

FRUITS, SEEDS AND POLLEN MORPHOLOGY OF *ALYSSUM* L. (BRASSICACEAE) AND THEIR TAXONOMIC VALUE

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ABSTRACT

In the current study, macro- and micromorphological characters of fruits, seeds, and pollen in *Alyssum* L. (14 to 19 species) were examined by stereo, light (LM) and scanning electron microscope (SEM) to evaluate the taxonomic significance of these characters. Detailed description of features of Turkish *Alyssum* species are provided with illustrations. Generally, the pollen grains are radially symmetrical and isopolar. The fruit surface is glabrous or stellate trichome. The seeds are ovate, spheroidal or oblong in shape among the studied species. The colors of the seed vary between light brown, dull yellow brownish, bright red brownish, dark brownish, dull light reddish, bright brownish, bright red brownish, dull brownish and dull yellowish. The surface of the seed is reticulate (normal reticulate, reticulate-foveate, reticulate-lineolate, reticulate-rugose), ruminant, rugose, lineolate, blister and colliculate in SEM. The pollen grains of the genus are subprolate or prolate. The pollen grains are tricolpate. Exine ornamentations are mainly reticulate. Ornamentations, pollen shape and size, aperture type, colpus length and width, fruit and seed shape, size and color, seed anti and periclinal walls have been observed as significant morphological characters.

KEYWORDS:

Alyssum L., Fruit, Pollen, Seed, Light microscope, Turkey.

INTRODUCTION

The Brassicaceae or Cruciferae family is a monophyletic group of about 325 genera and over 3740 species distributed worldwide [1]. Turkey has at least 606 Brassicaceae species, of which 226 are native [2, 3, 4]. The genus *Alyssum* L. is one of the largest genera, which includes about 195 species in the world with main distribution in Turkey and Eastern Europe [5]. There are about 100 species of the genus *Alyssum* in Turkey [6].

Industrialization, urbanization and due to the rapid growth of the world population has caused heavy metal pollution so that caused global problem over time [7, 8, 9]. The use of plants for the cleaning and remediation of contaminated areas is a safe way of ensuring natural balance [9, 10]. Many wild Brassicaceae species are known to hyperaccumulate heavy metals and have genes for tolerance to the toxic effects of a broad range of metals [11]. *Alyssum* species can grow in very high metal concentration soils. High Ni levels cause toxic effects on seed germination [12]. The effects of nickel on seed germination, root and hypocotyl elongation of the nickel hyperaccumulator some *Alyssum* species demonstrated in the study carried out by Pavlova et al. [12] distributed on the Albania. The determination of heavy metal distribution in plants is one of the most exert attribute related to environmental remediation [13]. Soil metal concentration ranges were reported from the studies carried out by Sağlam [14] and Bani et al. [15]. Branković et al. [16] reported that exhibit different metal concentration in *Alyssum* species, depending on kind of metals and plant species. Hyperaccumulator *Alyssum* species could be successfully used for the further biogeochemical prospecting and environmental monitoring [17]. Furthermore, some *Alyssum* species can be used as a precursor in erosion studies because they are not selective in terms of drought or soil requirements [18].

The taxonomic significance of pollen, seed and fruit morphological information has been stressed by several studies to solve phylogenetic and systematic problems between different taxa in the family Brassicaceae. Karaismailoğlu [19] genus *Aethionema*, Sagun and Auer [20] tribe Camelinae, Mutlu and Erik [21] genus *Arabis* L., Keshavarzi et al. [22] genus *Chypeola*, Khan [23] genera *Atelantha*, *Arcyosperma* and *Sisymbrium*, Khalik et al. [24] 39 species belonging to 23 genera of the tribes and Perveen et al. [25] 77 species belonging to 36 genera investigated pollen morphology in family Brassicaceae.

Pollen morphology of some *Alyssum* species was investigated by Inceoğlu and Karamustafa [26]. Khan [27] studied the pollen morphology 7 species of the *Alyssum*. Orcan and Binzet [28] investigated

TABLE 1
Collection data of *Alyssum* L. species examined for this study.

Collector Number	Taxon	Gps	Altitude (m)	Collection Date	Phytogeographic Region	Localities
4807	<i>A. murale</i> Waldst. & Kit. subsp. <i>murale</i> var. <i>alpinum</i> Boiss. ex Nyár.	K 39 28 01.7 D 040 03 47.2	2100	2014	Irano-Turanian Endemic	Tunceli: Pülümür, 2 km east of village Kırklar
5938	<i>A. virgatum</i> Nyár.	K 39 23 46.9 D 039 29 11.4	2133	2014	Endemic	Tunceli between Ovacik, IsikvuranAğaçpınar villages,5. km
5588	<i>A. peltarioides</i> Boiss. subsp. <i>virgatiforme</i> (Nyár.) T.R.Dudley	K 39 31 41.4 D 039 53 26.2	1900	2014	Iran-Turanian Endemic	Tunceli: Erzincan, Pülümür mountain passage
6577	<i>A. bulbotrichum</i> Hausskn. & Bornm.	K 38 09 21.5 D 43 53 21.3	2722	2015	Endemic	Van: Gürpınar east of the village of Doluçıkın
4381	<i>A. condensatum</i> Boiss. & Hausskn. subsp. <i>flexibile</i> (Nyár.) T.R.Dudley	39° 26'07.7"N 39° 45' 28.6"E	1750	2014	---	Tunceli: Pülümür, Çakırkaya village
5907	<i>A. murale</i> Waldst. & Kit. subsp. <i>murale</i> var. <i>haradjanii</i> (Rech.) T.R.Dudley	K 39 21 30.6 D 039 20 52.2	1400	2014	E.Mediterranean Iran Turanian Endemic	Tunceli: Ovacik, Tunceli-2.5 km from the village of Yakatarla on the road
4869	<i>A. pateri</i> Nyár.	K 39 2648.4 D 040 08 59.3	2080	2014	Iran Turanian Endemic	Tunceli: Pülümür around Şam-paşakaraderbent village
7964	<i>A. corsicum</i> Duby	37° 03'06.4"N 28° 55' 20.1"E	1100	2017	---	Muğla: Köyceğiz, north of the village Otmanlar
7356	<i>A. caricum</i> T.R.Dudley & Hub.Mor.	36° 59'32.4"N 28° 39' 15.3"E	7	2017	E.Mediterranean	Muğla: Köyceğiz, west of Toparlar
7794	<i>A. lepidotum</i> Boiss.	37° 19' 1.6"N 28° 22' 27.4"E	1618	2017	Endemic	Muğla: Kavaklıdere, Mentese village, 3.5 km south of Gökçukur highland
7977	<i>A. masmenaenum</i> Boiss.	37° 05'50.9"N 28° 52' 21.8"E	1665	2017	Endemic	Muğla: Köyceğiz, north mountain of Sandras
7961	<i>A. masmenaenum</i> Boiss.	36° 59'26.2"N 28° 53' 43.0"E	1042	2017	Endemic	Muğla: Köyceğiz, 4 km north of village Sazak
4123	<i>A. callichroum</i> Boiss. & Balansa	K 38 51 54.5 D 039 39 02.0	1250	2014	---	Tunceli: Mazgirt, Akpazar, Yenice south of village
7443	<i>A. discolor</i> T.R.Dudley & Hub.Mor.	36° 52'25.8"N 28° 16' 29.6"E	81	2017	E.Mediterranean Endemic	Muğla: Marmaris, Beldibineighborhood, Muğla highway exit
4274	<i>A. ochroleucum</i> Boiss. & A.Huet	K 39 25 27.2 D 039 28 36.5	2120	2014	Irano-Turanian Endemic	Tunceli: Ovacik, 3 km north of Isikvuran village Munzur Mountains
7353	<i>A. sibiricum</i> Willd.	37° 12'53.1"N 28° 23' 4.3"E	736	2017	---	Muğla: Center, Karşıyakaneighborhood
4412	<i>A. strictum</i> Willd.	K 39 27 18.8 - D 039 48 27.2	1610	2014	Irano-Turanian	Tunceli: Pülümür, between Dere-boyu and Sağlamtaş village
6803	<i>A. strigosum</i> Banks & Sol.	37° 52'31.1"N 41° 44' 1.3"E	726	2017	---	Siirt: Kurtalan, 500 m south-west of village Yeşilkonak
5043	<i>A. pateri</i> Nyár. subsp. <i>prostratum</i> (Nyár.) T.R.Dudley	K 39 25 21.1 D 039 16 55.1	1400	2014	Irano-Turanian Endemic	Tunceli: Between Ovacik, Yazıören - Gözeler villages
7673	<i>A. baumgartnerianum</i> Bornm. Ex Baumg.	37° 05'14.1"N 28° 49' 35.0"E	1985	2017	---	Muğla: Köyceğiz, Sandras western side (Çiçek Baba)
4477	<i>A. simplex</i> Rudolph	K 39 00 19.1 - D 039 11 24.1	1350	2014	---	Tunceli: Hozat, 2 km northeast of village Akpınar

on *Alyssum floribundum* morphological, anatomical and palynological. Pakravan et al. [29] investigated bio systematically on the four varieties of *Alyssum minus* in Iran. Pavlova et al. [30] gathered information on pollen morphology and localization of Ni in stamens and pollen grains of eight Ni hyperaccumulator *Alyssum* taxa. Pınar et al. [31] examined pollen and seed morphology of 35 specimens representing 25 Turkish species of the taxonomically complex genus *Hesperis* L. by light and scanning electron

microscopes. The structure of the seed coat is less influenced by the external environmental conditions, therefore it is a more stable character for evolutionary and taxonomic studies [32, 33, 34, 35]. Bona [36] investigated the seed exomorphic characteristics of 14 taxa of *Lepidium* L. in Brassicaceae. Hani et al. [37] studied production and morphological characteristics of seeds in Brassicaceae from Algeria. Karcz et al. [38] investigated micromorphological typology of seed surfaces using scanning electron

microscope. Kasem et al. [39] investigated seed exomorph characters of 32 taxa of Brassicaceae. Koul et al. [40] studied seed surface 44 species of Brassicaceae family. Moazzeni et al. [41] examined seed surfaces of 23 species of genus *Isatis*. Naggar [42] investigated seed coat sculpture of 93 taxa belonging to 45 genera of the family Brassicaceae using light and scanning electron microscope. Tantawy et al [43] reported seed exomorph characters of 34 taxa of Brassicaceae. Zeng et al. [44] studied six species (12 accessions), three amphidiploids and their three diploid parents using SEM. Kaya et al. [45] examined fruit and seed morphologies of 6 species in the genus *Malcolmia* using stereomicroscopy and scanning electron microscopy (SEM). Garb et al. [46] reported fruit, seed morphology and seed coat sculpturing were recorded for 10 species belongs to 9 genera and five tribes of Brassicaceae in eastern region of Saudi Arabia. Satil et al. [47] detailed investigated of fruit, seed and pollen macro and micro-morphological characters of Turkish *Chorispora* species.

Understanding and explain the evolutionary relationships among species of Brassicaceae is difficult with the naked eye or lens. It is the reason why micromorphological structures have been observed on surface of the seeds, trichome types, fruit shape and pollen morphology. The present study aimed to examine *Alyssum* species from Turkey based on macro and micro morphology of fruit, seed coat, and pollen features by using scanning electron microscopy (SEM), stereo and light microscopy and to provide new insight into its potential taxonomic value.

MATERIALS AND METHODS

The specimens were collected from natural populations in Turkey. A list of taxa and full voucher data is provided in Table 1. Macro and microphotographs which showed the general view of fruit, seed, and pollen surface were taken by JeolTescan model electron microscope in Bartın University Central Research Laboratory.

For SEM, specimens were mounted directly onto stubs, using single-sided adhesive tape, and coated with gold. Measurements and optical observations of fruit and seed colours were carried out under aOlympus SZ2- LGB stereomicroscope. Photographs were taken with digital imaging system. Pollen slides were prepared using the method of Wodehouse [48], and photographed by the Leica DM 750 digital imaging system. The mean and standard deviations of the measurements were calculated. The terms used for describing the seed surface patterns and pollen morphology adopted by [49, 50, 51, 52].

RESULTS

The fruit, seed and pollen morphological characters for 14 to 19 species of the genus *Alyssum* are summarized in Tables 1-4 and image by SEM, stereomicroscope and light microscopy are showed in Figures 1-13.

Fruit Characters. Fruit shapes of the studied taxa are found to be orbicular, ovoid, ovate, elliptical or obcordate. Most common shape is elliptical seen in 6 taxa. The fruit size ranges from 1.67 to 7.41 mm in length and from 0.95 mm to 7.61mm in width. The smallest fruits (*A. callichroum*) have 1.67 mm length and 0.95 mm width. The largest fruits (*A. virgatum*) have 5.76 mm length and 7.61 mm width (Table 2). Most studied species have trichome on surface of silicules. *A. virgatum*, *A. peltarioides*, *A. corsicum*, *A. caricum*, *A. masmenaeum* and *A. discolor* have glabrous on surface of silicules.

Seed Characters. The characters of seed of the examined *Alyssum* species are summarized in Table 3 and 4 by using stereomicroscope and SEM data and show in Figs 2 and 3.

The shape of seed varies from elliptical to spheroidal. Seeds are spheroidal in *A. virgatum*, *A. lepidotum*, *A. strictum* and *A. strigosum*, oblong in *A. peltarioides* subsp. *virgatiforme*, and *A. ochroleucum*. Seed size also varies among the examined species; the largest ovate seeds in *A. peltarioides* subsp. *virgatiforme* have a diameter of 2.04 mm length and 1.73 mm width the smallest seeds 0.6 mm length and 0.36 mm width in *A. sibiricum*, while the rest of the species have slightly larger seeds. The colors of the seeds give a supplemental indication for distinguished between species of *Alyssum*. Seed colour of examined taxa are found to be yellow or brown. However most of the seeds colour varies from light yellowish to dark brownish. Hilum position of examined species is mostly terminal. *A. murale* subsp. *murale* var. *alpinum*, *A. peltarioides* subsp. *virgatiforme*, *A. corsicum*, *A. caricum*, *A. masmenaeum*, *A. ochroleucum* are subterminal. In addition hilum size can be one of the diagnostic characters in *Alyssum* species. The hilum size among the examined species showed wide range of variations. Except *A. condensatum* subsp. *flexibile* and *A. sibiricum* all examined taxa have wing of seed. Seed wings are generally prominent and relatively wide. The size of wings ranges from 0.05 to 0.97 mm in length.

TABLE 2
Fruit morphology of *Alyssum* (values in mm)

	Fruit length				Fruit width				Shape	Texture
	M	Std	Min	Max	M	Std	Min	Max		
<i>A. murale</i> subsp. <i>murale</i> var. <i>alpinum</i>	3.51	0.17	3.19	3.74	2.84	0.35	2.35	3.32	Obcordate	Hairy
<i>A. virgatum</i>	5.76	0.36	5.04	6.7	7.61	0.6	6.3	8.67	Ovoid	Glabrous
<i>A. peltarioides</i> subsp. <i>virgatiforme</i>	7.41	0.88	4.48	8.74	4.86	1.01	0.49	6.49	Ovoid	Glabrous
<i>A. bulbosum</i>	5.55	0.38	5.12	5.83	4.82	0.28	4.5	4.99	Ovate	Hairy
<i>A. condensatum</i> subsp. <i>flexibile</i>	3.27	0.08	3.17	3.37	1.49	0.16	1.35	1.73	Elliptical	Hairy
<i>A. murale</i>	2.94	0.17	2.64	3.42	2.68	0.2	2.39	3.35	Orbicular	Hairy
<i>A. corsicum</i>	1.98	0.34	1.15	2.47	1.41	0.27	0.84	1.87	Ovoid	Glabrous
<i>A. caricum</i>	5.8	0.32	5.05	6.41	5.46	0.44	4.73	6.29	Obcordate	Glabrous
<i>A. lepidotum</i>	4.56	0.57	3.61	5.48	4.81	0.81	3.04	5.57	Elliptical	Hairy
<i>A. masmenaeum</i>	5.48	0.44	4.41	6.26	3.02	0.25	2.53	3.49	Ovate	Glabrous
<i>A. callichroum</i>	1.67	0.49	1.15	2.93	0.95	0.2	0.63	1.39	Elliptical	Hairy
<i>A. discolor</i>	4.23	0.51	2.85	4.92	2.2	0.32	1.19	2.57	Ovate	Glabrous
<i>A. ochroleucum</i>	2.62	0.33	2.3	3.1	2	0.30	1.50	2.49	Elliptical	Hairy
<i>A. sibiricum</i>	3.17	0.11	2.98	3.53	2.68	0.2	2.11	3.01	Obcordate	Hairy
<i>A. strictum</i>	3.92	0.2	3.35	4.30	2.35	0.2	1.92	2.64	Elliptical	Hairy
<i>A. strigosum</i>	3.7	0.33	3.31	4.04	4.31	0.17	4.1	4.52	Orbicular	Hairy
<i>A. pateri</i> subsp. <i>prostratum</i>	3.2	0.18	2.72	3.47	1.89	0.12	1.63	2.11	Elliptical	Hairy
<i>A. baumgartnerianum</i>	4.64	0.42	4.19	5.03	3.48	0.23	3.25	3.71	Ovate	Hairy
<i>A. simplex</i>	4.17	0.28	3.7	4.6	3.94	0.22	3.47	4.19	Orbicular	Hairy

*M: Mean, Std: Standard Deviation, Min: Minimum, Max: Maximum

TABLE 3
Seed morphology of *Alyssum* (values in mm)

	<i>A. murale</i> subsp. <i>murale</i> var. <i>alpinum</i>	<i>A. virgatum</i>	<i>A. peltarioides</i> subsp. <i>virgatiforme</i>	<i>A. bulbosum</i>	<i>A. condensatum</i> subsp. <i>flexibile</i>	<i>A. murale</i>	<i>A. corsicum</i>	<i>A. caricum</i>	<i>A. lepidotum</i>	<i>A. masmenaeum</i>	<i>A. discolor</i>	<i>A. ochroleucum</i>	<i>A. sibiricum</i>	<i>A. strictum</i>	<i>A. strigosum</i>	<i>A. pateri</i> subsp. <i>prostratum</i>	<i>A. baumgartnerianum</i>	<i>A. simplex</i>	
Fig No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Seed Length	M	1.94	1.68	2.04	1.59	0.81	1.97	1.66	1.25	1.75	1.79	0.73	0.61	0.97	0.9	1.06	0.71	1.17	
	Std.	0.97	0.24	0.41	0.01	0.04	0.12	1.01	0.09	0.21	0.33	0.09	0.12	0.05	0.11	0.28	0.11	0.14	
	Min	1.25	1.28	0.03	1.5	0.76	1.67	0.65	1.14	1.29	1.07	0.49	0.43	0.51	0.73	0.1	0.84	0.49	0.98
	Max	2.63	2.01	2.67	1.73	0.86	2.09	3.1	1.41	2.01	2.14	0.81	0.73	0.72	1.18	1.15	1.23	0.81	1.36
Seed Width	M	1.4	1.49	1.73	1.14	0.52	1.42	1.26	0.76	1.62	1.7	0.36	0.36	0.38	0.79	0.76	0.68	0.38	1.17
	Std	0.81	0.24	0.25	0.05	0.03	0.06	0.87	0.09	0.13	0.14	0.05	0.06	0.04	0.08	0.08	0.09	0.03	0.14
	Min	0.83	1.1	1.12	1.11	0.47	1.31	0.35	0.59	1.47	1.48	0.25	0.3	0.31	0.65	0.61	0.43	0.34	0.98
	Max	1.98	1.76	2.39	1.22	0.55	1.51	2.1	0.87	1.86	1.88	0.42	0.44	0.46	0.99	0.96	0.86	0.45	1.36
Seed wing length	M	0.97	0.15	0.2	0.07		0.35	0.08	0.14	0.08	0.21	0.05	0.06		0.09	0.17	0.08	0.11	0.12
	Std	0.76	0.04	0.1	0.01	wingless	0.09	0.01	0.04	0.03	0.04	0.01	0.01	wingless	0.02	0.06	0.03	0.02	0.02
	Min	0.15	0.07	0.01	0.05		0.13	0.07	0.06	0.04	0.13	0.03	0.04		0.07	0.1	0.03	0.09	0.08
	Max	2.01	0.24	0.35	0.09		0.49	0.09	0.24	0.15	0.27	0.08	0.08		0.17	0.34	0.21	0.15	0.19
Hilum Length	M	0.27	0.38	0.31	0.24	0.21	0.36	0.41	0.41	0.41	0.31	0.17	0.11	0.15	0.3	0.23	0.22	0.17	0.24
	Std	0.07	0.07	-	0.05	0.02	0.17	0.32	0.06	0.13	0.07	0.03	0.05	0.03	0.06	0.07	0.03	0.02	0.06
	Min	0.17	0.25	0.31	0.15	0.18	0.19	0.2	0.31	0.05	0.26	0.12	0.06	0.09	0.22	0.16	0.16	0.12	0.14
	Max	0.41	0.52	0.31	0.34	0.23	0.79	0.97	0.48	0.56	0.47	0.24	0.2	0.21	0.46	0.34	0.29	0.2	0.33
Hilum Width	M	0.2	0.32	0.42	0.16	0.15	0.35	0.16	0.23	0.29	0.27	0.11	0.08	0.14	0.15	0.14	0.15	0.1	0.11
	Std	0.04	0.05	0.03	0.04	0.02	0.09	0.04	0.09	0.09	0.1	0.02	0.04	0.03	0.02	0.03	0.02	0.02	0.03
	Min	0.13	0.26	0.42	0.09	0.14	0.17	0.12	0.14	0.08	0.16	0.07	0.06	0.1	0.1	0.08	0.1	0.07	0.05
	Max	0.28	0.45	0.42	0.25	0.17	0.47	0.21	0.42	0.42	0.48	0.15	0.16	0.2	0.21	0.19	0.21	0.15	0.17

*M: Mean, Std: Standard Deviation, Min: Minimum, Max: Maximum

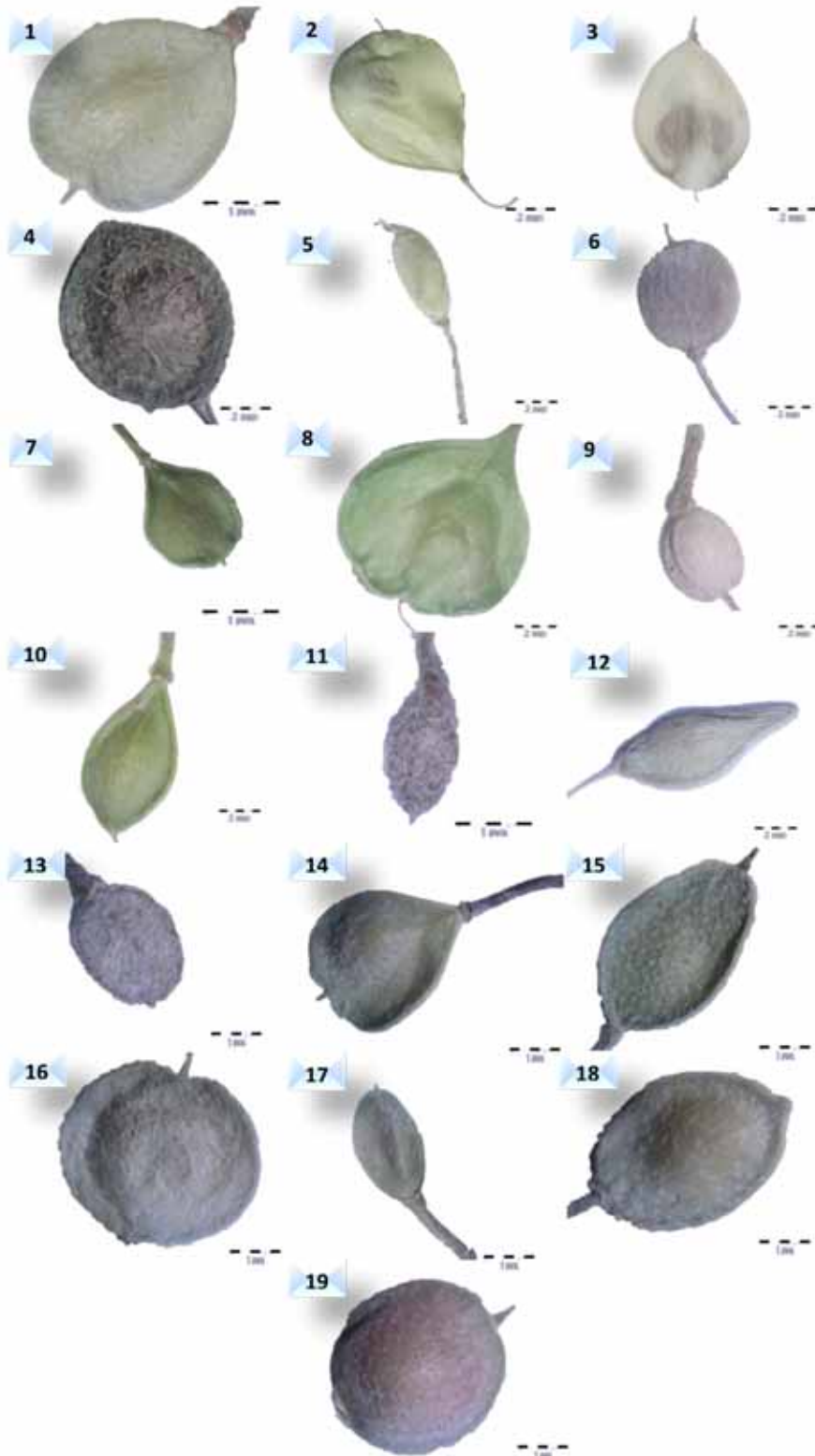


FIGURE 1

Stereomicroscope micrographs of fruit in *Alyssum* species.

1. *Alyssum murale* subsp. *alpinum*, 2. *Alyssum virgatum*, 3. *Alyssum peltarioides* subsp. *virgatiforme*, 4. *Alyssum bulbotrichum*, 5. *Alyssum condensatum* subsp. *flexibile*, 6. *Alyssum murale*, 7. *Alyssum corsicum*, 8. *Alyssum caricum*, 9. *Alyssum lepidotum*, 10. *Alyssum masmenaenum*, 11. *Alyssum callichroum*, 12. *Alyssum discolor*, 13. *Alyssum ochroleucum*, 14. *Alyssum sibiricum*, 15. *Alyssum strictum*, 16. *Alyssum strigosum*, 17. *Alyssum pateri* subsp. *prostratum*, 18. *Alyssum baumgartnerianum*, 19. *Alyssum simplex*

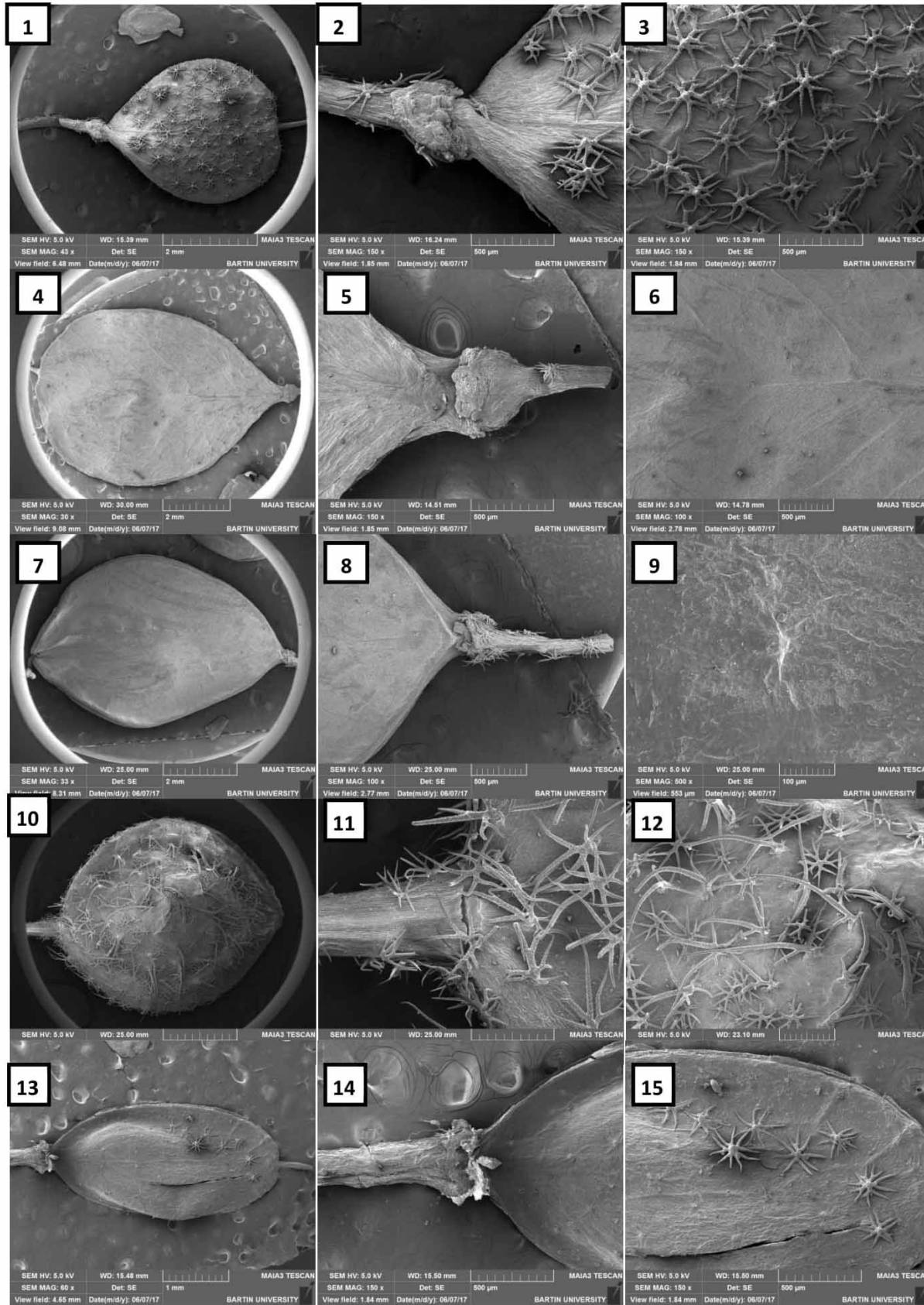


FIGURE 2

Scanning electron micrographs (SEM) of fruit in *Alyssum* species.

1-3 *Alyssum murale* subsp. *murale* var. *alpinum*, 4-6 *Alyssum virgatum*, 7-9 *Alyssum peltarioides* subsp. *virgatifforme*, 10-12 *Alyssum bulbotrichum*, 13-15 *Alyssum condensatum* subsp. *flexibile*.

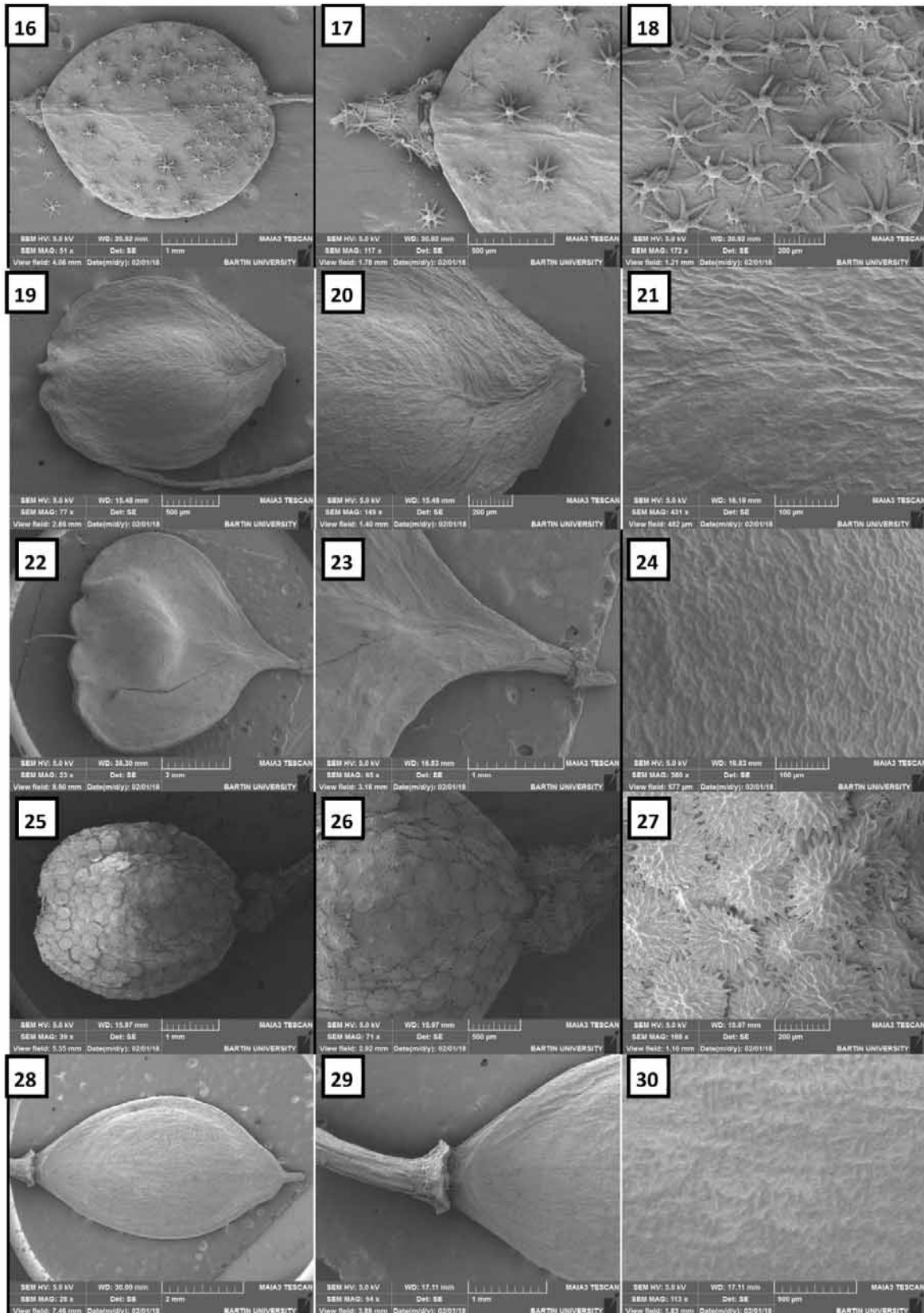


FIGURE 3

Scanning electron micrographs (SEM) of fruit in *Alyssum* species.

16-18 *Alyssum murale*, 19-21 *Alyssum corsicum*, 22-24 *Alyssum caricum*, 25-27 *Alyssum lepidotum*, 28-30 *Alyssum masmaeum*.

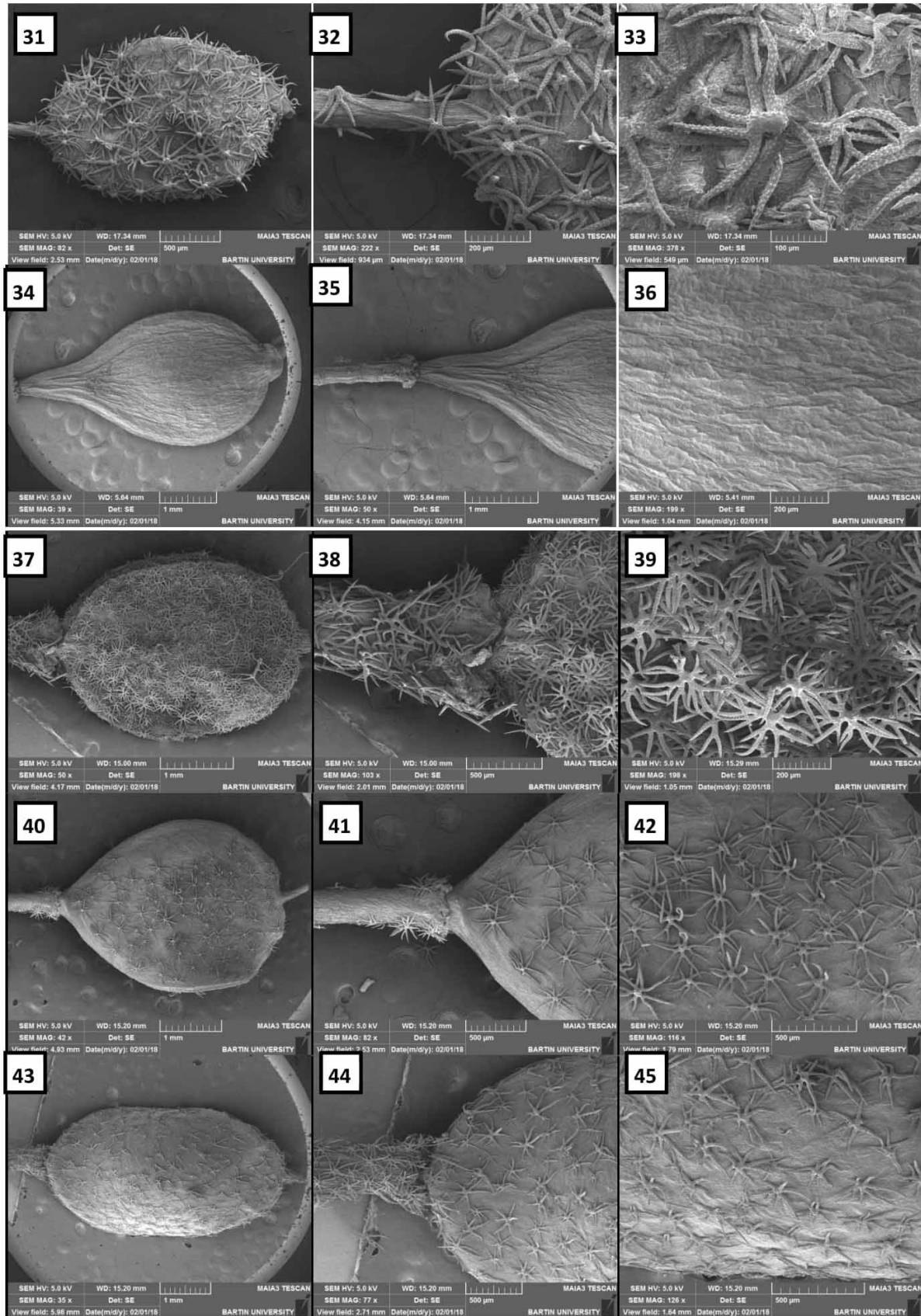


FIGURE 4

Scanning electron micrographs (SEM) of fruit in *Alyssum* species.

31-33 *Alyssum callichroum*, 34-36 *Alyssum discolor*, 37-39 *Alyssum ochroleucum*, 40-42 *Alyssum sibiricum*, 43-45 *Alyssum strictum*.

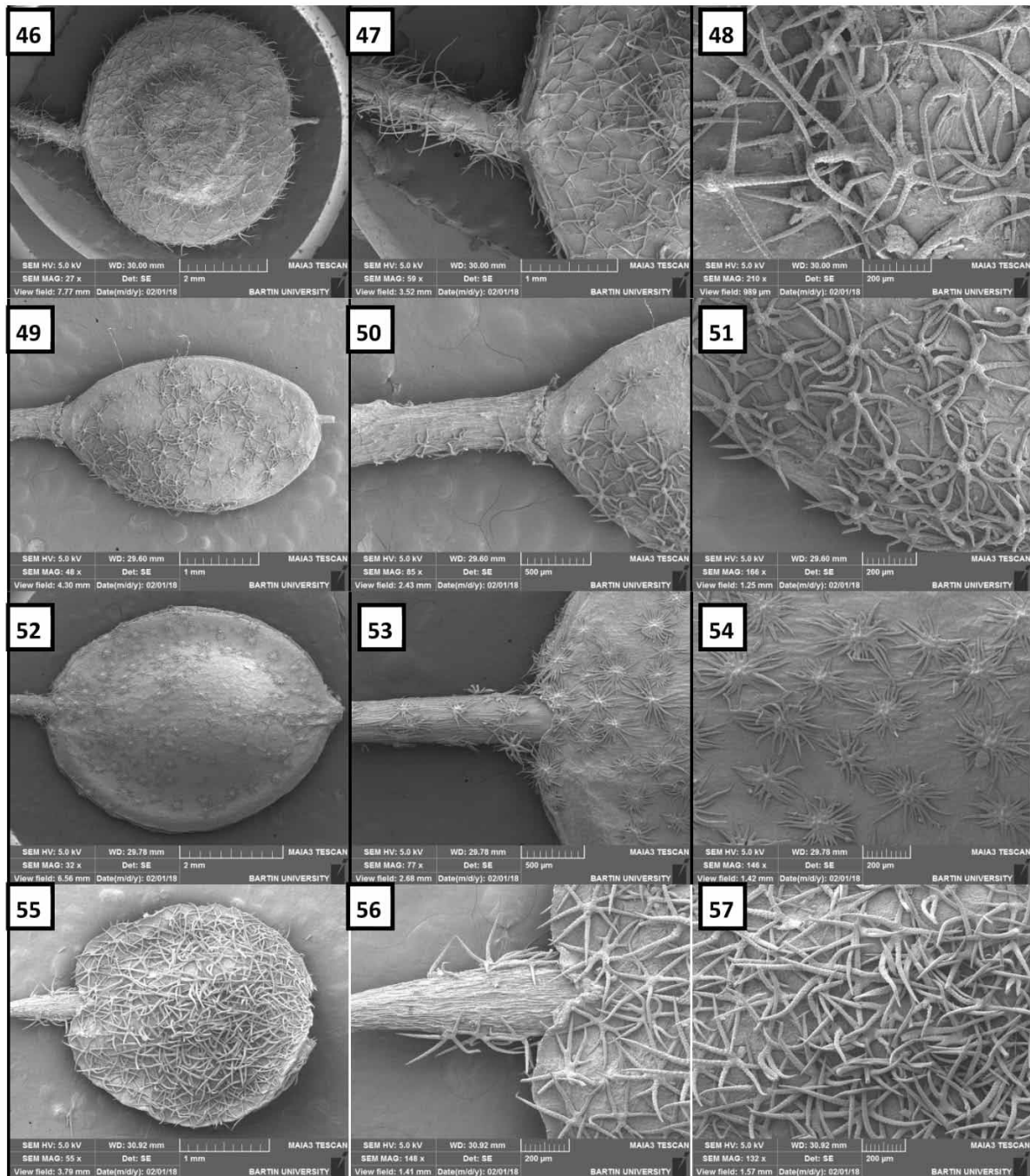


FIGURE 5

Scanning electron micrographs (SEM) of fruit in *Alyssum* species.

46-48 *Alyssum strigosum*, 49-51 *Alyssum pateri* subsp. *prostratum*, 52-54 *Alyssum baumgartnerianum*, 55-57 *Alyssum simplex*.

The surface ornamentation, periclinal and anticlinal walls of seeds are studied by SEM. Examination species demonstrated 6 different types of seed coat pattern. The most common types is reticulate (Figure 6-10).

1) Reticulate, with 4 subtypes; Normal reticulate in *A. peltarioides* subsp. *virgatiforme*, *A. caricum*, *A. pateri* subsp. *prostratum*. Reticulate-foveate in *A. virgatum*, *A. condensatum* subsp. *flexibile*, *A. corsicum*, *A. sibiricum*, and *A. strigosum*. Reticulate-

lineolate in *A. Murale* subsp. *murale* var. *alpinum*. Reticulate-rugose in *A. ochroleucum*, and *A. simplex*.

2) Ruminant in *A. bulbotrichum* and *A. strictum*.

3) Rugose in *A. discolor* and *A. baumgartnerianum*.

4) Lineolate in *A. murale*.

5) Blister in *A. lepidotum*.

6) Colliculate in *A. masmenaemum*.

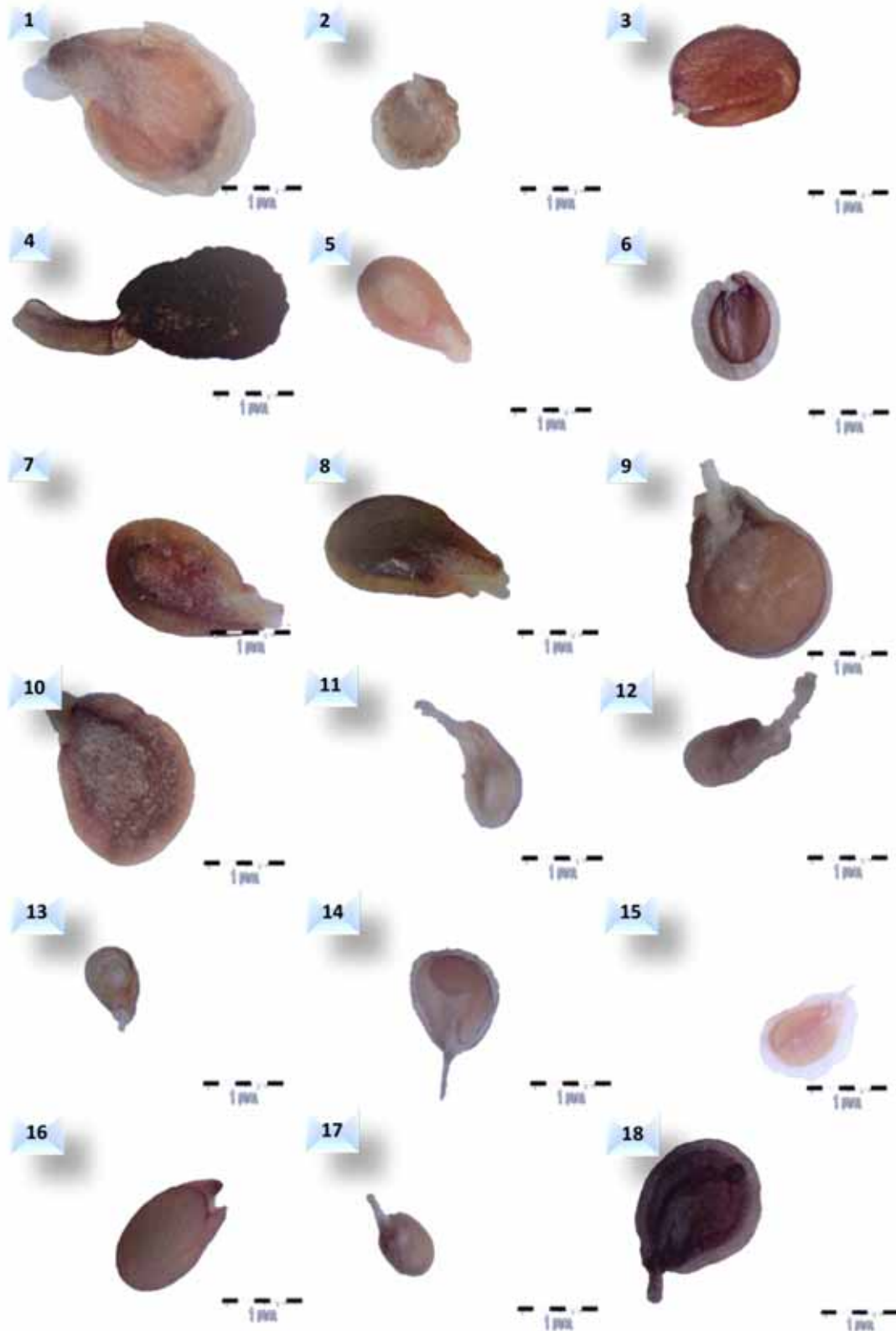


FIGURE 6

Stereomicroscop micrographs of seed in *Alyssum* species.

1. *A. murale* subsp. *murale* var. *alpinum*, 2. *A. virgatum*, 3. *A. peltarioides* subsp. *virgatiforme*, 4. *A. bulbotrichum*, 5. *A. condensatum* subsp. *flexibile*, 6. *A. murale*, 7. *A. corsicum*, 8. *A. caricum*, 9. *A. lepidotum*, 10. *A. masmenaeum*, 11. *A. discolor*, 12. *A. ochroleucum*, 13. *A. sibiricum*, 14. *A. strictum*, 15. *A. strigosum*, 16. *A. pateri* subsp. *prostratum*, 17. *A. baumgartnerianum*, 18. *A. simplex*

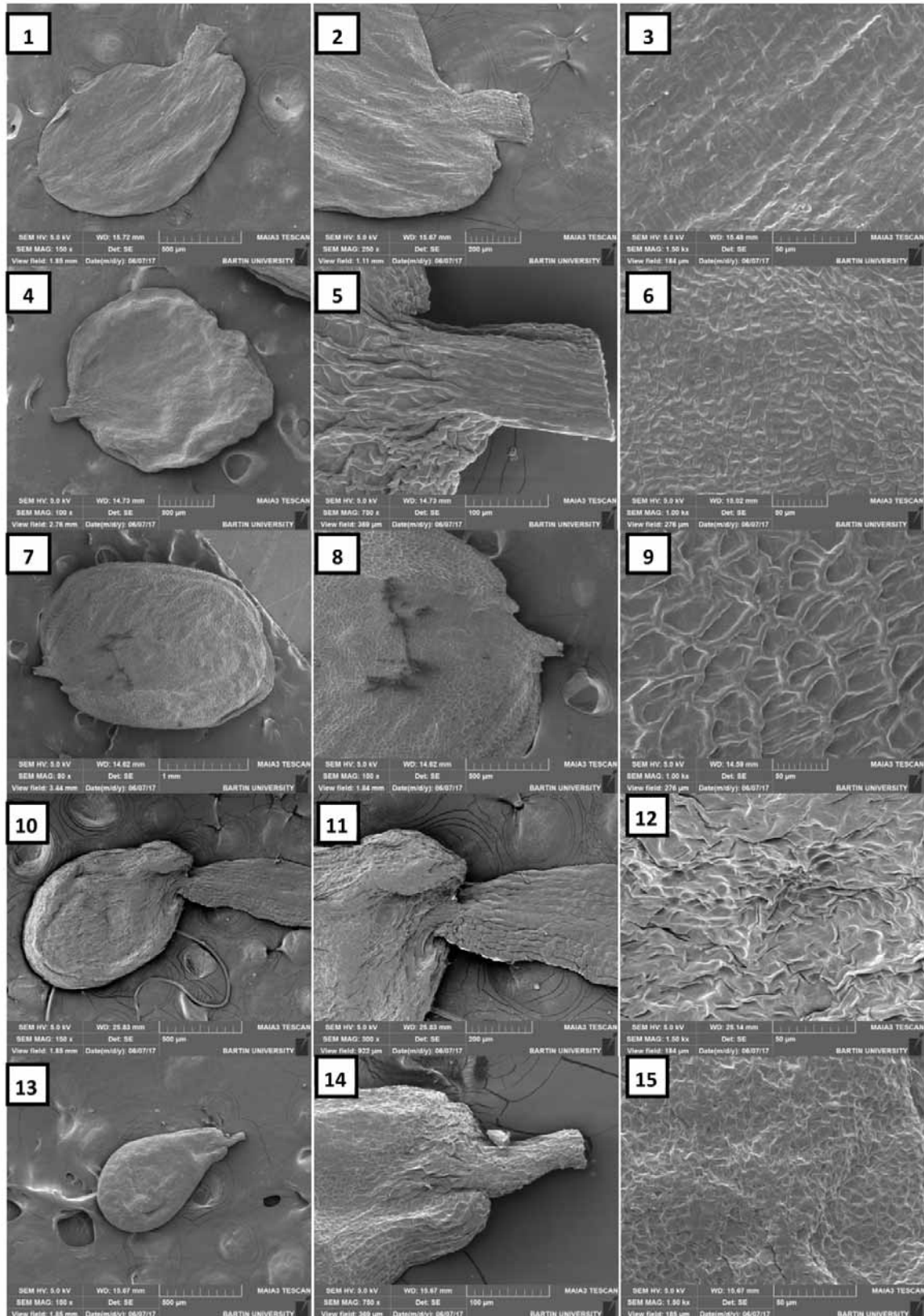


FIGURE 7

Scanning electron micrographs (SEM) of seed in *Alyssum* species.

1-3*A. murale* subsp. *murale* var. *alpinum*, 4-6*A. virgatum*, 7-9*A. peltarioides* subsp. *virgatiforme*, 10-12*A. bulbotrichum*, 13-15*A. condensatum* subsp. *flexibile*.

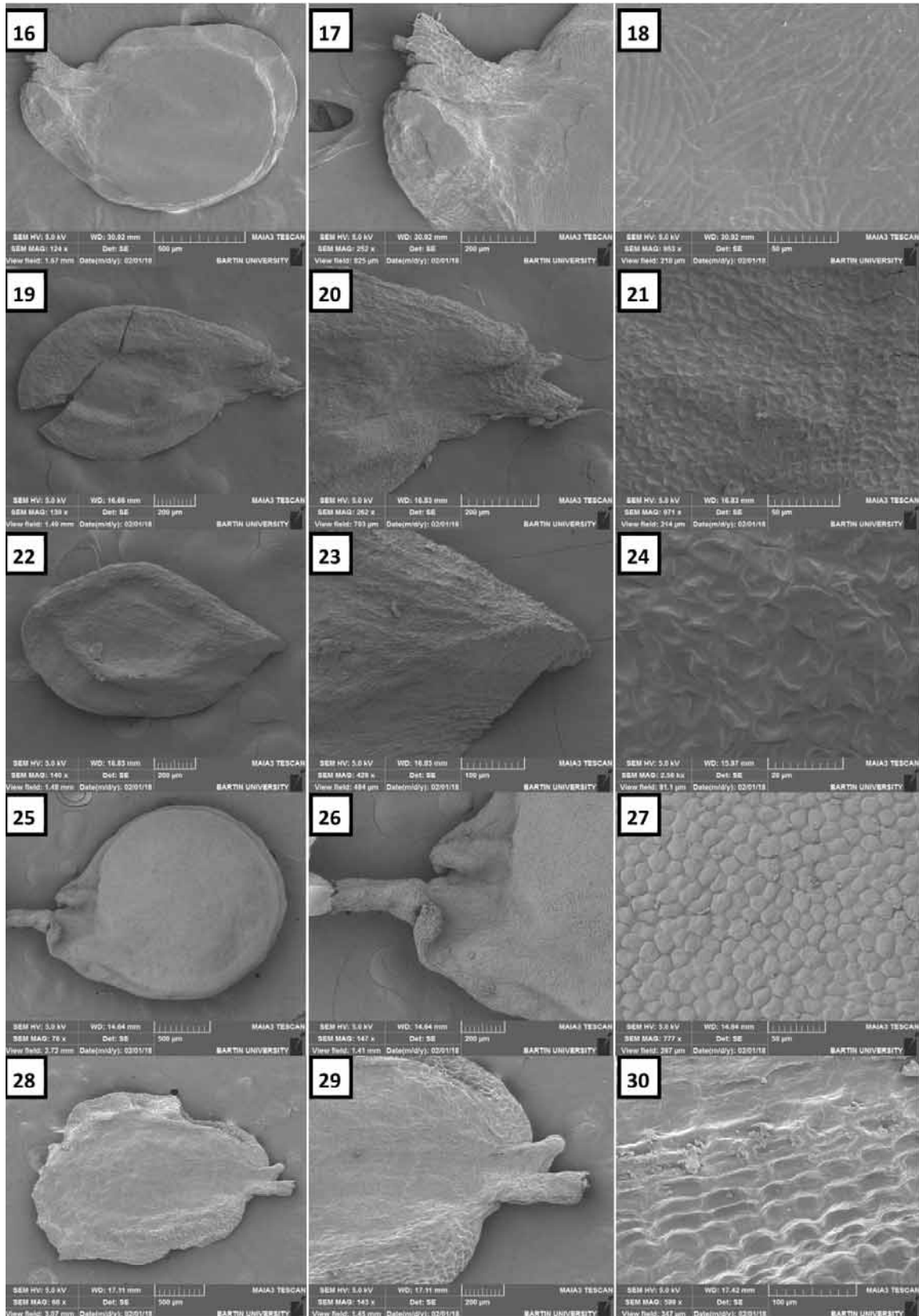


FIGURE 8

Scanning electron micrographs (SEM) of seed in *Alyssum* species.

16-18*A. murale*, 19-21 *A. corsicum*, 22-24 *A. caricum*, 25-27 *A. lepidotum*, 28-30*A. masmenaem*

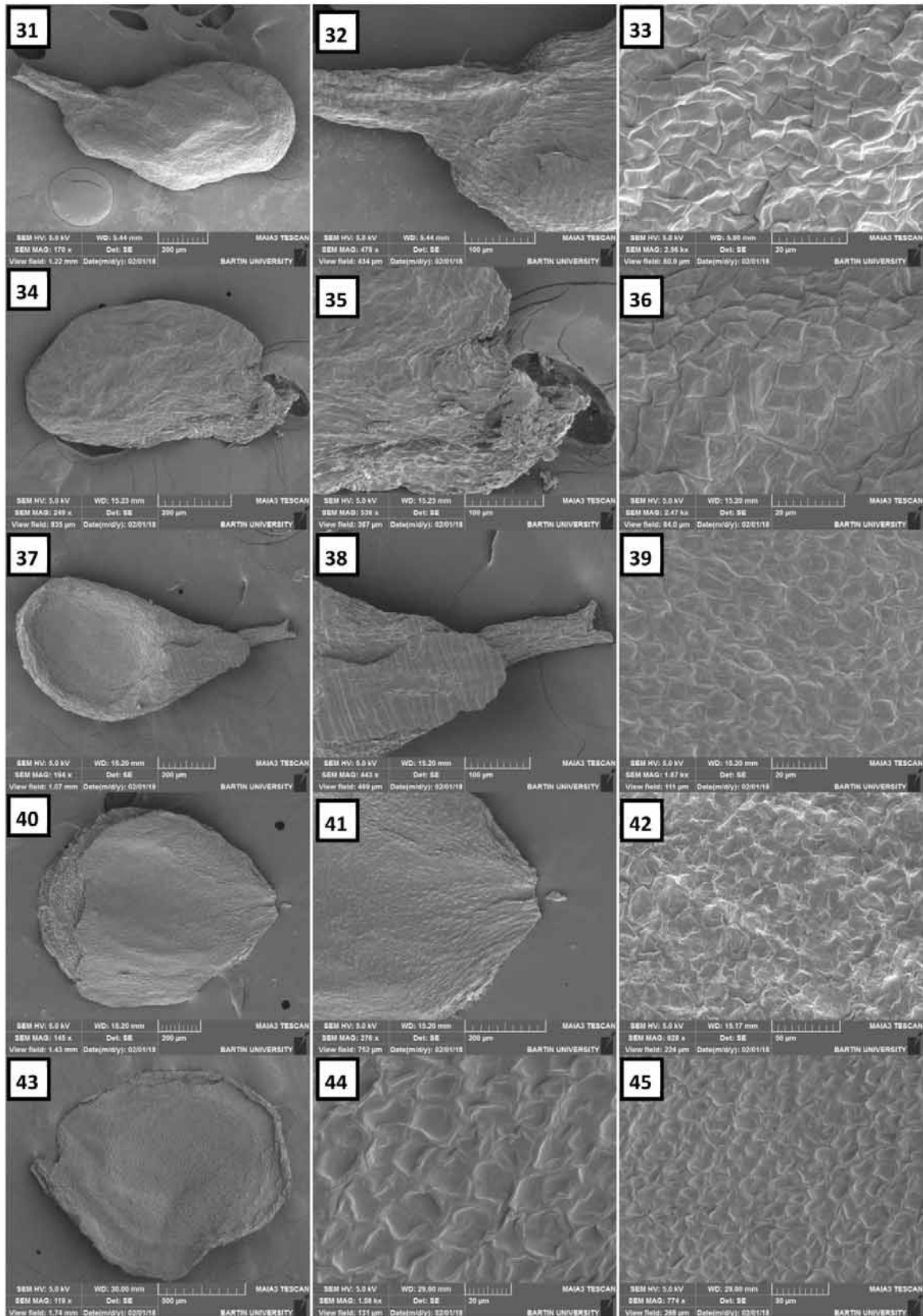


FIGURE 9

Scanning electron micrographs (SEM) of seed in *Alyssum* species.

31-33A. *discolor*, 34-36A. *ochroleucum*, 37-39 *A. sibiricum*, 40-42A. *strictum*, 43-45A. *strigosum*.

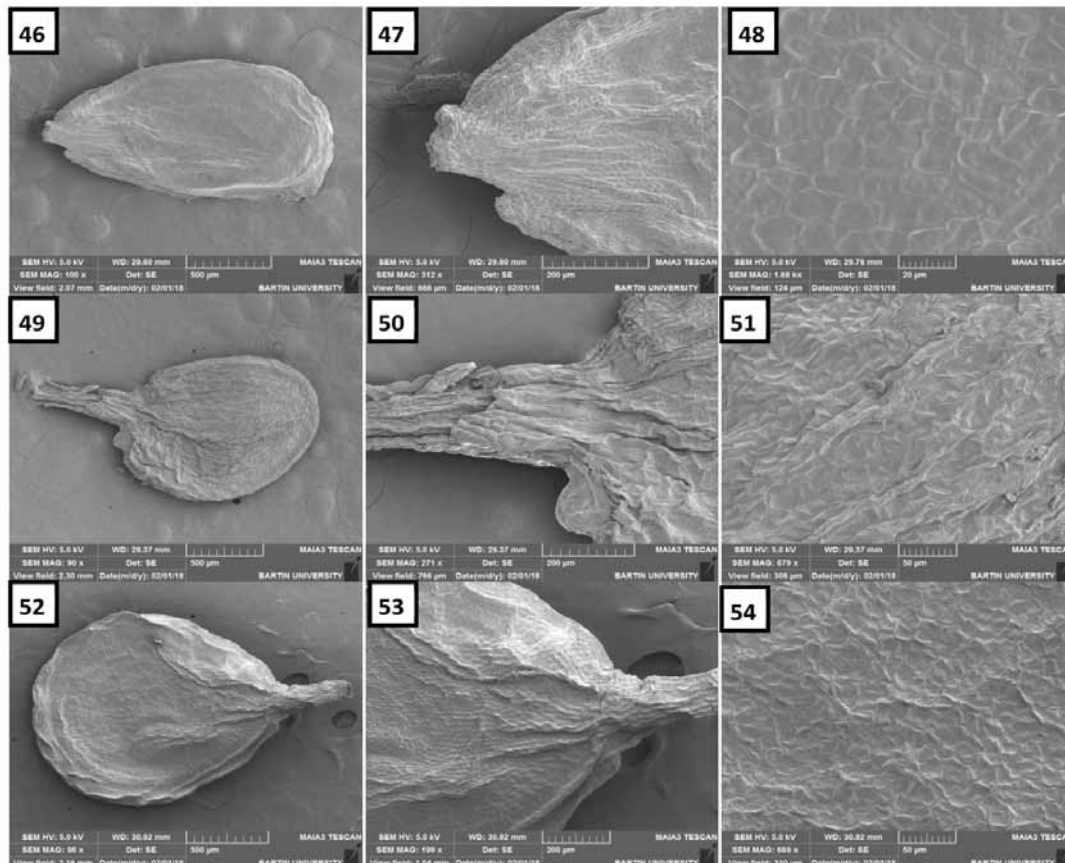


FIGURE 10

Scanning electron micrographs (SEM) of seed in *Alyssum* species.46-48 *A. pateri* subsp. *prostratum*, 49-51 *A. baumgartnerianum*, 52-54 *A. simplex*.

TABLE 4

The seed morphological characters as seen by LM and SEM between taxa of *Alyssum*

Taxa	Fig No	Seed Shape	Ratio L/W	Seed Colour	Seed Margin	Hilum Position	Seed Surface	Anticlinal	Periclinal
<i>A. murale</i> subsp. <i>murale</i> var. <i>alpinum</i>	1	Ovate	1.38	Light Brown	Winged	Subterminal	Reticulate-lineolate	Raised	Flat
<i>A. virgatum</i>	2	Spheroidal	1.12	Dull Yellow Brownish	Winged	Terminal	Reticulate-foveate	Raised	Concave
<i>A. peltarioides</i> subsp. <i>virgatifforme</i>	3	Oblong	1.17	Bright Red Brownish	Winged	Subterminal	Reticulate	Raised	Concave
<i>A. bulbotrichum</i>	4	Ovate	1.39	Dark Brownish	Winged	Terminal	Ruminate	Indefinite	Indefinite
<i>A. condensatum</i> subsp. <i>flexibile</i>	5	Ovate	1.55	Dull Light Reddish	Wingless	Terminal	Reticulate-foveate	Raised	Concave
<i>A. murale</i>	6	Ovate	1.53	Bright Brownish	Winged	Terminal	Lineolate	Sunken	Convex
<i>A. corsicum</i>	7	Ovate	1.31	Bright Red Brownish	Winged	Subterminal	Reticulate-foveate	Raised	Concave
<i>A. caricum</i>	8	Ovate	1.64	Bright Brownish	Winged	Subterminal	Reticulate	Raised	Concave
<i>A. lepidotum</i>	9	Spheroidal	1.08	Dull Brownish	Winged	Terminal	Blister	Sunken	Convex
<i>A. masmenaeum</i>	10	Ovate	1.05	Dull Red Brownish	Winged	Subterminal	Colliculate	Sunken	Convex
<i>A. discolor</i>	11	Ovate	2.02	Dull Yellowish	Winged	Terminal	Rugose	Indefinite	Indefinite
<i>A. ochroleucum</i>	12	Oblong	1.69	Dull Yellow Brownish	Winged	Subterminal	Reticulate-rugose	Sunken	Indefinite
<i>A. sibiricum</i>	13	Ovate	1.57	Dull Yellowish	Wingless	Terminal	Reticulate-foveate	Raised	Concave
<i>A. strictum</i>	14	Spheroidal	1.22	Dull Yellow Brownish	Winged	Terminal	Ruminate	Indefinite	Indefinite
<i>A. strigosum</i>	15	Spheroidal	1.18	Bright Yellow Brownish	Winged	Terminal	Reticulate-foveate	Raised	Concave
<i>A. pateri</i> subsp. <i>prostratum</i>	16	Ovate	1.55	Bright Brownish	Winged	Terminal	Reticulate	Raised	Flat
<i>A. baumgartnerianum</i>	17	Ovate	1.86	Dull Brownish	Winged	Terminal	Rugose	Indefinite	Indefinite
<i>A. simplex</i>	18	Ovate	1	Dark Brownish	Winged	Terminal	Reticulate-rugose	Raised	Indefinite

TABLE 5
Pollen morphology of *Alyssum* (values in μm)

Figure Number		<i>A. murale</i> subsp. <i>murale</i> var. <i>alpinum</i>	<i>A. virgatum</i>	<i>A. peltarioides</i> subsp. <i>virgatiforme</i>	<i>A. bulbotrichum</i>	<i>A. condensatum</i> subsp. <i>flexibile</i>	<i>A. pateri</i>	<i>A. corsicum</i>	<i>A. caricum</i>	<i>A. baumgartnerianum</i>	<i>A. callichroum</i>	<i>A. discolor</i>	<i>A. ochroleucum</i>	<i>A. sibiricum</i>	<i>A. strigosum</i>
Polar axes	M	20.3	18.1	20.6	27.5	18.8	20.2	17.8	21.4	38.1	20.3	20.9	31.0	19.9	29.4
	Std	3.75	3.48	3.01	6.19	1.55	2.26	2.41	2.46	3.87	2.12	1.37	2.96	2.01	1.43
	Min	14.5	11.9	17.3	17.1	15.6	16.6	12.1	17.0	31.9	16.5	18.5	26.6	17.0	26.7
	Max	24.1	23.7	31.8	36.4	22.2	26.5	21.9	25.9	43.1	23.7	24.1	35.0	23.6	30.9
Equatorial axes	M	12.9	13.5	16.4	20.2	13.8	14.64	15.2	14.4	25.5	14.8	15.1	21.6	16.1	24.6
	Std	2.19	2.11	0.79	5.71	0.91	1.18	1.8	1.59	4.13	1.30	1.17	2.53	1.64	1.9
	Min	10.3	10.1	14.9	10.5	12.4	12.9	11.2	10.9	21.0	11.56	12.1	17.3	12.3	22.1
Colpus length	M	14.6	14.2	15.4	22.4	14.3	14.51	13.8	17.2	33.8	16.3	17.1	24.4	16.5	24.2
	Std	3.09	2.32	1.59	5.36	2.03	1.94	1.93	3.16	1.92	2.11	1.4	3.4	2.11	2.88
	Min	10.	10	12.8	12.4	10.1	11.06	11.4	11.0	32.1	12.3	14	20.1	12.7	21.0
Colpus width	M	18.7	18.5	19.7	32.5	17.1	18.2	18.9	22.5	36.6	19.9	19.9	31.2	20.7	28.7
	Std	0.77	1.13	0.91	1.57	0.94	1.21	1.07	0.96	1.61	1.54	1.3	1.64	1.2	1.5
	Min	0.05	0.41	0.32	0.51	0.19	0.54	0.21	0.21	0.13	0.52	0.17	0.10	0.20	0.07
Exine thickness	M	0.7	0.72	0.08	0.79	0.7	0.65	0.58	0.24	1.43	0.91	0.93	1.54	0.83	1.43
	Std	0.86	2.67	2.01	2.94	1.44	2.8	1.69	1.42	1.74	3.07	1.74	1.93	1.58	1.63
	Min	0.97	1.33	1.30	1.58	0.85	1.22	1.29	1.3	1.68	1.31	1.35	1.61	1.23	1.66
Intine thickness	M	0.21	0.24	0.23	0.32	0.14	0.22	0.15	0.36	0.20	0.13	0.1	0.03	0.15	0.26
	Std	0.72	0.99	0.93	0.78	0.58	0.93	0.85	0.45	1.4	1.09	1.16	1.56	0.92	1.30
	Min	1.23	2.05	1.92	2.31	1.11	1.84	1.56	2.24	1.89	1.57	1.58	1.69	1.49	2.22
Apocolpium	M	0.43	0.47	0.41	0.49	0.46	0.47	0.56	0.47	0.66	0.53	0.52	0.62	0.50	0.57
	Std	0.08	0.08	0.03	0.06	0.09	0.08	0.18	0.08	0.04	0.05	0.05	0.03	0.07	0.03
	Min	0.35	0.37	0.35	0.40	0.33	0.31	0.39	0.33	0.61	0.42	0.40	0.58	0.33	0.52
Mesocolpium	M	0.58	0.70	0.51	0.61	0.62	0.61	0.94	0.62	0.69	0.65	0.59	0.67	0.59	0.62
	Std	3.71	7.06	8.47	6.47	8.34	7.95	10.9	6.38	6.52	7.1	7.17	6.43	6.25	6.51
	Min	0.73	2.19	3.44	0.72	0.9	2.94	3.29	1.39	0.82	1.8	2.13	0.69	1.51	0.65
Mesocolpium	M	3.01	1.04	1.08	5.7	6.64	0.32	6.74	3.64	5.9	4.14	3.24	5.7	4.01	5.8
	Std	5.01	8.5	11.23	7.6	9.44	11.2	18.5	8.23	7.9	10.8	10.7	7.5	7.91	7.8
	Min	4.31	5.1	6.74	9.99	7.11	6.67	10.2	7.74	10.8	6.31	7.76	11.6	8.91	13.3
Mesocolpium	Std	1.04	1.15	1.75	3.63	2.47	1.80	0.85	2.38	2.51	2.42	1.18	1.04	2.12	0.18
	Min	2.85	3.30	3.09	4.44	2.28	4.4	8.75	4.92	8.75	4.11	6.83	10.9	4.89	13.2
	Max	6.01	7.01	9.51	16	9.55	10.1	11.1	10.1	11.2	10.1	9.75	12.8	11.05	13.4

*M: Mean, Std: Standard Deviation, Min: Minimum, Max: Maximum

TABLE 6
The pollen morphological characters as seen by SEM between taxa of *Alyssum*

Taxa	Fig No	P/E ratio	Pollen shape	Pollen Size	Lumen (μm)Mean	Muri (μm)Mean	Ornamentation
<i>A. murale</i> subsp. <i>murale</i> var. <i>alpinum</i>	1	1.57	Prolate	Small	307	295	Microreticulate
<i>A. virgatum</i>	2	1.34	Prolate	Small	197	563	Microreticulate
<i>A. peltarioides</i> subsp. <i>virgatiforme</i>	3	1.26	Subprolate	Small	1818	334	Reticulate
<i>A. bulbotrichum</i>	4	1.36	Prolate	Medium	1013	460	Reticulate
<i>A. condensatum</i> subsp. <i>flexibile</i>	5	1.36	Prolate	Small	531	321	Microreticulate
<i>A. pateri</i>	6	1.39	Prolate	Small	291	180	Microreticulate
<i>A. corsicum</i>	7	1.17	Subprolate	Small	537	428	Microreticulate
<i>A. caricum</i>	8	1.48	Prolate	Small	None	None	Microreticulate
<i>A. baumgartnerianum</i>	9	1.49	Prolate	Medium	None	None	Microreticulate
<i>A. callichroum</i>	10	1.37	Prolate	Small	682	361	Microreticulate
<i>A. discolor</i>	11	1.39	Prolate	Small	760	450	Microreticulate
<i>A. ochroleucum</i>	12	1.43	Prolate	Medium	597	371	Microreticulate
<i>A. sibiricum</i>	13	1.24	Subprolate	Small	559	324	Microreticulate
<i>A. strigosum</i>	14	1.19	Subprolate	Medium	790	510	Microreticulate

Pollen Characters. The characters of pollen grains of the examined *Alyssum* species are summarized in Table 5 by using light microscope and SEM data, and show in Figs 5 and 6. The pollen grains of

Alyssum are isopolar and radial symmetric. Pollen shape, calculated as a ratio between polar and equatorial diameter (P/E). Four taxa have subprolate pollen grain, observed in *A. peltarioides* subsp.

virgatiforme, *A. corsicum*, *A. sibiricum*, *A. strigosum*, and prolate in rest of the examined taxa. Erdtman [52] categorized the different pollen size classes based on expressed as length of the longest axis. According to this classification examined species are small or medium size. Pollen grains show a wide variety in their sizes. The pollen grains are monad, polar length and equatorial diameter ranging

from 17.38 (in *A. corsicum*) to 38.17 μm (in *A. baumgartnerianum*). The highest mean value of polar length and equatorial diameter is $P=38,17\ \mu\text{m}$ and $E=25,59\ \mu\text{m}$ in *A. baumgartnerianum*, and the smallest mean value of polar length and equatorial diameter are 17.83 μm in *A. corsicum* and 12.91 μm in *A. murale* subsp. *murale* var. *alpinum*.

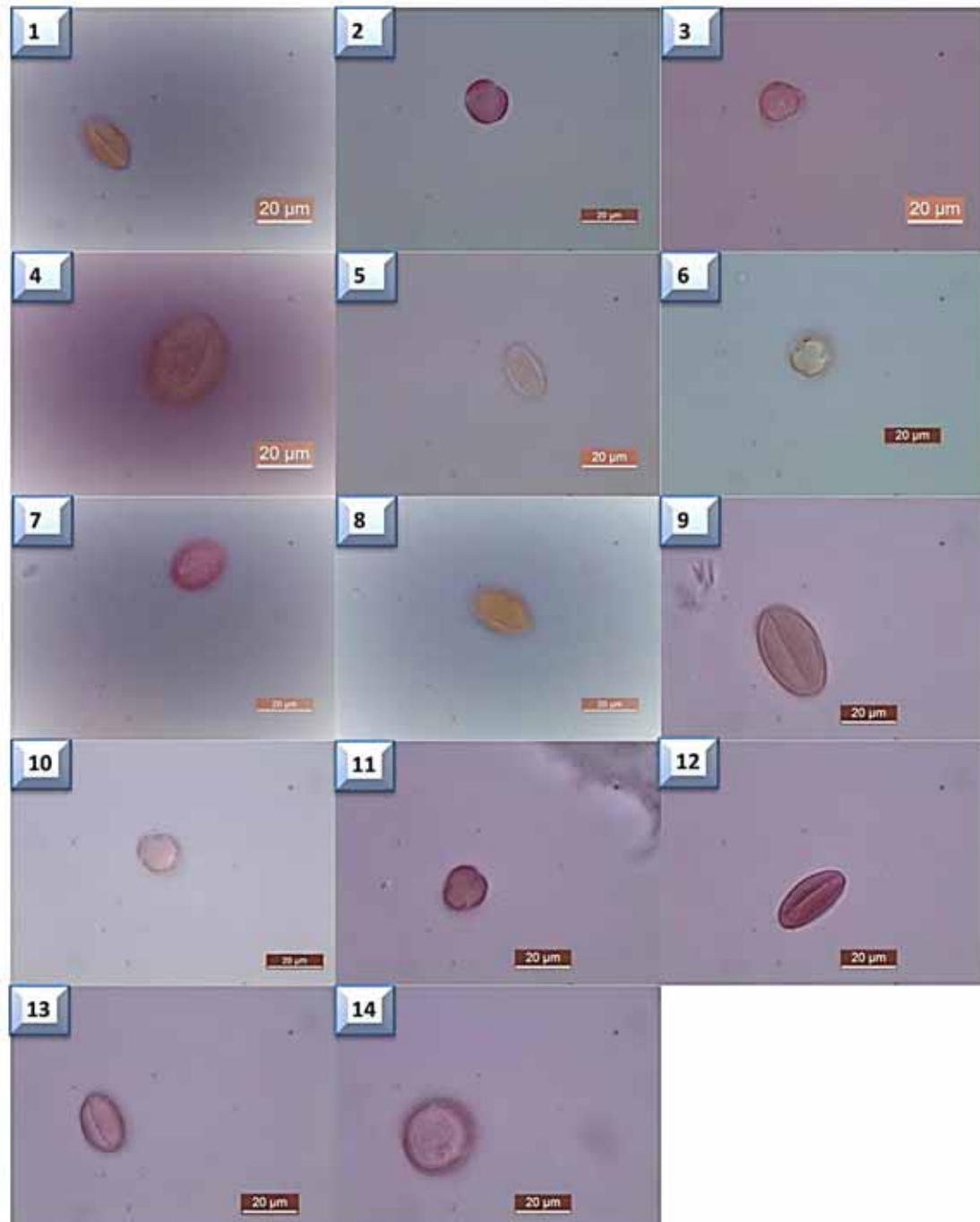


FIGURE 11

LM micrographs of pollen in *Alyssum* species.

1. *A. murale* subsp. *murale* var. *alpinum*, 2. *A. virgatum*, 3. *A. peltarioides* subsp. *virgatiforme*, 4. *A. bulbotrichum*, 5. *A. condensatum* subsp. *flexibile*, 6. *A. pateri*, 7. *A. corsicum*, 8. *A. caricum*, 9. *A. baumgartnerianum*, 10. *A. callichroum*, 11. *A. discolor*, 12. *A. ochroleucum*, 13. *A. sibiricum*, 14. *A. strigosum*.

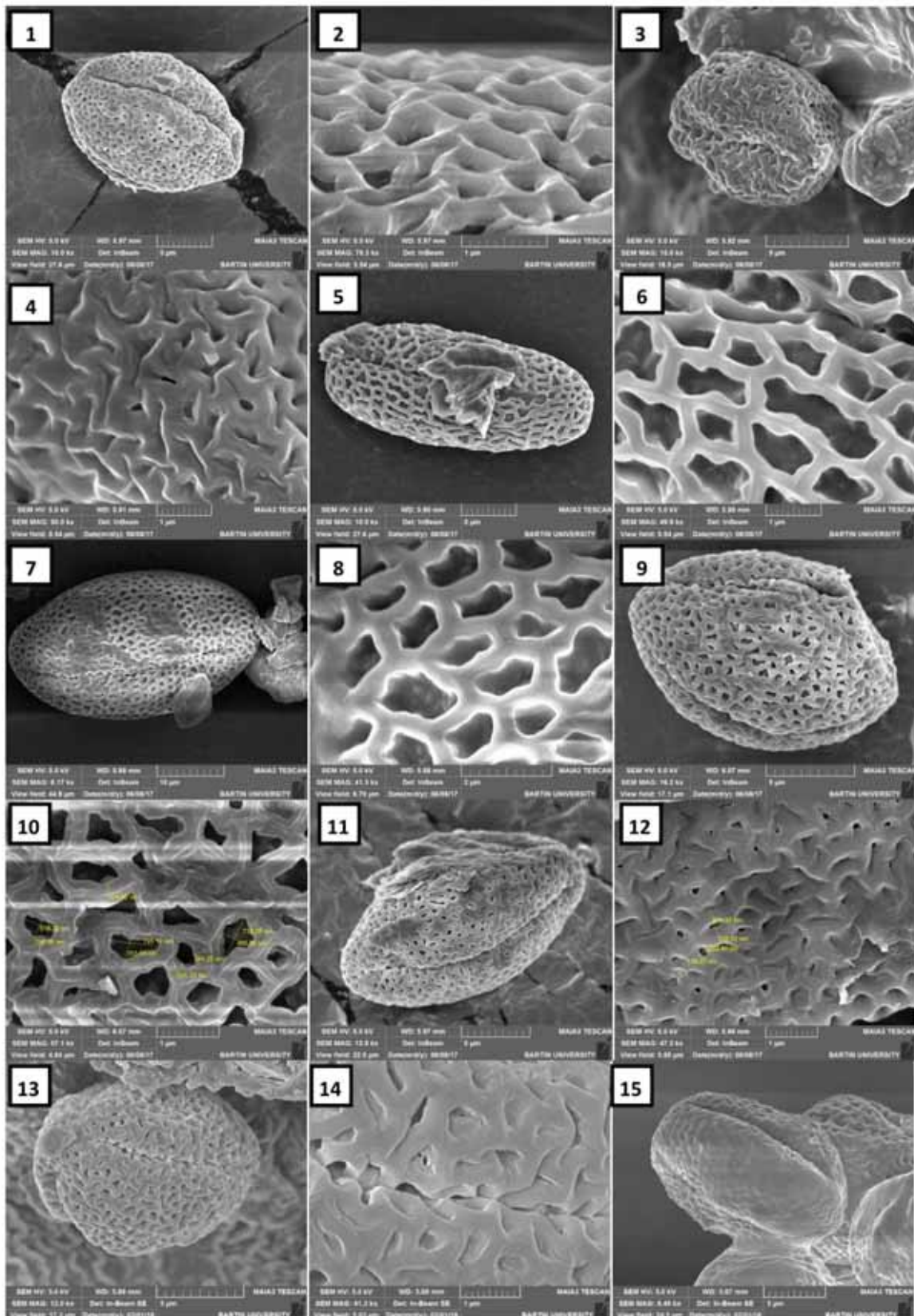


FIGURE 12

LM micrographs of pollen in *Alyssum* species.

1-2*A. murale* subsp. *murale* var. *alpinum*, 3-4*A. virgatum*, 5-6*A. peltarioides* subsp. *virgatiforme*, 7-8*A. bulbotrichum*, 9-10*A. condensatum* subsp. *flexibile*, 11-12*A. pateri*, 13-14*A. corsicum*, 15*A. caricum*.

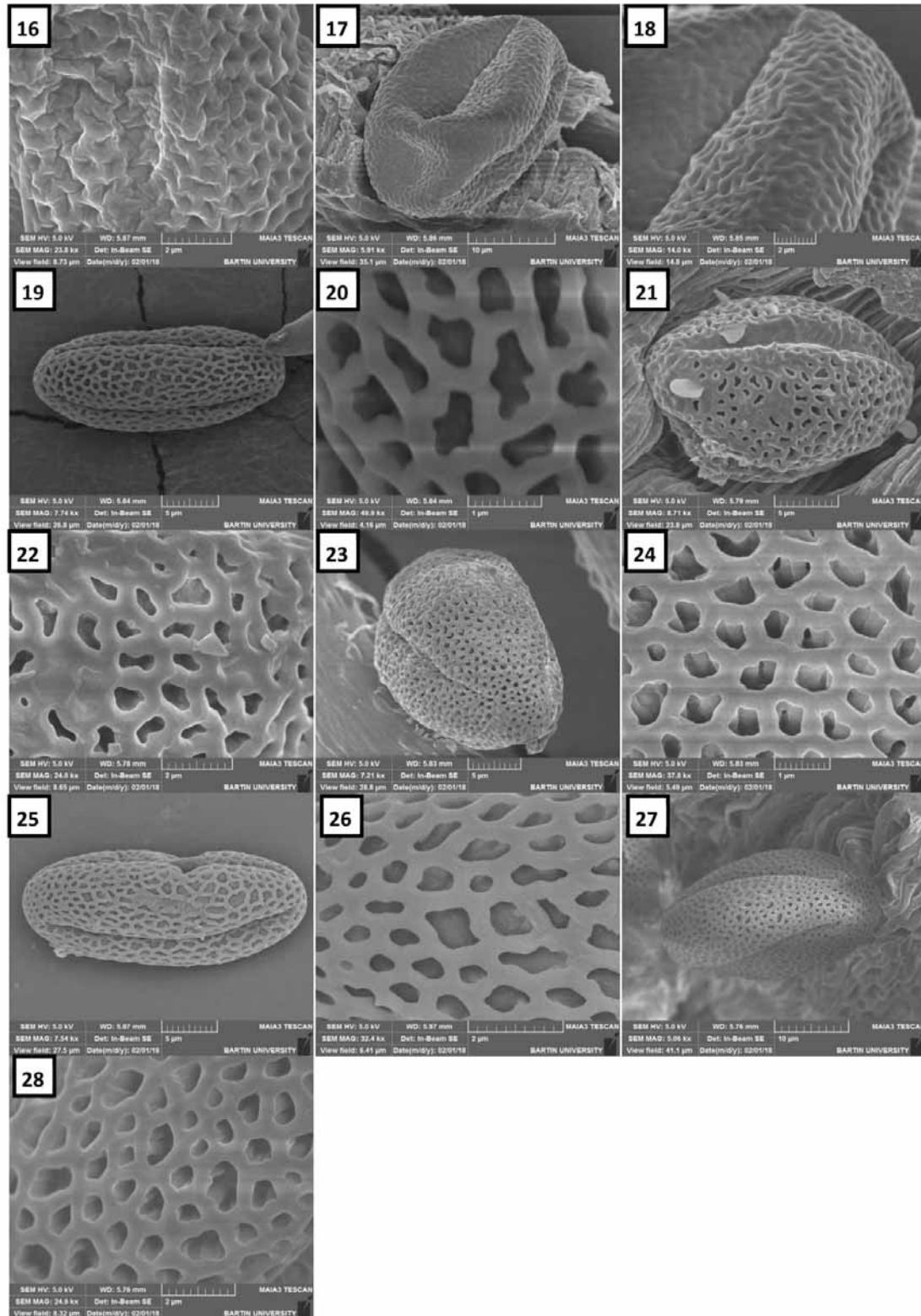


FIGURE 13

LM micrographs of pollen in *Alyssum* species.

16A. *caricum*, 17-18A. *baumgartnerianum*, 19-20 *A. callichroum*, 21-22 *A. discolor*, 23-24A. *ochroleucum*, 25-26A. *sibiricum*, 27-28A. *strigosum*.

Pollen grains are tricolpate. The colpus is long, flat, slowly narrowing towards the poles. Colpus length and colpus width diameter ranging from 13.88 (in *A.corsicum*) to 33.86 μm (in

A.baumgartnerianum). The highest mean value of colpus length is $clg = 33.86 \mu\text{m}$ in *A.baumgartnerianum*, and the lowest mean value of $clg = 13.88 \mu\text{m}$ in *A.corsicum*. The highest mean value of colpus

width is $clt = 1.64 \mu\text{m}$ in *A. ochroleucum*, and the lowest mean value of $clt = 0.77 \mu\text{m}$ in *A. muralesubsp. murale* var. *alpinum*. The exine ornamentation of the examined *Alyssum* pollen was microreticulate. Reticulate ornamentation consisting of muri and lumina bigger than $1 \mu\text{m}$ in *A. peltarioides* subsp. *Virgatiforme* and *A. bulbotrichum*. The largest lumina were observed in the equatorial zone. The average thickness of the exine was 0.85 to $1.66 \mu\text{m}$. The average thickness of the intine was 0.41 to $0.6 \mu\text{m}$. The apocolpium length varied between 3.71 – $10.91 \mu\text{m}$. The mesocolpium length varied between 4.31 – $13.3 \mu\text{m}$.

DISCUSSION

The fruit, seed, and pollen morphology of the Turkish *Alyssum* species are taxonomically significant character features. Fruit, seed, and pollen characteristic, particularly features revealed by means of scanning electron microscopy (SEM), have been used in resolving problems of systematics of family.

Two general types of fruit surface structure were observed in SEM in Turkish *Alyssum*, most species have stellate trichome on surface of fruit, only six species have glabrous surface. In addition fruit shape and size can be useful characteristic for determining in *Alyssum* species. Investigated the pollen morphology and microsculpturing in species of *Alyssum* and provided evidence for the close relationships among various species [27, 28, 30]. The general aperture form of *Alyssum* is tricolporate but colpus length and width highly different in taxa. Useful variations in seed surface ornamentation were determined in species. The seed ornamentation clearly has diagnostic value in distinguishing *A. murale*, *A. lepidotum*, *A. masmenaeum* from the other species. Seed colour, seed size, and wing length of seed provide valuable characteristics in delimitation of genus *Alyssum*. *A. condensatum* subsp. *flexibile*, and *A. sibiricum* have wingless seed. The fruit, seed, and pollen morphology of *Alyssum* species was examined with light microscope and scanning electron microscope. Four qualitative or quantitative morphological characteristics of fruits, 13 micro and macro morphological characteristics of seed, and 14 micro and macromorphological characteristics of pollen were evaluated in these studies.

CONCLUSION

From the above studies; we can conclude that the pollen grains are usually radially symmetrical and isopolar. The fruit surface is usually glabrous or stellate trichome. The seeds are ovate, spheroidal or oblong in shape among the studied species. The hilum position is terminal or subterminal. They show variations in color; light brown, dull yellow

brownish, bright red brownish, dark brownish, dull light reddish, bright brownish, bright red brownish, dull brownish, and dull yellowish. Several types of ornamentations have been observed on surface structures: reticulate (normal reticulate, reticulate-foveate, reticulate-lineolate, reticulate-rugose), ruminant, rugose, lineolate, blister, and colliculate. The pollen grains of the genus are subprolate or prolate. The pollen grains are tricolpate. Exine ornamentation are mainly reticulate. In conclusion, this study supports the use of fruit, seed and pollen morphology as a diagnostic character for species level.

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