

## SELAGINELLACEAE SPIKEMOSS FAMILY

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Perennial herbs in ours with often dichotomously branched stems. ROOTS adventitious, short, produced from near the tips of modified leafless root-like stems (rhizophores), branched or more commonly unbranched. LEAVES variously arranged, scale-like, with the venation restricted to a midvein. SPORANGIA of two types, kidney-shaped to depressed-ovoid, positioned on the adaxial base of leaf-like sporophylls, arranged in strobili terminal on the branches. MEGASPORANGIA with usually 4 megaspores, these relatively large, trilete, tetrahedral-globose. MICROSPORANGIA with numerous microspores, these minute, trilete, tetrahedral-globose. GAMETOPHYTES reduced, developing mostly inside the spores, the archegonia and antheridia protruding from the spore wall. —1 genus, 700–750 spp., nearly worldwide.

### **Selaginella** P. Beauv. Spikemoss

STEMS (except in *S. rupincola*) not differentiated into rhizomes and aerial stems, branching dichotomously or more commonly pinnately, the branches sometimes dichotomously forked. RHIZOPHORES produced from leaf axils on the adaxial side of the stem, elongate, slender, white to more frequently dark brown. LEAVES sometimes dimorphic (those on the abaxial stem side sometimes larger and gray to tan or brown), appearing densely spirally arranged, narrowly elliptic to ovate, papery to somewhat hardened, tapered at the tip, the midvein usually noticeably ridged, sometimes extended into an awn-like or hair-like appendage (seta), the margins variously entire to ciliate. STROBILI solitary on the branch tips, 4-ranked, the sporophylls differentiated from vegetative leaves, usually somewhat keeled and strongly folded around the sporangia, often slightly auriculate at the base. MEGASPORES 0.2–1.3 mm in diameter. MICROSPORES 30–75 μm in diameter. —700–750 species, nearly worldwide. (Diminutive form of ancient name “Selago” for a kind of club-moss [small *Lycopodium*]).

The above description applies primarily to species of *Selaginella* subg. *Tetragonostachys* Jermy (ca. 50 species), to which all of the Arizona species belong. Taxa in this subgenus often are relatively difficult to determine, differing in small structural details. All of the Arizona taxa are hygroscopic, but some species, like *S. arizonica* and *S. eremophila*, have branch tips that curl inward with drought, whereas in others the leaves merely become more appressed and duller gray to

brown. Terminal setae are best observed on leaves near the tips of vegetative branches on newer growth.

Of the 5 currently accepted subgenera, 2 others occur in temperate North America. Subgenus *Selaginella* comprises only 2 species of northern North America and Hawaii that resemble certain kinds of diminutive clubmosses. The resurrection plants are a small group presently classified in the large, mostly tropical subg. *Stachygynandrum* (P. Beauv.) Baker, which is considered polyphyletic by some pteridologists (Korall & Kenrick 2002). There are persistent anecdotal reports that one of these species grows somewhere in southeastern most Arizona, but this has not been confirmed to date. The resurrection plants have the main stems densely cespitose and forming a dense rosette that curls inward during times of drought. Rhizophores are restricted to the basal portions of the stems. Two mainly Mexican species, *S. lepidophylla* (Hook. & Grev.) Spring and *S. pilifera* A. Braun, are found in southern New Mexico and adjacent Texas, and a third, *S. novoleonensis* Hieron., occurs from the mountains of central Sonora eastward. These should be searched for in eastern Cochise County on rocky slopes and exposed canyon walls.

1. Stems dimorphic, differentiated into a rhizomatous, prostrate main stem system (this sometimes subterranean) with shorter leaves and aerial branches, these elongate, procumbent or more commonly ascending to erect, with longer leaves, with rhizophores produced only below the midpoint; leaves grayish green ..... *S. rupincola*  
 1' Stems monomorphic, not differentiated into rhizomatous and aerial portions (very short ascending branches present in some species), prostrate to decumbent or uncommonly procumbent; rhizophores produced more or less throughout, at least on the main stems; at least the adaxial leaves green to dark, olive, or yellowish green when hydrated ..... 2
  2. Leaves slightly to strongly dimorphic, those on the abaxial stem side somewhat larger, decurrent at the base, somewhat chaffy or hardened, and persistently gray to tan or brown, those on the adaxial stem side somewhat smaller, adnate to the stem, herbaceous to somewhat papery or leathery, green when hydrated ..... 3
    3. Leaves slightly dimorphic; ends of branches appearing relatively straight when dried ..... *S. densa*  
 3' Leaves relatively strongly dimorphic; ends of branches appearing curled when dried ..... 4
      4. Leaves on adaxial side of stem 1.9–2.3 mm long; setae 0.1–0.3 mm long, relatively stout and straight, frequently persistent on at least some of the mature leaves (but most easily observed at the branch tips) ..... *S. arizonica*  
 4' Leaves on adaxial side of stem 1.3–1.5 mm long; setae 0.3–0.4 mm long, relatively slender and contorted, usually shed as the leaves develop (visible only at the developing branch tips) ..... *S. eremophila*
- 2' Leaves monomorphic, those of the abaxial and adaxial stem sides similar in size, color, and texture ..... 5
  5. Both abaxial and adaxial leaves adnate (not decurrent) at the base, abruptly differentiated in color from the stems ..... *S. mutica*  
 5' Leaves of at least the main stems decurrent at the base, not distinct in color from the stems ..... 6

6. Lateral branches mostly elongate, prostrate to loosely spreading, the plants usually forming loose mats ..... *S. underwoodii*  
 6' Lateral branches short, ascending, the plants forming dense low cushion-like mats ..... 7  
 7. Dry stems not or rarely fragmenting ..... *S. leucobryoides*  
 7' Dry stems readily fragmenting ..... *S. watsonii*

**Selaginella arizonica** Maxon (of Arizona; Fig. 2). Arizona Spikemoss. —STEMS monomorphic, not readily fragmenting when dry, the branch tips appearing more or less curled when dry, prostrate, usually forming small loose low mats. RHIZOPHORES produced throughout. LEAVES relatively strongly dimorphic, the tip sharply pointed, with a stiff straight white glabrous seta 0.1–0.3 mm long (these sometimes breaking off with age), the margins ciliate; those of the adaxial stem side 1.9–2.3 mm long, narrowly lanceolate, green to yellowish green when hydrated, the base abruptly adnate (differing in color from the stem); those of the abaxial stem surface 2.0–2.5 mm long, lanceolate to narrowly lanceolate, persistently gray to brown, the base decurrent (similar in color to the stem). STROBILI 4–10 mm long, the sporophylls ovate-deltate, narrowed to an acute tip lacking a seta, the margins denticulate to short-ciliate. MEGASPORES finely and often faintly rugose-reticulate, orange or yellow. —Rock ledges, cliffs, and open gravelly to rocky areas, usually on igneous or volcanic substrates or on sandstone: Gila, Graham, Maricopa, Pima, Pinal, Yavapai cos. (Fig. 1A); 600–1700 m (2000–5600 ft); AZ, TX; nw Mex.

The taxonomy of *S. arizonica* is still not fully understood. In the desert mountains of western Pima County uncommon apparent hybrids occur between *S. arizonica* and the closely related *S. eremophila*. Some of these putative hybrids are sterile with abortive spores, but other plants intermediate for one or more morphological traits produce apparently well-formed spores that are slightly larger than those of either of the parents. These may represent an allopolyploid that should be recognized taxonomically. Where *S. arizonica* co-occurs with the morphologically distinctive *S. rupicola*, occasional putative hybrids also are encountered with intermediate morphology and abortive spores.

**Selaginella densa** Rydb. (dense). Rocky Mountain Spikemoss. —STEMS monomorphic, not readily fragmenting when dry, the branch tips appearing straight when dry, prostrate, forming small, low, loose or dense cushion-like mats. RHIZOPHORES produced throughout. LEAVES slightly dimorphic, 2.5–5.0 mm long, (adaxial leaves sometimes slightly shorter than the abaxial leaves), linear to narrowly lanceolate, green to dark green when hydrated (adaxial leaves often persistently tan to brownish-tinged), the base decurrent (similar in color to the stem) and somewhat oblique, the tip with a straight or somewhat curved white seta 0.4–1.9 mm long (often breaking off with age), the margins ciliate. STROBILI 1–3 mm long, the sporophylls broadly lanceolate to ovate, narrowed to an acute tip with or without a seta, the margins entirely ciliate or denticulate distally. MEGASPORES usually relatively coarsely rugose-reticulate, orange. —3 vars.; w U.S. e to ND and TX, AK; Can.

1. Leaf margins relatively long-ciliate, the terminal seta 1.2–1.9 mm long, moderately puberulent; sporophyll margins ciliate ..... var. *densa*  
 1' Leaf margins relatively short-ciliate, the terminal seta 0.4–1.2 mm long, glabrous, sparsely denticulate, or sparsely puberulent; sporophyll margins ciliate proximally grading to denticulate distally ..... var. *scopulorum*

Var. **densa** (dense; Fig. 4). —LEAVES 2.5–5.0 mm long, the margins relatively long-ciliate, the cilia 0.07–0.20 mm long, the tip with a seta 1.2–1.9 mm long, this moderately puberulent. SPOROPHYLLS with the margins ciliate their entire length, the tip usually with a well-differentiated seta. —Exposed rock ledges and rock outcrops in high mountains on volcanic substrates: Apache Co. (Fig. 1B); 2650–3500 m (8700–11,500 ft); ID to ND s to AZ and NM; Can.

Var. **scopulorum** (Maxon) R. M. Tryon (of the Rocky Mountains). —LEAVES 2.5–4.5 mm long, the margins relatively short-ciliate, cilia 0.02–0.07 mm long, the tip lacking a seta or with a seta 0.4–1.2 mm long, this glabrous, sparsely denticulate, or sparsely puberulent. SPOROPHYLLS with the margins ciliate proximally grading to denticulate distally, the tip lacking a seta or with a short poorly differentiated seta. [*S. scopulorum* Maxon]. —Exposed rock ledges and rock outcrops in high mountains on volcanic substrates: Apache Co. (Fig. 1B); 3250–3500 m (10,650–11,500 ft); WA to MN s to n CA, AZ, and NM; w Can.

Some botanists consider this taxon to represent a separate species. However, Tryon (1955) indicated that some plants at the summit of Mt. Baldy, are somewhat intermediate in morphology with var. *densa*. The situation requires more detailed biosystematic study.

**Selaginella eremophila** Maxon (desert-loving). Desert Spikemoss. —STEMS monomorphic, not readily fragmenting when dry, the branch tips appearing curled when dry, prostrate, usually forming small loose low mats. RHIZOPHORES produced throughout. LEAVES relatively strongly dimorphic, the tip sharply pointed (Fig. 3), with a delicate contorted white seta 0.3–0.4 mm long (this often breaking off with age), the margins ciliate; adaxial stem leaves 1.3–1.5 mm long, lanceolate, green to yellowish green when hydrated, the base abruptly adnate (differing in color from the stem); abaxial stem leaves 2.0–2.7 mm long, lanceolate to elliptic-lanceolate, persistently gray to brown, the base decurrent (similar in color to the stem). STROBILI 3–8 mm long, the sporophylls ovate-deltate, narrowed to an acute tip lacking a seta, the margins short-ciliate. MEGASPORES with the surface, finely rugose-reticulate, light yellow. —Rock ledges, cliffs, and open gravelly to rocky areas, usually on igneous or volcanic substrates: Maricopa, Pima, Yuma cos. (Fig. 1C); 150–800 m (500–2600 ft); endemic to the Sonoran Desert region of s CA, s AZ, nw Mex.

The distribution of *S. eremophila* in Arizona is somewhat broader than was known to Tryon (1955) and Morton (1960), who knew the species in the state only from Yuma County. The easily abscised setae make some specimens difficult to distinguish from the closely related *S. arizonica*. See the treatment of that species for a discussion of possible hybridization between it and *S. eremophila*.

**Selaginella leucobryoides** Maxon (like *Leucobryum*, a moss genus). Mohave Spikemoss. —STEMS monomorphic or slightly dimorphic, the main stem prostrate, with short ascending branches, readily fragmenting when dry, the branch tips appearing straight when dry, forming small, low, dense cushion-like mats. RHIZOPHORES produced throughout. LEAVES monomorphic, 2.0–4.5 mm long, linear to narrowly oblong-lanceolate, green to dark green when hydrated, the base decurrent (similar in color to the stem) and more or less symmetrically narrowed, the tip narrowly pointed, sometimes with a straight or somewhat curved white seta 0.2–0.5 mm long (often breaking off with age), this denticulate, the margins relatively short-ciliate, sometimes grading to denticulate distally. STROBILI 4–15 mm long, the sporophylls broadly lanceolate to ovate-deltate, narrowed to an acute tip with a short seta, the margins denticulate, sometimes short-ciliate proximally. MEGASPORES smooth to finely rugose-reticulate, orange. —Rock outcrops, ledges, and cliffs, on limestone: Coconino, Mohave cos. (Fig. 1D); 600–1300 m (2000–4300 ft); nw AZ and adjacent s NV and e CA.

**Selaginella mutica** D. C. Eaton ex Underw. (blunt). —STEMS monomorphic, the main stem prostrate, with prostrate to loosely ascending branches, not readily fragmenting when dry, the branch tips appearing straight when dry, forming loose mats. RHIZOPHORES produced throughout. LEAVES monomorphic, 1–2 mm long, narrowly lanceolate to narrowly elliptic-lanceolate, green to dark green when hydrated, the base adnate (differing in color from the stem) and more or less symmetrically rounded or narrowed, the tip bluntly or sharply pointed, with or without a seta, the margins short- to long-ciliate, sometimes mostly denticulate. STROBILI 6–25 mm long, the sporophylls narrowly ovate to elliptic-ovate or ovate-deltate, narrowed to a blunt or sharply pointed tip with or without a short seta, the margins denticulate to ciliate. MEGASPORES finely to relatively coarsely rugose-reticulate, orange. —2 vars.; WY s to AZ and TX.

1. Leaves and sporophylls with the margins denticulate to irregularly short-ciliate, the teeth or hairs ascending; leaf tip with a well-defined, short seta 0.2–0.5 mm long ..... var. *limitanea*
- 1'. Leaves and sporophylls with the margins usually relatively long-ciliate, the hairs spreading; leaf tip without a seta or with a minute, poorly differentiated seta to 0.06 mm long ..... var. *mutica*

Var. **limitanea** Weath. (bordered). —LEAVES with the margins denticulate to irregularly short-ciliate, the teeth or hairs ascending, the tip sharply pointed, with a well developed seta, this 0.2–0.5 mm long, straight or somewhat curved, white or milky white. SPOROPHYLLS with the margins denticulate to irregularly short-ciliate, the teeth or hairs ascending. —Rock ledges and cliffs: Cochise co. (Fig. 1E; known from a single historical collection: *Ferris s.n.*, *Paradise, AZ, March 1904*, GH); ca. 1700 m (5600 ft); se AZ to sw TX.

Var. **mutica** (blunt). —LEAVES with the margins usually relatively long-ciliate, the hairs spreading, the tip bluntly or sharply pointed, with a minute poorly

differentiated seta, this 0.03–0.06 mm long, straight, yellowish green. SPOROPHYLLS with the margins usually relatively long-ciliate (rarely denticulate elsewhere), the hairs spreading.  $2n = 18$ . —Rock outcrops, ledges, boulders, and cliffs, on various substrates: Cochise and disjunctly Apache, Coconino, Navajo cos. (Fig. 1E); ca. 1400–2600 m (4600–8500 ft); WY to AZ and sw TX.

**Selaginella rupincola** Underw. (rock-loving; Fig. 5). —STEMS dimorphic, not readily fragmenting when dry, the branch tips appearing straight when dry, forming loose low clumps, differentiated into a rhizomatous, prostrate, main stem system with elongated procumbent or more commonly ascending to erect main branches, some of the basal branches of the aerial stems (and rhizomes) remaining bud-like and not elongating. RHIZOPHORES of the aerial stems produced only below the midpoint. LEAVES dimorphic, those of the rhizomes 1.5–2.5 mm long, ovate to narrowly ovate, persistently gray to tan, the midvein slightly ridged, the base more or less adnate (not strongly different in color to the stem), the tip sharply pointed, without a seta, the margins denticulate to nearly entire; aerial stem leaves 3.0–4.7 mm long, narrowly elliptic-lanceolate to linear-lanceolate, light grayish green, the minutely puberulent base adnate (different in color from the stem) and rounded, the tip sharply pointed, with a white to pale yellow seta 0.7–1.8 mm long, this often bent outward, denticulate, the margins relatively long-ciliate, the cilia spreading. STROBILI 5–30 mm long, the sporophylls lanceolate, tapered to an acute tip, with a well-developed seta, the margins short-ciliate. MEGASPORES finely rugose to rugose-reticulate, orange. —Rock ledges, cliffs, and open gravelly to rocky areas, usually on igneous or volcanic substrates or on sandstone: Cochise, Gila, Pima, Pinal, Santa Cruz cos. (Fig. 1F); 900–1850 m (3000–6000 ft); s AZ to s TX; Mex.

For a discussion of possible hybridization with *S. arizonica*, see the treatment of that species. Tryon (1955) discussed the sporadic distribution in southern Arizona, New Mexico, and Texas of the rare *S. ×neomexicana* Maxon, which he thought to represent a sterile hybrid between *S. rupincola* and *S. mutica*, citing a single historical Arizona collection (*Ferris s.n., March 1904*, GH, US) from near Paradise (Cochise County). Aside from its abortive spores, this taxon closely resembles *S. rupincola*, but has leaves with shorter setae and the margins denticulate distally and with short ascending ciliation proximally. Valdespino (1993) suggested that more detailed biosystematic research is necessary to confirm the parentage of this putative hybrid. The report of *S. ×neomexicana* from Graham County by Buegge (2001) was based upon a misdetermined specimen of *S. rupincola*.

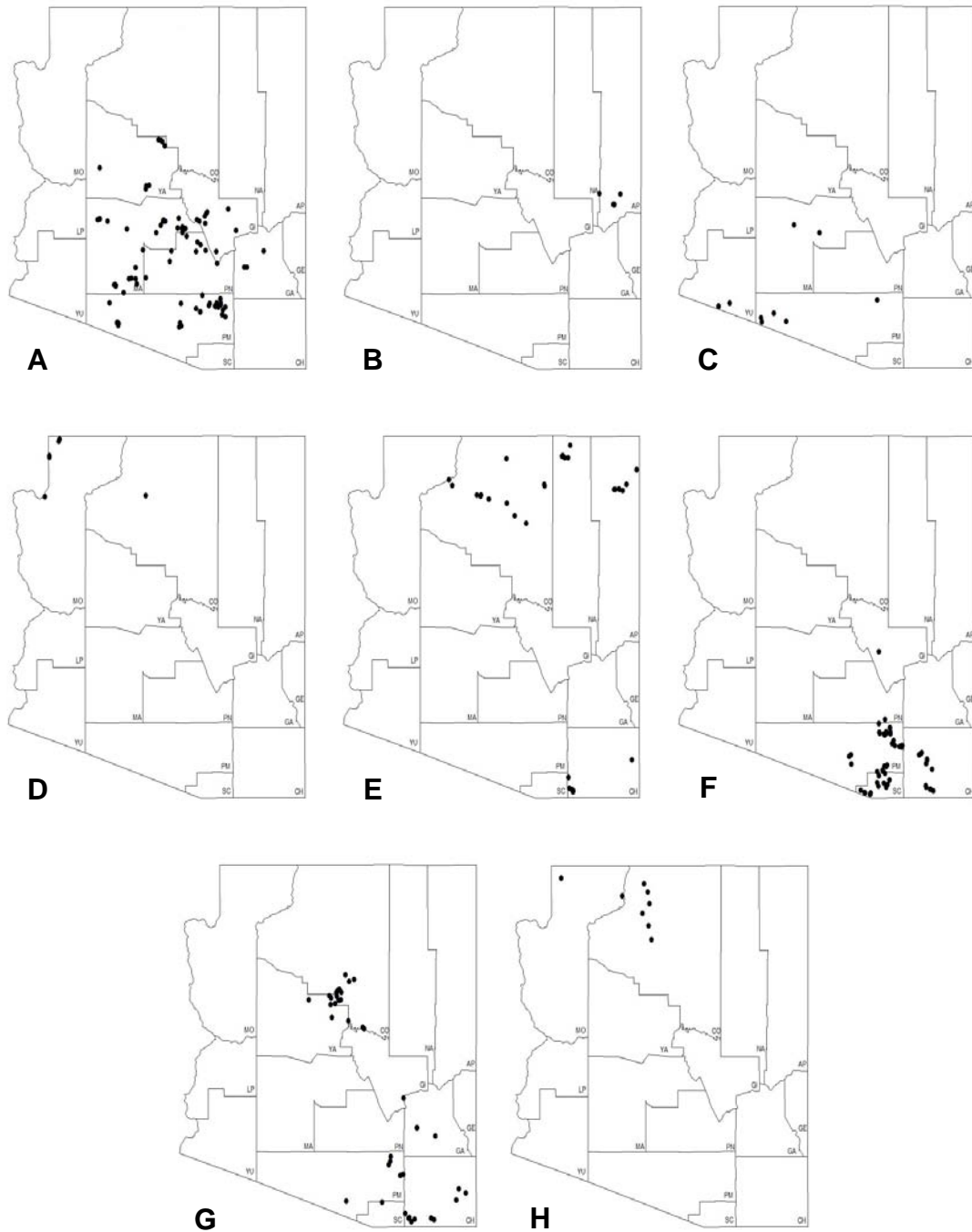
**Selaginella underwoodii** Hieron. (for Lucius M. Underwood, American botanist). Underwood's Spikemoss. —STEMS monomorphic, prostrate to loosely ascending, occasionally pendant, not readily fragmenting when dry, the branch tips appearing straight when dry, forming usually loose mats. RHIZOPHORES produced throughout. LEAVES monomorphic, 2.0–3.5 mm long, linear to narrowly triangular-lanceolate, green to dark green when hydrated, the base more or less decurrent (similar in color to the stem) and more or less symmetrically narrowed, the tip with a straight or somewhat curved yellowish green seta 0.2–0.8(–1.2) mm long

(sometimes breaking off with age), the margins short-ciliate, sometimes grading to denticulate distally. STROBILI 5–30 mm long, the sporophylls lanceolate to broadly lanceolate with a strongly auriculate base, narrowed to an acute tip with a short seta, the margins denticulate, sometimes grading to short-ciliate proximally. MEGASPORES finely rugose-reticulate, orange. [*S. underwoodii* var. *dolichotricha* Weath.]. —Rock outcrops, ledges, boulders, and cliffs, on various substrates: Cochise, Coconino, Gila, Graham, Pima, Santa Cruz, Yavapai cos. (Fig. 1G); 1500–2450 m (5000–8000 ft); UT and s CO s to AZ and TX; n Mex.

***Selaginella watsonii*** Underw. (for Sereno Watson, American botanist). Watson's Spikemoss. —STEMS monomorphic, prostrate, not readily fragmenting when dry, the branch tips appearing straight when dry, forming dense usually cushion-like mats. RHIZOPHORES produced throughout. LEAVES monomorphic, 2.5–4.0 mm long, narrowly lanceolate, green to yellowish green when hydrated, the base more or less decurrent (similar in color to the stem) and more or less symmetrically narrowed, the tip with a straight or somewhat curved white seta 0.2–0.5 mm long (sometimes breaking off with age), the margins entire, denticulate, or short-ciliate. STROBILI 5–30 mm long, the sporophylls lanceolate to broadly lanceolate, narrowed to an acute tip with a short seta, the margins entire or denticulate. MEGASPORES finely rugose to rugose-reticulate, orange. —Rock outcrops, ledges, boulders, cliffs, and rarely on open gravelly slopes, on igneous and volcanic substrates and sandstone: Coconino, Mohave cos. (Fig. 1H); 2400–2550 m (7850–8400 ft); e WA s to e CA, e to MT and AZ.

#### LITERATURE CITED

- BUEGGE, J.J. 2001. Flora of the Santa Teresa Mountains in Graham County, Arizona. *Journal of the Arizona-Nevada Academy of Science* 33: 132–149.
- KORALL, P. and P. KENRICK. 2002. Phylogenetic relationships in *Selaginellaceae* based on rbcL sequences. *American Journal of Botany* 89: 506–517.
- MORTON, C.V. 1960. *Pteridophyta*. Pp 27–49. In: T.H. Kearney, R.H. Peebles and collaborators (eds.). *Arizona Flora*. 2<sup>nd</sup> edn. University of California Press, Berkeley.
- THERRIEN, J.P. 2003. *Phylogeny of Selaginella subgenus Tetragonostachys based on nuclear and chloroplast DNA sequence data*. Ph.D. dissertation, University of Kansas, Lawrence.
- TRYON, R.M. 1955. *Selaginella rupestris* and its allies. *Annals of the Missouri Botanical Garden* 42: 1–99.
- VALDESPINO, I.A. 1993. *Selaginellaceae*. Pp. 38–63. In: Flora of North America Editorial Committee (eds.). *Flora of North America North of Mexico*. Vol. 2. Oxford University Press, New York.



**Selaginellaceae** Figure 1. Distributions of: (A) *Selaginella arizonica*; (B) *Selaginella densa*; (C) *Selaginella eremophila*; (D) *Selaginella leucobryoides*; (E) *Selaginella mutica*; (F) *Selaginella rupincola*; (G) *Selaginella underwoodii*; (H) *Selaginella watsonii*.





**Selaginellaceae** Figure 2. *Selaginella arizonica*, habit.



**Selaginellaceae** Figure 3. *Selaginella eremophila*, close-up.



**Selaginellaceae** Figure 4. *Selaginella densa* var. *densa*, habit.



**Selaginellaceae** Figure 5. *Selaginella rupicola*, habit.