Morphological Variation and Palynomorphology of *Rosa laxa* in Xinjiang, China

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**ABSTRACT.** *Rosa laxa* is widely distributed in the Xinjiang Uyghur Autonomous Region of China and is highly adaptable and rich in variation. In this study, we investigated the morphology, habitats, and palynomorphology of *R. laxa* botanical varieties from Xinjiang, China. In addition to *R. laxa* var. *laxa*, there were three other botanical varieties of *R. laxa* growing in southern Xinjiang, including var. *mollis*, var. *kaschgarica*, and var. *tomurensis*. Together, these four botanical varieties exhibited morphological variation, mainly in the morphology of prickles and the glandular trichome and in flower color. The pollen grains of the *R. laxa* botanical varieties, all medium in size (21.77–48.39 μm), came in three shapes: perprolate, prolate, and subspheroidal. Their pollen exine sculptures were characterized by either a striate-perforation pattern or striate pattern, but perforation varied in terms of diameter and density and striae varied in depth and density. Palynomorphological assessment showed that three types of evolution, i.e., primitive, transitive, and evolved, were present among *R. laxa* botanical varieties, and pollen dimorphism was observed in the same botanical variety. Perprolate pollen with a dense striate pattern was the most evolved type. Based on morphological and palynomorphological investigations, var. *tomurensis* was considered to be the most evolved one among the studied botanical varieties.

As one of the biodiversity centers of wild *Rosa*, China is home to 95 species (65 endemic) of *Rosa*, accounting for nearly half of the world total (Ku and Kenneth, 2003). The Xinjiang Uyghur Autonomous Region is a large and sparsely populated area located in the northwest of China covering 1.6 million km² (about one-sixth of the total land area of China). Separated by the Tianshan Mountains, north Xinjiang is characterized by temperate climate, whereas south Xinjiang possesses a warm temperate climate. These complex environments make Xinjiang host to a rich variety of plant species. Although officially 14 species (including three botanical varieties) of wild *Rosa* are found in this region (Ku and Kenneth, 2003), there may be as many as 22 wild *Rosa* species in the region (Bao, 1993; Liu, 1993; Liu and Cong, 2000; Ma and Chen, 1990).

There are about 50 species of *Rosa* section *Cinnamomeae*, 36 of which are in China (26 endemic) (Ku and Kenneth, 2003; Yu et al., 1985). *Rosa laxa* var. *laxa* is one of these 36 species, and it grows extensively in the Xinjiang region only. In addition to the var. *laxa*, three other botanical varieties of *R. laxa* are also known to grow in Xinjiang (Liu and Cong, 2000), although only *R. laxa* var. *mollis* is recorded in the *Flora Repubicae Popularis Sinicae* (Yu et al., 1985) and *Flora of China* (Ku and Kenneth, 2003). In the *Flora of China*, *R. laxa* is described as follows:

Shrubs 1–2 m tall. Branchlets terete, straight or slightly curved, glabrous; prickles in pairs below leaves or scattered. Leaves including petiole 4.5–10 cm; leaflets 7–9, elliptic, oblong, or ovate, rarely obovate, 1.5–4 cm long, 1–3 cm wide, glabrous or pubescent. Flowers often 3–6 in corymb, sometimes solitary, 1.5–3 cm in diam.; pedicel 1–1.8 (–3) cm, glandular; bracts ovate, pubescent, glandular hispid, apex acuminate. Sepals 5, ovate-lanceolate, leaflike, abaxially sparsely pubescent and glandular hispid, adaxially densely pubescent, margin entire. Petals 5, white or pink, obovate, apex erose. Hip red, oblong or ovoid, 1.8 cm in diameter, glabrous, often shiny, apex with a short neck and persistent, erect sepals.

Other recorded botanical varieties of *R. laxa* include 1) var. *mollis*, 2) var. *kaschgarica*, and 3) var. *tomurensis*. *Rosa laxa* varies considerably in terms of morphological characteristics. There is abundant inter- and intrapopulation genetic diversity among six natural populations of *R. laxa* var. *laxa* in the Tianshan Mountains of north Xinjiang (Guo, 2010). However, there is little information in the literature focused on the detailed descriptions (and specimens) of these botanical varieties in the Xinjiang region. Furthermore, only a relatively small area has been previously surveyed for *R. laxa*, although it is well known that Xinjiang is a biodiversity center of *Rosa*.

In this study, we reported the results of a recent survey (2007–18) of the distribution of *R. laxa* botanical varieties and their morphological characteristics in the Xinjiang region. In addition to the usual morphological characters, we also measured pollen traits. Because the morphological characteristics of pollen grains are generally unaffected by environmental factors but exhibit strong genetic stability, considerable evolutionary information regarding species and botanical varieties may be inferred from
pollen characteristics (Wang and Wang, 1983; Wrońska-Pilarek and Jagodziński, 2011).

**Material and Methods**

**Survey Area.** Cities, counties, or districts were selected from the following 13 areas across the Xinjiang region (Fig. 1; Table 1), including all regions where climatic conditions are suitable for *Rosa* species: 1) Altay city, Habake County, Burjin County, and Fuhai County (Altay Prefecture, Ili Kazakh Autonomous Prefecture); 2) Tacheng city, Emin County, and Yumin County (Tacheng Prefecture, Ili Kazakh Autonomous Prefecture); 3) Bole city and Jinghe County (Bortala Mongol Autonomous Prefecture); 4) Kuitun city, Yining city, Gongliu County, Tekes County, and Nilka County directly under the control of Ili Kazakh Autonomous Prefecture; 5) Dushanzi district of Karamay city; 6) Manas County (Shihezi city); 7) Tianshan district and Urumqi County (Urumqi city); 8) Turpan city and Toksun County (Turpan Prefecture); 9) Korla city and Luntai County (Bayingolin Mongol Autonomous Prefecture); 10) Aksu city, Wensu County, and Kuqa County (Aksu Prefecture); 11) Artux city (Kizilsu Kirghiz Autonomous Prefecture); 12) Kashgar city, Shule County, Shufu County, and Yinggisha County (Kashgar Prefecture); and 13) Hotan city (Hotan Prefecture).

**Plant Materials.** *Rosa laxa* pollen samples were collected and preserved in the specimen bank of the China National Engineering Research Center for Floriculture, Beijing, China (Table 1).

**Methods and Analysis.** The morphology of each *R. laxa* botanical variety was identified and assessed to assign each collection to a specific *R. laxa* using the *Flora of China* (Ku and Kenneth, 2003), *Flora Republicae Popularis Sinicae* (Yu et al., 2018).

### Table 1. Pollen samples of *Rosa laxa* for palynomorphologic study.

| No. | Latin name | Voucher specimen | Location |
|-----|------------|------------------|----------|
| R1  | *R. laxa* var. *laxa* | Luo le, bjfu-xj-09008 | Sandy land and slope shrub, Kuitun city, 685 m |
| R2  | *R. laxa* var. *laxa* | Luo le, bjfu-xj-10035 | Brook bank and forest edge, Wensu County, Aksu city, 1,108 m |
| R3  | *R. laxa* var. *laxa* | Luo le, bjfu-xj-10085 | Saline-alkaline land, Xiaocaohu, Turpan city, 330 m |
| R4  | *R. laxa* var. *mollis* | Luo le, bjfu-xj-09024 | Forest edge, Xiaodonggou, Altay city, 982 m |
| R5  | *R. laxa* var. *kaschgarica* | Luo le, bjfu-xj-10101 | Gravel land, Kashgar city, 1,001 m |
| R6  | *R. laxa* var. *kaschgarica* | Luo le, bjfu-xj-10083 | Saline-alkaline land, Tiemenguan, Korla city, 1,012 m |
| R7  | *R. laxa* var. *kaschgarica* | Luo le, bjfu-xj-10095 | Brook bank, Nature Tuomuer, Aksu city, 1,399 m |
| R8  | *R. laxa* var. *kaschgarica* | Luo le, bjfu-xj-10072 | Seasonal river valleys, Wensu County, Aksu city, 1,312 m |
| R9  | *R. laxa* var. *tomurensis* | Luo le, bjfu-xj-10113 | Seasonal river valleys, Nature Tuomuer, Aksu city, 2,103 m |
| R10 | *Rosa* sp. | Luo le, bjfu-xj-10115 | Seasonal river valleys, Nature Tuomuer, Aksu city, 2,103 m |

Fig. 1. Survey areas in 13 prefectures/cities of Xinjiang, China (2007–18): (A) Altay Prefecture (subordinate to Ili Kazakh Autonomous Prefecture); (B) Tacheng Prefecture (subordinate to Ili Kazakh Autonomous Prefecture); (C) Bortala Mongol Autonomous Prefecture; (D) directly controlling area of Ili Kazakh Autonomous Prefecture; (E) Karamay city; (F) Shihezi city; (G) Urumqi city; (H) Turpan Prefecture; (I) Bayingolin Mongol Autonomous Prefecture; (J) Aksu Prefecture; (K) Kizilsu Kirghiz Autonomous Prefecture; (L) Kashgar Prefecture; (M) Hotan Prefecture.
Results

General descriptions of *R. laxa* botanical varieties

The survey results confirmed that in addition to *R. laxa* var. *laxa*, three other botanical varieties (var. *mollis*, var. *kaschgarica*, and var. *tomurensis*) were also present in Xinjiang.

**Rosa laxa** var. **laxa**. *Rosa laxa* var. *laxa* represents the original botanical variety of *R. laxa*. It is widely distributed in sandy or rocky areas, north-slope shrub, dry river-beds, stream sides, forest edge, and near farmland at altitudes of 500–2500 m in Altay, Tacheng, Ili, and Urumqi in north Xinjiang. This botanical variety was also found in the Gobi desert, saline-alkaline land and flood land, and near farmland at altitudes of 700–2700 m in Turpan, Korla, Aksuand, and Kashi in south Xinjiang (Fig. 2A–F). Its morphological characteristics varied greatly, as follows:

Leaflet: oval or oblong in areas with sufficient water, with smooth petioles or a few small and scattered prickles; subrotund or obovoid in arid areas, with smaller leaf size and glandular pubescence or puberulous on petioles (Fig. 2A).

Prickle: Recurved, broadly dilated at base, especially in burgeon, but to varying degrees; varying frequency of prickles with higher frequency in arid areas (Fig. 2B).

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**Rosa laxa** var. **mollis**. *Rosa laxa* var. *mollis* (Fig. 2G). Leaflet densely pubescent on both surfaces; (H) hip red, 3–6 in corymb; *R. laxa* var. *kaschgarica* (I) leaflet thickness, almost leathery, mostly oval, base subrounded or cuneate; (J) old branch 10–15 cm in diameter; (K) prickle significantly and strongly hooked; (L) large shrub near the water with 3.8 m shrub crown; (M) flower white or pale pink; (N–O) bud often with pink mark; (P) hip red, ovoid or nearly spherical; (Q) a variant in Shenmu Park, leaflet almost leathery, very narrow oval, flower mostly solitary.

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Glandular pubescence: Greatest changes in pedicel, receptacle, and sepals (Fig. 2C); pedicel glandular pubescent or glabrous; sometimes premature glandular pubescence shedding, leading to smooth surface of stalk and hip during the fruiting stage. Flower: Often three to six in corymb, sometimes solitary, mostly in south Xinjiang; white petals, but buds often with pink tips just before flowering (Fig. 2D and E).

**R. laxa var. mollis.** *Rosa laxa var. mollis* is easily distinguished from *R. laxa var. laxa* by its dense pubescence on both adaxial and abaxial leaflet surfaces. It contains white flowers in the corymb, with glandular pubescence on the pedicels and sepals. This botanical variety was only found in wet meadow or poplar forests at altitudes of 580–1100 m in Altay-Xibodu in north Xinjiang (Ku and Kenneth, 2003; Liu and Cong, 2000; Yu et al., 1985) (Fig. 3G and H). However, it was found to be more widespread throughout Xinjiang than previously reported. *R. laxa var. mollis* was frequently found at

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**Fig. 3.** *Rosa laxa var. tomurensis* [(A)] leaflet glabrous, elliptic or oblong; prickle with nonobvious camber in tip, branchlet often purplish red; [(B)] pedicel glandular pubescent or glabrous, long; [(C–D)] flower white and big with long pedicel, mostly solitary; [(E)] habitat near river bank; [(F)] hip large, often pendulous, stalk slightly swelling; new variant of *R. laxa* in the Tuomuer Nature Reserve [(G–I)] flower pale pink in corymb, sometimes solitary; [(J)] leaflet almost leathery, oblong; [(K)] hip oval or flat round, with erect sepals persistent or not; [(L)] prickle slightly curved; *R. beggeriana* [(M)] hip round or flat round; sepal deciduous; *R. albertii* [(N)] hip oblong or pyriform; sepal deciduous.
R. LAXA VAR. TOMURENSIS. This botanical variety is characterized by the following features: branchlets often purplish red; prickles with nonobvious camber in tip (Fig. 3A); flowers often solitary, rarely in clusters of 2–3 flowers; often large solitary fruits; only at altitudes of 750–1700 m, mainly in arid plains (e.g., the Gobi, arid slopes, seasonal river valleys, gravel land, and saline-alkaline land, especially in the Kashgar area) in south Xinjiang. It is also reported to grow in central Asia, Siberia, and Mongolia (Han, 1995; Liu and Cong, 2000).

A new variant type (narrow leaf shape) of this botanical variety was found in Shenmu Park in Wensu County during this survey (Fig. 2Q). The leaflets of this variant of R. laxa var. kaschgarica are almost leathery, but narrow oval in shape. Flowers are mostly solitary, white, buds with pink tips, and pedicels are short, about 0.5–1 cm. Furthermore, large shrubs (3–5 m in shrub canopy, 2–4 m in height, with old branches 10–15 cm in diameter) of this variant of R. laxa var. kaschgarica were found in habitats close to water (Fig. 2J–L). The almost leathery leaflets distinguish this variant from the original botanical variety.
flowers (1.5–2.5 cm in diameter, Fig. 3B–D); long pedicels, up to 2.5 cm (Fig. 3B and F); pedicel glandular pubescent or glabrous; large and shiny hips, 1.5–2 cm long, 1–1.5 cm wide, and often pendulous; and fruit-stalks slightly swelling (Fig. 3E and F). The flowering period lasts for 6–7 months and the fruiting stage for 8–10 months.

This botanical variety, which was not reported in *Flora Reipublicae Popularis Sinicae* (Yu et al., 1985) or *Flora of China* (Ku and Kenneth, 2003), was proposed by Liu and Cong (2000). This survey confirmed that this botanical variety has a stable trait profile and is present only at altitudes of 1650–2200 m in shrubs at river banks (Fig. 3E) and in river valleys in arid, hilly areas in the Tuomuer Nature Reserve in Wensu County, south Xinjiang. This area has an arid climate, and the temperature and rainfall vary greatly at different altitudes. *Rosa laxa* var. *kaschgarica*, *R. beggeriana*, *R. albertii*, *Berberis*, and *Caragana* under these conditions. Liu and Cong (2000) described this botanical variety as having fewer prickles than the original botanical variety, which was, however, not supported by the present survey.

**New variant**

A new variant of *R. laxa* was found in the Tuomuer Nature Reserve (Fig. 3G–L) and is characterized by the following: small leaflets, almost leathery, base cuneate, entire margin (Fig. 3J); prickles slightly recurved (Fig. 3L); glandular on sepals and bracts, gradually shedding at later stages; and flowers pale pink, in groups of three to five on stems or sometimes solitary, 1.5–2 cm in diameter, with petal tip slightly curling and splitting (Fig. 3G–I). This was originally thought to be a variant of *R. albertii*, (Fig. 3M) and *R. albertii* (Fig. 3N) were also found nearby, with the apical part of the hypanthium and sepals deciduous after the hips ripened. Based on these observations, we suggest that this new variant was a natural hybrid of *R. beggeriana* or *R. albertii* with *R. laxa* var. *kaschgarica* and that *R. laxa* var. *kaschgarica* was likely to be the female parent.

**Pollen grain morphology**

*R. laxa* var. *laxa*. R1 was perprolate in shape (P/E = 2.04) and 32.80 to 39.86 × 16.58 to 19.48 μm in size (Fig. 4A–H; Table 2). Its shape in the equatorial view was long-elliptic and in the polar view was trilobate-circular with tricolporate, which extended toward the polar axis. Thin striae on the exine sculpture were almost parallel to the polar axis, with light muri and perforations in wide intervals between striae.

R2 and R3 were dimorphic and were prolate (P/E = 1.72) and subspheroidal (P/E = 1.01), respectively, in shape. The prolate pollen grains were 22.73 to 36.74 × 16.27 to 20.58 μm in size. Their equatorial and polar views were the same as those of R1. The prolate pollen grains were also similar to those of R1 in exine sculpturing but with much thicker and denser striae at 0.56–0.83 μm². The subspheroidal pollen grains were 19.15 to 4.44 × 16.80 to 22.67 μm in size and were circular or subcircular in the equatorial view and obtuse-triangular with tricolporate in the polar view. The colpus was spindle-shaped, with a width ranging from 0.71 to 4.53 μm. There was a significant difference in sculpturing between R2 and R3. R3 had the densest striae on the sculpture, ranging from 1.03 to 

| Specimens | Pollen grain (mean ± SD) | Exine sculpture (mean ± SD) | Pollen grain (mean ± SD) | Exine sculpture (mean ± SD) |
|-----------|--------------------------|----------------------------|--------------------------|----------------------------|
| R1        | 35.63 ± 2.27 d y         | 17.52 ± 1.15 a             | 2.04 ± 0.20 de           | 0.25 ± 0.03 de             |
| R2–1      | 30.64 ± 3.99 c           | 17.89 ± 1.61 a             | 1.72 ± 0.27 c            | 0.13 ± 0.01 ab             |
| R3–2      | 21.93 ± 0.88 a           | 21.89 ± 1.51 b             | 1.11 ± 0.06 c            | 0.11 ± 0.03 ab             |
| R5        | 37.82 ± 2.43 b           | 18.09 ± 1.25 b             | 1.71 ± 0.19 c            | 0.21 ± 0.05 ab             |
| R6        | 43.95 ± 3.34 f           | 21.11 ± 2.34 f             | 2.17 ± 0.15 c            | 0.14 ± 0.02 ab             |
| R7        | 38.20 ± 1.96 b           | 21.39 ± 1.96 b             | 2.02 ± 0.05 e            | 0.22 ± 0.04 ab             |
| R8        | 38.39 ± 2.78 b           | 23.30 ± 1.70 d             | 2.47 ± 0.24 e            | 0.14 ± 0.02 ab             |
| R9–1      | 48.39 ± 2.73 g           | 22.39 ± 1.00 d             | 2.17 ± 0.17 e            | 0.15 ± 0.02 ab             |
| R10       | 35.26 ± 1.69 d           | 17.52 ± 1.27 a             | 2.02 ± 0.46 bc           | 0.13 ± 0.02 bc             |

*Shape of pollen grain* (Erdtmann, 1952). Subspheroidal: P/E ratio of 0.75–1.35. Prolate: P/E ratio of 1.33–2. Perprolate: P/E ratio >2.

*Table 2. The palynomorphology characters of Rosa laxa botanical varieties.*
1.76 μm²; these were clear without puncture and ran almost parallel to the polar axis. The sculpturing of R2 looked like multiple ornamentation with striae and subsident foveae.

R. laxa var. mollis. R4 was prolate (P/E = 1.62), with a size of 36.31 to 42.35 × 21.19 to 26.79 μm, and was long-elliptic in the equatorial view and trilobate-circular with tricolporate extending toward the polar axis in the polar view (Fig. 4I–M). Sculpturing was characterized by a perforate-striate pattern, almost parallel to the polar axis, but the perforations were irregular, sometimes fewer and smaller and sometimes denser and larger near the colpus.

R. laxa var. kaschgarica. R5 was prolate in shape (P/E = 1.97) and 33.78 to 40.32 × 17.98 to 21.15 μm in size (Figs. 4N, 4O, and 5A–E). R6–R8 were perprolate (P/E = 2.06–2.17), with a size of 29.20 to 50.46 × 14.96 to 24.33 μm. They were all long-elliptic with acute or obtuse poles in the equatorial view and trilobate-circular with tricolporate extending toward the polar axis in the polar view. Sculpturing was characterized by a striate pattern, with R5 having the densest striae at 2.95 μm². R5–R8 differed in foveae or perforation: 1) R5 and R7 had more obvious striae, but fewer large perforations with a density of 0.85–1.44 μm²; 2) thick striae were observed in R6 and R8, with dense perforations at 2.22–2.47 μm²; and 3) no pits but perforations were seen in R6.

Rosa laxa var. tomurensis. R9 was dimorphic, with a perprolate shape (P/E = 2.17) measuring 42.86 to 51.87 × 20.67 to 23.63 μm in size, and a subspheroidal (P/E = 1.01) shape measuring 23.43 to 30.07 × 22.89 to 29.41 μm in size. Pollen grains were long-elliptic or subcircular in the equatorial view and trilobate-circular or subcircular, with deeper tricolpus, in the polar view. The exine sculpture exhibited prominent striae parallel to the equatorial axis and close to the colpus, but only perprolate pollen grains had perforations, with a density of 1.24 μm². Subspheroidal pollen grains had thin striae that were wide in ridges and narrow in grooves, and the colpus was spindle-shaped with the width ranging from 0.31 to 5.12 μm.

New variant

R10, representing the special variant of R. laxa, was perprolate (P/E = 2.02) in shape and 33.32 to 37.68 × 16.21 to 20.15 μm in size (Fig. 5M–O). It was long-elliptic in the equatorial view and trilobate-circular with a deeper tricolporate.
in the polar view. The sculpture was characterized by a perforate-striate pattern. There were no significant differences between R10 and R. laxa var. kaschgarica (R5–R8).

Discussion

Rosa laxa botanical varieties represent stable variants in terms of certain morphological characteristics and are able to adapt to a range of geographical regions with varying climatic conditions in Xinjiang, China (Yu et al., 2014). Although R. laxa botanical varieties could be identified with these stable morphological variants, it remains difficult to distinguish them morphologically because of both intra- and interpopulation variation in these morphological characteristics, such as flower color and the morphology of prickles, indumentum, and glandular pubescence. A comparison of the morphological traits of these botanical varieties from different habitats suggests that flower color is not a suitable character for distinguishing R. laxa botanical varieties. In addition, prickles varied greatly in their shape and number. By contrast, branches, which showed stable growth, would be a preferred morphological character for classification. The indumentum and glandular pubescence of R. laxa are variable in number, even within the same plant; similarly, the constant shedding of the indumentum and glandular pubescence is also a problem worth noting to minimize errors in classification.

Palynomorphological data indicated that all pollen grain samples of R. laxa were monad with an NPC (aperture number, position, and character) = 345. There was a considerable amount of intraspecific variation in pollen grain morphological characters, and there was also shape dimorphism of pollen grains, particularly in R. laxa var. laxa and R. laxa var. tomurensis. In all botanical varieties, the colpus of the pollen grain was long, elliptic in outline, deeply set into the exine, and ended sharply. The colpus of the pollen grain was wide in the center and narrow at the ends, but this was not the case for prolate or perprolate pollen grains.

Previous research on plant geography in Xinjiang (Hui et al., 2003) found primitive, transitive, and evolved Rosaceae communities. Yu (1984) speculated that the Rosaceae had evolved mostly from a multiflowered compound inflorescence toward a few-flowered, simple inflorescence, and finally toward a solitary flower with large petals. In this sense, R. laxa var. tomurensis and R. laxa var. kaschgarica may be most recently diverged from the original botanical variety.

Ma and Chen (1992) reported that R. laxa has 2n = 2x = 14 chromosomes in the shoot tips; by contrast, Krussmann (1981) and Yang et al. (2008) reported 2n = 4x = 28 chromosomes in the root tips. Mixoploidy and intraspecific polyplody are widespread in Rosa species (Luo et al., 2009; Ma and Chen, 1992; Simon et al., 2006) and polyploid pollen grains or spores are larger than diploid ones (Erdtman, 1952). Zlesak (2009) concluded that pollen diameter and guard cell length could be used to predict the ploidy level in Rosa species, with diploid pollen exhibiting a diameter <35.6 μm, and tetraploid exhibiting a diameter of 35.6–43.7 μm. In this study, pollen grains were all monads and medium in size (21.77–38.39 μm), with the maximum observed in R. laxa var. tomurensis. Based on the pollen diameters, we infer that R. laxa var. kaschgarica is tetraploid and that both diploids and tetraploids might exist for other botanical varieties. Plants with subspheroidal pollen grains might be the more primitive diploids.

In terms of palynology, Wodehouse (1935) inferred that longer pollen grains were stronger in regulatory function; hence, pollen grains with smaller volume/surface area ratios are likely to be more recently evolved. Pollen grains of primitive angiosperms are believed to be large in size, with pollen evolving toward a smaller size (Feng, 2007; Walker, 1976; Zhou et al., 2005). It has been hypothesized that the exine sculpture of the angiosperm pollen grain evolved from a nonstructural layer (smooth) toward a perforation foveola and then toward a striate pattern (Erdtman, 1952). Moreover, the perforation pattern might be the most primitive in the Rosaceae, with striate and striate-reticulate patterns being more recently evolved. The exine sculpture is also believed to be better able to provide evolutionary information than pollen size (Moore et al., 1991; Reitsma, 1966; Wroniska-Pilarek, 2006; Wrónska-Pilarek and Boratyńska, 2005; Li and Zhang, 2009; Zhou et al., 1999a, 1999b, 2000).

Based on the present study of R. laxa botanical varieties, exine sculpture and P/E ratio are the main characters that should be used for the identification of related botanical varieties. Small pollen grains with dense striae may be considered to be the most recently derived. For example, among the four samples of R. laxa var. kaschgarica, the R5 and R7 specimens with pink flowers, which exhibited denser striae, may be considered to be recently evolved. Although the pollen grains of R. laxa var. tomurensis are comparatively larger, it can still be regarded as recently evolved because of its dense striae and low-density foveae, in agreement with the aforementioned inference made on the basis of Yu’s (1984) results.

The extensive adaptability of R. laxa, especially R. laxa var. kaschgarica, indicates that R. laxa botanical varieties may possess gene(s) conferring tolerance or resistance to environmental stresses. Same results on karyotype analysis were also found among these R. laxa species (Yu et al., 2014). Introduction of these genes into commercial breeding lines would greatly assist in the production of high-quality modern roses. Thus, effective conservation measures should be taken to preserve these genes.

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