\ 300$)

Table 2 The pollen morphological description of *Artemisia* L.

Species	Equatorial view	Size(length × height) μm	P/E	Ora of aperture	Thickness of exine μm	Sculpture of exine	
						LM	SEM
Sie	globular or approximate	(25.29 ± 2.31) × (23.94 ± 2.02)	1.057	TBI	1.05 ± 0.10	granular	Myr-type
Ser	oblate or globular	(25.53 ± 1.83) × (28.63 ± 2.13)	0.872	ROR	1.87 ± 0.25	granular	Myr-type
Obt	oblate or globular	(25.12 ± 1.87) × (27.31 ± 2.05)	0.912	ROS	3.91 ± 0.13	granular	Myr-type
Min	globular or approximate	(23.00 ± 2.50) × (22.5 ± 1.85)	1.028	ROS	5.20 ± 0.40	granular	Myr-type
Pol	long or round	(32.75 ± 2.25) × (28.3 ± 1.65)	1.158	WOR	6.21 ± 0.40	rough granular	Myr-type
Aks	globular or approximate	(31.40 ± 2.5) × (29.16 ± 2.25)	1.078	round	5.06 ± 0.23	granular	Myr-type
Max	long or globular	(24.75 ± 2.00) × (23.05 ± 2.5)	1.078	TLO	5.87 ± 0.21	granular	Myr-type
Ind	oblate or globular	(20.25 ± 2.25) × (21.38 ± 2.5)	0.917	LOU	5.28 ± 0.36	granular	Myr-type
Aba	long or globular	(25.6 ± 2.50) × (23.52 ± 2.5)	1.087	EOR	5.62 ± 0.50	granular	Myr-type
Cam	globular or approximate	(21.3 ± 2.50) × (23.5 ± 2.10)	1.031	EOR	1.87 ± 0.35	granular-reticulate	Myr-type
Imp	long or globular	(28.3 ± 0.73) × (22.15 ± 1.5)	1.278	ROR	5.87 ± 0.32	granular-reticulate	Myr-type
Sel	globular	(26.88 ± 1.8) × (26.15 ± 2.50)	1.078	Bigger ROR	5.59 ± 0.26	granular-reticulate	Myr-type
Oce	long or globular	(22.15 ± 1.5) × (23.5 ± 2.10)	0.918	Bigger ROR	5.66 ± 0.12	granular	Myr-type
Erl	oblate or globular	(26.63 ± 2.25) × (29.8 ± 2.25)	0.898	ROR	5.16 ± 0.30	granular	Myr-type
Myr	oblate or globular	(23.88 ± 2.25) × (21.91 ± 2.35)	0.957	ROR	1.96 ± 0.25	granular reticulate	Myr-type
Sph	globular or approximate	(20.25 ± 2.55) × (20.02 ± 1.50)	1.013	Obscure	3.05 ± 0.15	granular	Myr-type
Ord	globular	(23.19 ± 2.25) × (23.19 ± 1.50)	1.000	LOR	3.41 ± 0.25	granular	Myr-type
Mar	long or globular	(23.16 ± 2.05) × (21.50 ± 1.80)	1.000	LOR	3.15 ± 0.18	granular	Myr-type
Wel	globular or approximate	(23.22 ± 2.00) × (22.44 ± 1.85)	0.990	TLO	3.00 ± 0.20	granular	Myr-type
Nan	long or globular	(21.50 ± 1.85) × (21.10 ± 2.30)	1.017	TLO	1.22 ± 0.38	granular	Myr-type
Xer	globular or approximate	(21.50 ± 2.05) × (22.50 ± 1.50)	0.958	BOI	3.25 ± 0.15	granular	S-subtype
You	globular	(21.25 ± 1.50) × (25.25 ± 2.05)	0.970	ROR	5.23 ± 0.30	granular	S-subtype
Str	globular	(25.60 ± 2.00) × (25.40 ± 2.25)	1.007	ROR	5.25 ± 0.40	granular	S-subtype
Anc	globular	(22.40 ± 1.50) × (22.40 ± 1.55)	1.000	ROR	2.89 ± 0.20	granular	S-subtype
Fau	globular	(22.40 ± 2.05) × (22.40 ± 2.10)	1.000	LOR	3.25 ± 0.15	granular	S-subtype
Sac	globular	(21.81 ± 1.25) × (21.63 ± 1.25)	1.007	Round	5.05 ± 0.40	granular	S-subtype
Suc	globular	(21.37 ± 2.05) × (23.40 ± 2.05)	1.051	EOI	5.66 ± 0.05	granular reticulate	S-subtype
Rob	long or globular	(21.70 ± 1.75) × (19.80 ± 1.90)	1.098	EOC	3.15 ± 0.25	granular-reticulate	S-subtype
Phy	long or globular	(21.20 ± 1.70) × (20.87 ± 2.15)	1.158	LOR	3.26 ± 0.25	granular-reticulate	S-subtype
Yac	oblate or globular	(23.11 ± 2.25) × (21.75 ± 1.25)	0.917	LOI	5.87 ± 0.15	granular-reticulate	S-subtype
Tan	oblate or globular	(22.69 ± 0.20) × (23.13 ± 1.25)	0.988	LOR	5.28 ± 0.20	granular-reticulate	S-subtype
Fla	globular or approximate	(26.30 ± 1.90) × (21.50 ± 1.60)	1.077	TLO	5.32 ± 0.10	granular	S-subtype
Son	globular or approximate	(21.50 ± 1.60) × (20.50 ± 1.40)	1.017	TLO	3.17 ± 0.15	granular	S-subtype
Wal	globular or oblate	(23.22 ± 1.50) × (23.30 ± 0.25)	0.998	LOR	3.18 ± 0.10	granular	S-subtype
Gya	globular or long	(23.80 ± 2.20) × (21.8 ± 2.00)	1.092	LOR	1.27 ± 0.06	granular	S-subtype
Sco	globular or oblate	(20.40 ± 1.50) × (21.31 ± 1.75)	0.917	LOR	3.08 ± 0.18	granular	S-subtype
Pew	globular or approximate	(21.25 ± 1.55) × (21.25 ± 1.85)	1.000	LOR	5.20 ± 0.33	granular	S-subtype
Ble	globular or approximate	(23.16 ± 2.00) × (23.17 ± 2.00)	0.999	LOR	3.89 ± 0.05	granular	S-subtype
Des	globular or oblate	(21.25 ± 0.150) × (21.50 ± 0.25)	0.988	TLO	3.80 ± 0.30	rough granular	S-subtype
Dut	globular or oblate	(20.16 ± 1.60) × (21.30 ± 0.18)	0.917	TLO	3.11 ± 0.20	granular-reticulate	S-subtype
Jap	globular	(21.81 ± 2.05) × (21.56 ± 2.25)	1.017	TLO	1.28 ± 0.38	granular reticulate	S-subtype
Aur	long or globular	(18.25 ± 0.26) × (16.98 ± 1.15)	1.072	EOR	2.15 ± 0.15	granular	O-subtype
Dra	globular or oblate	(32.38 ± 2.26) × (33.69 ± 1.25)	0.961	LOR	3.6 ± 0.20	granular	O-subtype
Oli	globular or oblate	(23.17 ± 2.40) × (21.60 ± 1.80)	0.912	LOR	1.94 ± 0.15	granular	O-subtype
Sha	oblate or globular	(23.69 ± 2.85) × (26.19 ± 2.50)	0.901	round, sharp	1.63 ± 0.25	granular reticulate	L-subtype
Ann	globular	(25.10 ± 2.25) × (21.97 ± 2.25)	1.007	LOR	3.91 ± 0.06	granular reticular	L-subtype
Arg	globular	(23.85 ± 1.85) × (23.81 ± 2.25)	1.002	LOR	1.32 ± 0.20	granular-reticulate	L-subtype
Lav	oblate or globular	(28.16 ± 1.85) × (28.96 ± 1.50)	0.977	round	5.20 ± 0.30	granular reticulate	L-subtype
Cal	long or globular	(25.88 ± 2.70) × (24.02 ± 1.63)	1.071	EOR	4.56 ± 0.25	granular-reticulate	L-subtype
Vel	oblate or globular	(23.11 ± 2.25) × (21.50 ± 2.10)	0.917	EOI	1.38 ± 0.15	granular reticulate	L-subtype
Mon	globular or approximate	(22.13 ± 2.00) × (23.40 ± 1.75)	0.904	LOS	4.78 ± 0.20	granular	L-subtype
Bat	globular or approximate	(24.94 ± 1.50) × (21.38 ± 2.50)	1.168	ROR	5.28 ± 0.15	granular	L-subtype
Dub	globular	(23.62 ± 1.90) × (23.62 ± 1.50)	1.000	round	3.15 ± 0.28	granular	L-subtype
Con	globular	(26.70 ± 2.40) × (26.70 ± 2.65)	1.000	TLO	5.63 ± 0.10	granular	L-subtype
Chi	globular	(20.75 ± 2.05) × (20.53 ± 1.50)	1.018	EOI	2.66 ± 0.25	granular	A-subtype
Ano	globular or approximate	(19.50 ± 1.25) × (19.81 ± 1.95)	0.982	TLO	2.54 ± 0.10	granular	A-subtype
Edg	globular or approximate	(21.5 ± 2.00) × (20.88 ± 1.80)	1.028	LOS	3.11 ± 0.28	granular	A-subtype

P/E: Polar length/Equatorial length; TBI: transversely broad with irregular margins; ROR: round opening with ruminate margins; ROS: round opening with smooth margins; WOR: wider opening with ruminate margins; TLO: transversely long opening; LOU: long opening with unclear margin; EOI: ellipse opening with irregular margin; EOR: ellipse opening with ruminate margin; BOI: broad opening with irregular margins; EOC: ellipse opening with clear margin; LOS: long opening with slightly clear margin

exine along with the smooth inter space distinguishable from others which is determined likely to be associated with the humid north-eastern Asian stony hillsides where it grows; the pollen of the *A. lactiflora* Wall. ex DC. in addition is also special among pollens of *Artemisia* L. for possessing large and small two types of spinulose structures on surface^[13]; and pollens of *A. integrifolia* var. *Subulata* (Nakai) Pamp. And the *A. pontica* L. feature dicolporate type (NPC-245) according to the reports of Prageowski^[11].

The morphological changes of pollens within *Artemisia* L. are probably associated with the adaptation to the anemophily pollination. The degenerative small spinulose sculpture of the exine of the *Artemisia* L. pollens is distinctly different from those of other genera in family Compositae depending on the entomophily pollination. It shows that every type (sub types) of *Artemisia* L. in their evolution developed more and more degenerative small thorns along with less and less or even no granules between spinules sharing evolved regular arrangement from dense to loose. The types (sub types) of *Artemisia* L. pollens above are also related to their distribution, that is, the primitive group defined to Myriantha type is generally dispersed in the high-latitude high-elevation arid regions while the low-latitude low elevation moist regions are more likely to have the advanced categories defined to Oligocarpa subtype and Anomale subtype. The possible tendency for the pollen morphological evolution of each type (sub-type) is as below:

Myriantha type → Sacrorum subtype → Oligocarpa subtype

Myriantha type → Lavandulaefolia subtype → Anomale subtype

(3) The primitive group of *Artemisia* L. pollen usually has a broader colpus. The evolved species and those widely distributed or those in the east and south generally have thinner groove and narrower polar region, minorly thinner colpus, demonstrating that *Artemisia* L. is originated in temperate zone and shifted southward in the third and forth glacial epoch leaving the primitive species in the north temperate zone or high latitude regions and the advanced ones in the low latitude and low elevation regions, hypothesis according the conclusion and results of Lin^[14,15] and Jiang's^[16-18] experiments.

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