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CYTOGEOGRAPHY OF *SOLIDAGO JULIAE*, *S. LEAVENWORTHII*, AND *S. TORTIFOLIA* (ASTERACEAE: ASTEREAE)

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ABSTRACT

The cytogeographies of *Solidago juliae*, *S. leavenworthii*, and *S. tortifolia* are mapped with new chromosome counts for *S. juliae* and *S. leavenworthii* and a list of all previously published chromosome counts for the three species. All reports for *S. tortifolia* were diploid 2*n*=18. *Solidago juliae* includes mostly diploids 2*n*=18 and one tetraploid 2*n*=36. *Solidago leavenworthii* includes tetraploids 2*n*=36 in the northern portion of its range and hexaploids 2*n*=54 in southern Florida.

As delimited by Semple and Beck (2021) *Solidago* ser. *Tortifoliae* Semple & Beck of sect. *Unilaterales* G. Don subsect. *Triplinerviae* (Torr. & Gray) Nesom includes eight species: *S. durangensis* Nesom, *S. gypsophila* Nesom, *S. juliae* Nesom (Figs. 1-2), *S. leavenworthii* Torr. & Gray (Figs. 3-5), S. *pringlei* Fernald, *S. macvaughii* Nesom, S. *tortifolia* Ell. (Figs. 6-7), and *S. veracruzensis* Semple. *Solidago tortifolia* was the first described species (Elliott 1823) in ser. *Tortifoliae*, followed by *S. leavenworthii* (Torrey & Gray 1842). Nearly 150 years later G.L. Nesom described *S. gypsophila* (Nesom 1989a), *S. macvaughii* (Nesom 1989b), *S. juliae* (Nesom 1989c), and *S. durangensis* (Nesom 1991). Most recently, Semple (2018) in the protologue of *S. veracruzensis* included a map of the narrow distributions of the five Mexican endemics in ser. *Tortifoliae*.

Opinions on relationships of the eight species of *Solidago ser. Tortifoliae* have varied over time. Torrey & Gray (1842) placed *S. tortifolia* after *S. odora* in their flora, as did Gray (1884). Nesom (1993) placed *S. tortifolia* in subsect. *Junceae,* which also included *S. pringlei*. Semple and Beck (2021) placed *S. odora* in *S.* subg. *Triactis* Raf. and *S. tortifolia* in *S.* subg. *Pleiactila* Raf. Torrey and Gray (1842) placed *S. leavenworthii* near *S. canadensis* in their unranked group *Triplinerviae*. Nesom (1993) placed *S. leavenworthii* in subsect. *Triplinerviae* as did Semple and Beck (2021). Nesom (1989a) considered *S. gypsophila* to be similar to *S. canadensis* L. var. *canescens* A. Gray, which he subsequently treated as a synonym of *S. juliae* (Nesom 1989c). Nesom (1989b) hypothesized that *S. macvaughii* was closely related to *S. velutina* DC., but Semple and Beck (2021) placed *S. velutina* in subsect. *Radulae* (Rydb.) Semple & Beck, based at the time on the unpublished results of the polygenomic phylogeny for the genus (Semple et al. 2023 in press). Semple (2018) placed *S. macvaughii* in subsect. *Triplinerviae*. Nesom (1991) hypothesized that *S. durangensis* was closely related to *S. paniculata* DC. Much later, Semple and Beck (2021) placed *S. paniculata* in sect. *Maritimae* (Torr. & Gray) Semple & Beck. Lopez Laphitz and Semple (2015), Semple and Lopez Laphitz (2016), and Semple et al. (2016) included multiple species of ser. *Tortifoliae* in multivariate morphometric comparisons with species placed in subsect. *Junceae*, sect. *Maritimae*, subsect. *Serotinae*, and subsect. *Triplinervae* by Semple and Beck (2021).

Such statistical comparisons indicated which species were most and least similar in the different analyses based on the characters selected in the analyses, but these all predate the polygenomic phylogeny of the genus (Semple et al. 2023 in press), which did not sample most species in ser. *Tortifoliae*. Semple and Beck (2021) placed all species in the genus into the infrageneric classification, but some of the placements were based on morphology because some species were not included in the polygenomic study either because they were known polyploids or because the ploidy level was not known. Until further DNA research includes the five Mexican endemics, their placement in ser. *Tortifoliae* should be considered tentative, although this author believes the placement is correct. One or more of these five Mexican species might be more closely related to *Solidago chilensis* and thus belong in ser. *Serotinae.*

Figure 1. *Solidago juliae*, shoot, *Nesom & Nesom 7211* WAT, Gillespie Co., Texas.

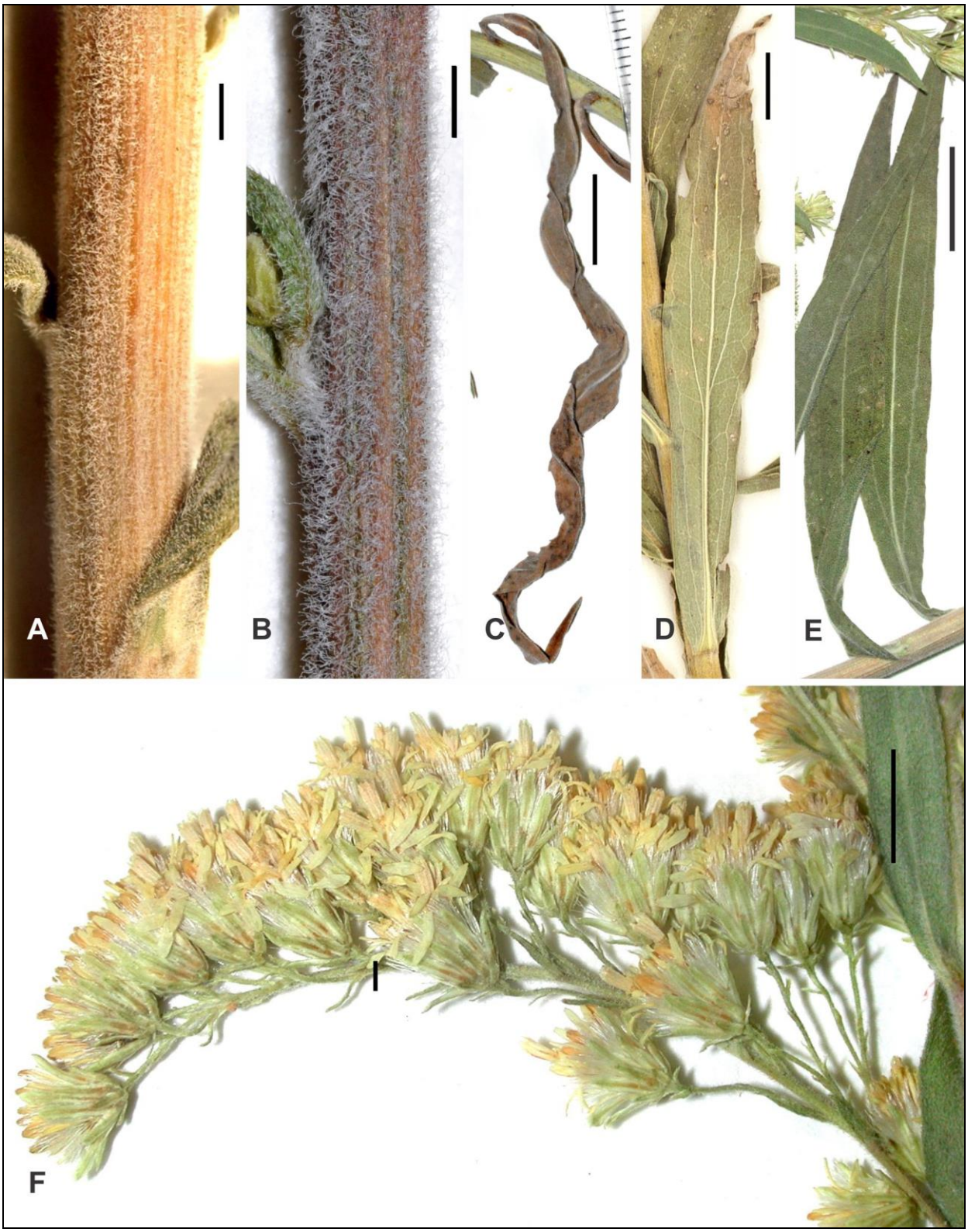

Figure 2. Details of the morphology of *Solidago juliae*. **A.** Mid stem, *Nesom 7212* (WAT, isotype). **B.** Stem in inflorescence, *Nesom 7211* (WAT). **C.** Dried, twisted lower stem leaf, *Nesom 7524* (WAT). **D.** Upper lower mid stem leaf, *Correll 24736* (LL). **E.** Lower mid stem leaf, *Nesom 7212* (WAT). **F.** Lower inflorescence branch, *Nesom 7212* (WAT). Scale bar = 1 mm in A-B, F; = 1 cm in C-E.

Figure 3. *Solidago leavenworthii* shoot, *Semple 11703* WAT, Taylor Co., Florida.

Figure 4. *Solidago leavenworthii* shoots with narrower inflorescences and a lower stem ball gall, *Semple 11704* WAT, Taylor Co., Florida.

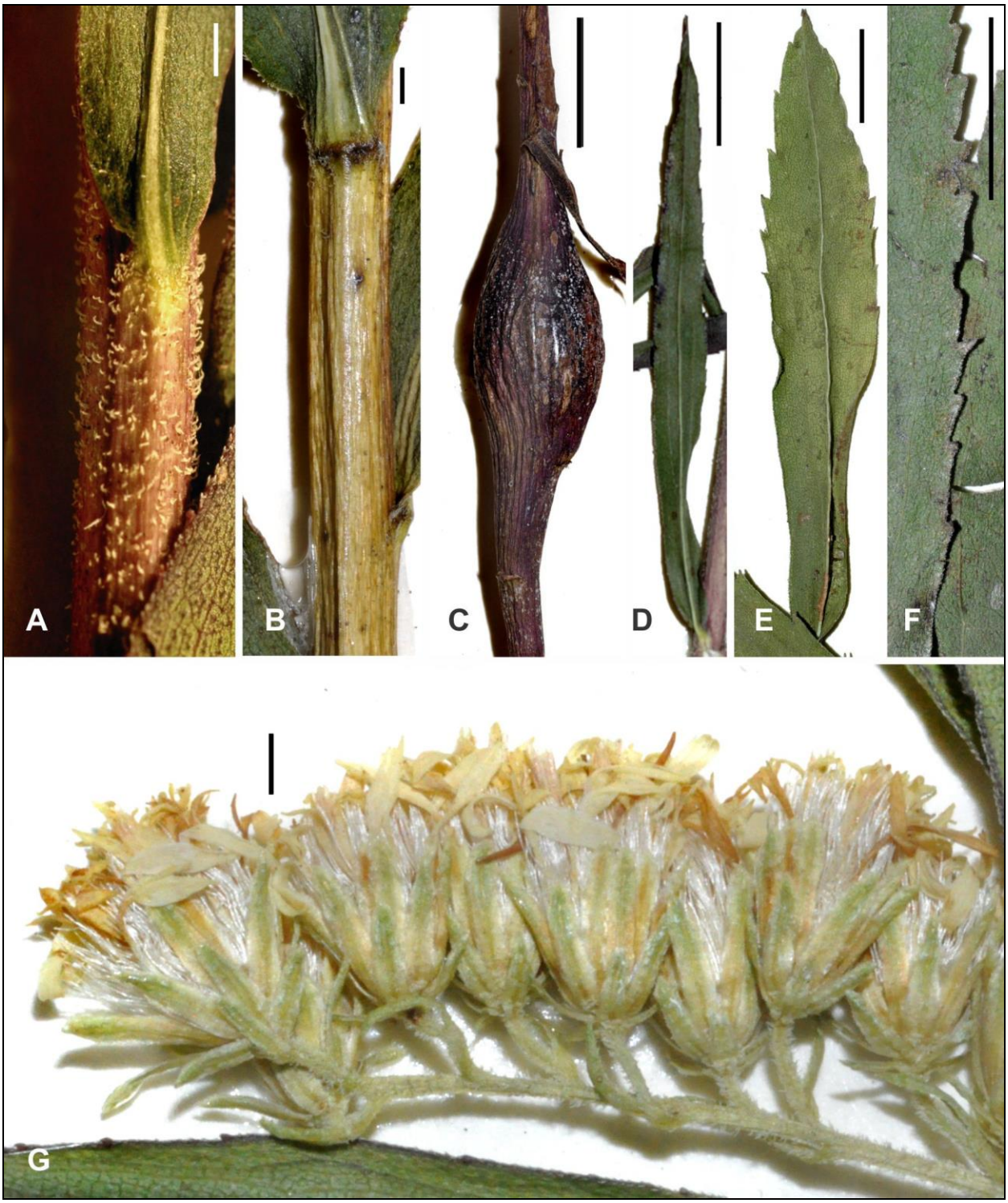

Figure 5. Details of the morphology of *Solidago leavenworthii*. **A-B.** Lower and upper stems, *Semple 11703* (WAT). **C.** Lower stem ball gall, *Semple 11704* (WAT). **D.** Upper stem, *Semple 11733* (WAT), hexaploid. **E.** Mid stem leaf, *Semple 11703* (WAT). **F.** Mid stem leaf margin, abaxial surface, *Semple 11704* (WAT). **G.** Heads, *Semple 11704* (WAT). Scale bar = 1 mm in A-B, G; = 1 cm in C-F.

Figure 6. *Solidago tortifolia* shoot, *Weber 0S0110* USF, Sarasota Co., Florida.

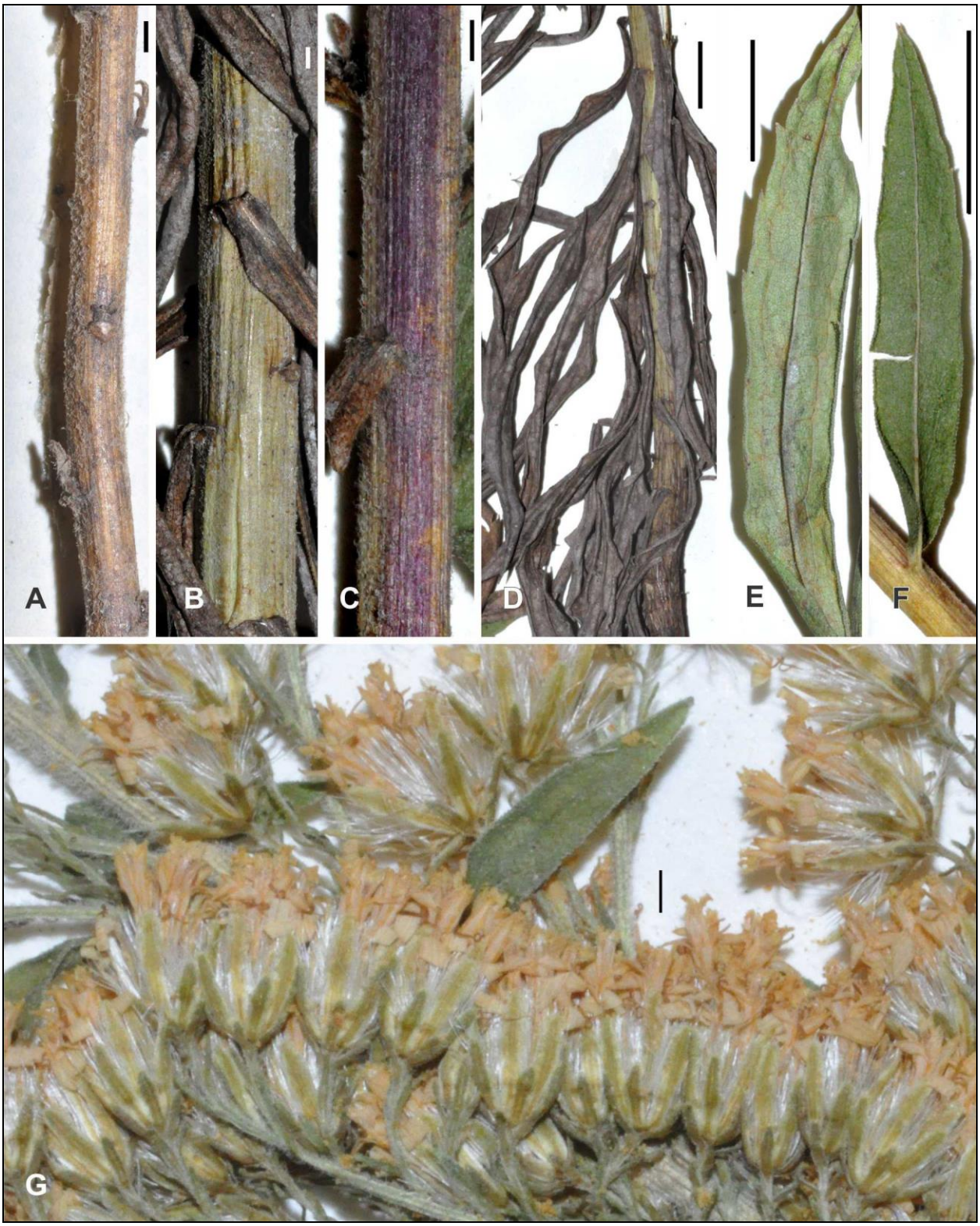

Figure 7. Morphology of *Solidago tortifolia*. **A**. Lower stem, *Elliott s.n.* (K, holotype). **B-C.** Lower and upper stems, *Semple 7534* (WAT). **D.** Lower stem leaves, dried twisted, pendant, *Semple 7534* (WAT). **E-F.** Lower mid stem and upper stem leaves, *Semple 7543* (WAT). **G.** Heads, *Morton & Venn NA16515* cult. (TRT). Scale bar = 1 mm in A-C and G; = 1 cm in D-F.

Previously published chromosome counts for *Solidago juliae* (5 counts: 2*n*=9_{II}, 2*n*=18, 2*n*=36), *S. leavenworthii* (14 counts: 2*n*=36, 2*n*=54), *S.* aff. *pringlei* (1 count: 2*n*=9_{II}), and *S. tortifolia* (16 counts: 2*n*=9II, 2*n*=18) are presented in Table 1 with details on the counts, cytovouchers, and geographic locations. No chromosome counts have been reported for the other four species in the series, which are native to Mexico.

Table 1. Previously published chromosome counts for *Solidago juliae*, *S. leavenworthii*, and *S. tortifolia*.

Solidago juliae Nesom 2*n*= 9II **U.S.A.** Texas: Brewster Co., Alpine, *Weedin 909* SRSC (Weedin & Powell 1980); Gillespie Co., NE of Leakey, *Nesom & Nesom 7211* BRIT (Nesom 1989c); Kerr Co., between Ingram and Kerrville, *Nesom & Nesom 7212* BRIT (Nesom 1989c); Kinney Co., Pinto Creek, Turner 16012 TEX (Turner and Zhao 1992); Real Co., NE of Leakey *Nesom & Nesom 7213* BRIT (Nesom 1989c). **U.S.A.** Texas: Kerr Co., Kerrville, *Morton & J. Venn NA16365* (TRT (Morton et al. 2018).

Solidago leavenworthii Torr. & Gray 2*n* = 36 **U.S.A. Florida**: Gadsden Co., *Beaudry & Godfrey* 57-504, 57-505, 576-507 MT! (Beaudry 1963); Indian River Co., *Semple et al. 7524* WAT (Semple et al. 1984 as *S. petiolaris*; corrected in Semple and Cook 2004); Taylor Co., *Semple et al. 7443* WAT (Semple et al. 1984, SOLCNTS-2, as *S. petiolaris*; corrected in Semple et al. 2015), *Semple 10918* WAT (Semple et al. 2015). **South Carolina**: Barnwell Co., *Semple & Suripto 9807* WAT (Semple et al. 1993); Charleston Co., *Horlbeck 57-467, 57-477, 57-583* MT (Beaudry 1963), Dorchester Co., *Beaudry 57- 497* MT (Beaudry 1963). 2*n* = 54 **U.S.A. Florida**: Dade, *Semple et al. 5392* WAT (Semple et al. 1984), *Morton & Venn NA16526* TRT (Morton et al. 2018).

Solidago aff. *pringlei* Fernald 2*n*=9_{II} MEXICO. Nuevo Leon: S of Montemorelos, NMC! (Ward and Spellenberg 1986 as *S. canadensis* ssp. *salebrosa* corrected in Semple and Chmielewski (2022).

Solidago tortifolia Ell. 2*n*=9_{II} U.S.A. **Florida**: Volusia Co., Merritt Is., *Semple, Wunderlin, Poppleton & Norman 2535* WAT (Semple et al. 1981). Georgia: Brooks Co., SE of Quitman, *Semple & B. Semple 11833* WAT (Semple et al. 2019). 2*n*=18 U.S.A. **Florida**: Holmes Co., Ponce de Leon, *Semple & Godfrey 3175* WAT (Semple et al. 1981); Jefferson Co., N of Ashville, *Semple et al. 7422* WAT (Semple et al. 1984); Marion Co., NW of Ocala, *Semple 10911* WAT (Semple and Cook 2004). Georgia.: Screven Co., N of Sylvania, *Semple & Chmielewski 6136* WAT (Semple et al. 1984). **Louisiana**: Sabine Par., N of Many, *Semple & Suripto 10040* WAT (Semple et al. 1993). **Mississippi**: Harrison Co., I-10, c. 26 mi E of LA/MS border, *Morton & J. Venn NA16458* TRT (Morton et al. 2018). **South Carolina**: Berkeley Co., E of St. Stephen, *Semple & Suripto 9789* WAT (Semple et al. 1993); Beaufort Co., Beaufort, *Horlbeck 57-700-1* MT (Beaudry 1963); Charleston Co., Charleston, *Beaudry & Barrington 57-488* MT (Beaudry 1963), *Beaudry & Barrington 57-489, 57-490, 57-487, 57-486* MT; (not published ??). 2*n*=18+1 supernumerary. U.S.A. **Florida:** Brevard Co., N of Shiloh, *Semple & B. Semple 7534* WAT (Semple et al. 1984).

RESULTS AND DISCUSSION

Additional chromosome counts were determined from one or two individuals from 1 location for *Solidago juliae* and 16 locations for *S. leavenworthii* (Table 2.). In total, 8 locations have been sampled across the range of *S. juliae*, with all but one being diploid (Fig. 8, dots) and one being tetraploid (Fig. 8 white square with black outline). In total, 20 locations have been sampled across the range of *S. leavenworthii*. All 15 samples of *S. leavenworthii* from South Carolina, Georgia, and Florida south to Lake Okeechobee Co. were tetraploids 2*n*=36 (Fig. 9, open squares). Six hexaploid 2*n*=54 samples were found only in southern Florida from east of Lake Okeechobee in Martin Co. to southern Dade Co. (Fig. 9, black squares). Although the sample size is small, the pattern is clear and the two cytotypes are allopatric in *S. leavenworthii.* In total, 12 locations were sampled across the range of *S. tortifolia* and all were diploid 2*n*=18 (Fig 10, dots).

Table 2. Previously unpublished chromosome number determinations in *Solidago juliae* and *S. leavenworthii* (vouchers in WAT unless otherwise indicated).

Solidago juliae Nesom

2*n*=18 U.S.A. Texas: Kendall Co., Ranger Creek at exit 538, I-10, Boerne, *Morton & Venn NA16370* TRT (count by J.K. Morton).

Solidago leavenworthii Torr. & Gray

2*n*=36 U.S.A. Florida: Alachua Co., S of Gainesville, Payne's Prairie St. Preserve, along entrance rd, *Semple 11747*, *Semple 11748*, N end of prairie, fields behind Gainesville Police Mounted Unit paddocks and FL D.O.E. District HQ, *Heard 2003-118* (ISC); S end of the park, near visitor centre, W of Cone's Dike Trail and E of observation tower, *Heard 2003-103* (ISC). Ockeechobee Co., FL-28, ridge by Triple S Ranch, *Semple 11739*. Taylor Co., N of Steinhatchee, FL-361 S of Howell Place, *Semple 11702*, *11703*; FL-361 0.2 km S of Salem Tower Rd, *Semple 11704*; SW of Salem, Fish Creek Rd 5.6 km W of US-98, *Semple 11699*. Lake Co., Co.Rd-561 between Co.Rd.-455 and Astatula, *J.K. Morton & J. Venn NA16539* (TRT). Pasco Co.:, US-98 ca. 7 mi N of Dade City, old field, *Morton & Venn NA16510* (TRT, count by J.K. Morton). Georgia.: Long Co., US-301/25/82 at Altamaha River, *Morton & Venn NA16543* (TRT).

2*n*=54 **U.S.A.** Florida: Hendry Co., LaBelle, FL-80A just E of FL-29, *Semple 11724*. Martin Co., Co.Rd-609 2.5 km N of FL-214, *Semple 11733*. Palm Beach Co., Loxahatchee, US-441/98 & FL-88 just E of Binks Forest Dr., *Semple 11726*. St. Lucie Co., NE of Cana, CoRd-709 ca 1 km NE of CoRd-609, *Semple 11*735.

A single diploid count of $2n=9_{II}$ was reported for *Solidago leavenworthii* from Oseola Co., Florida, by Semple (1985) and is rejected here. The voucher collection was found to include samples of *S. leavenworthii* (*Semple 5356* WAT) and *S. fistulosa* Mill. (renumbered as *Semple 5421* WAT), and it was determined that there was no way to be certain which shoot was the source of the meiotic material. However, it seems likely that the diploid count was for the *S. fistulosa* individual because all other counts for that species are also diploid (Beaudry 1963; Semple et al. 1993; Semple et al. 1984; Semple 1985; Semple & Cook 2004; Semple et al. 2015; Morton et al. 2018; Semple et al. 2019; Semple unpublished data), while no other diploid counts have been reported for *S. leavenworthii*.

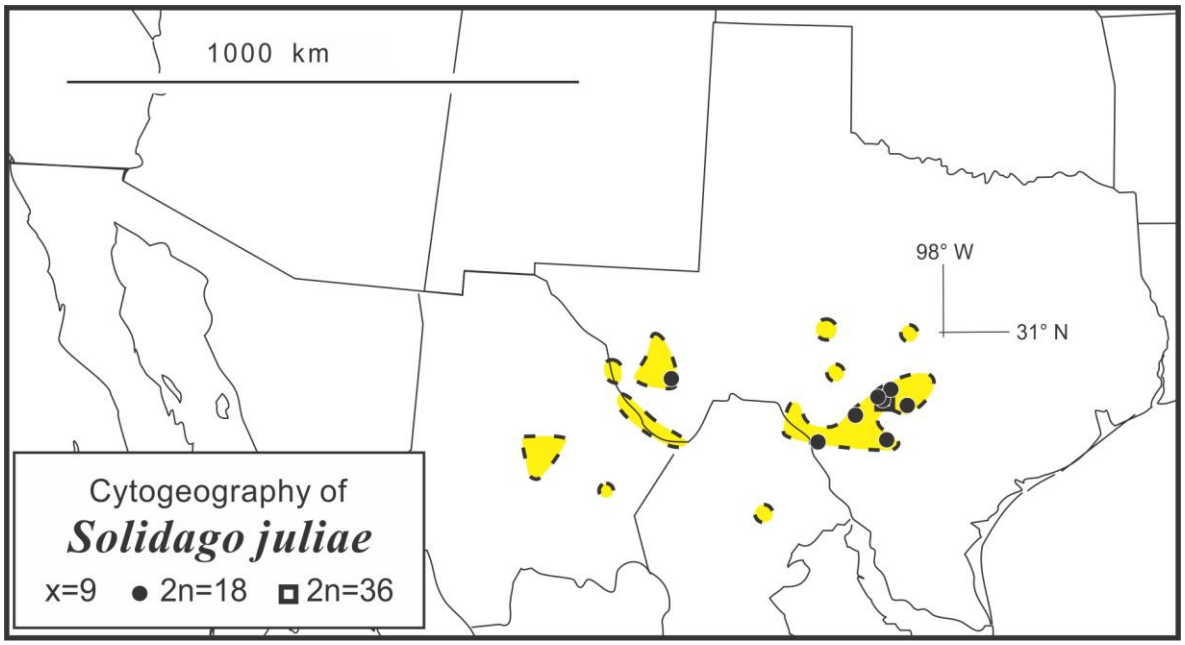

Figure 8. Cytogeography of *Solidago juliae*; range based on all collections seen and literature.

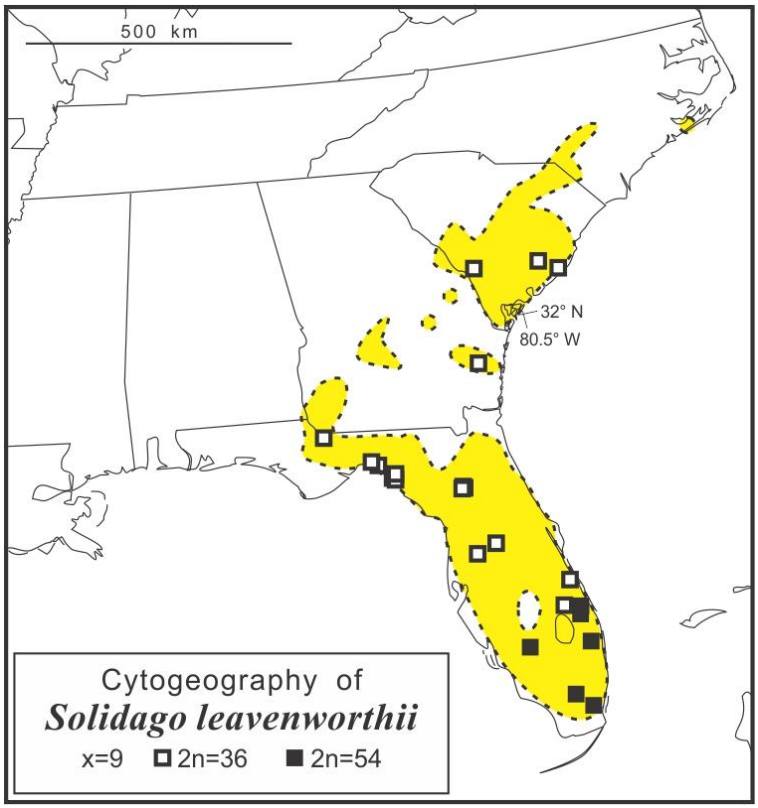

Figure 9. Cytogeography of *Solidago leavenworthii*; range based on all collections seen and literature.

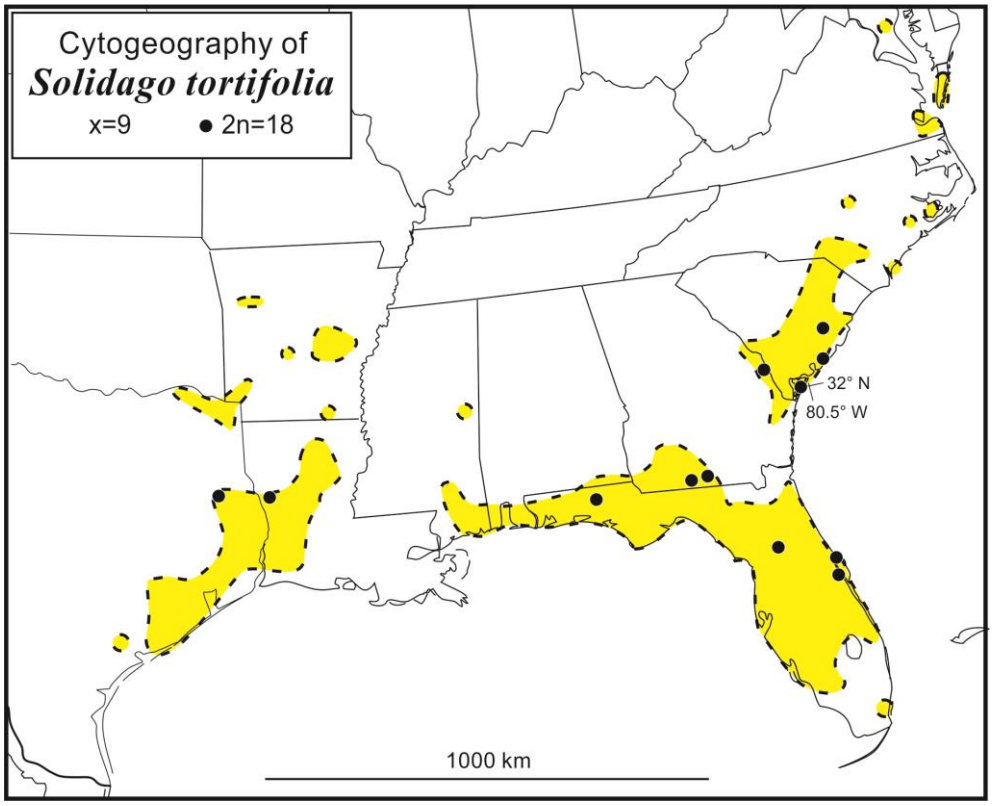

Figure 10. Cytogeography of *Solidago tortifolia*; range based on all collections seen and literature.

LITERATURE CITED

Beaudry, J.R. 1963. Studies on *Solidago* L. VI. Additional chromosome numbers of taxa of the genus. Canad. J. Genet. Cytol. 5: 150–174.

Elliott, S. 1823. A sketch of the botany of South-Carolina and Georgia. Charleston, South Carolina.

Fernald, M.L. 1901. Some new spermatophytes from Mexico and Central America. Proc. Amer. Acad. 36: 491–506. [Contr. Gray Herb., n. ser. 21].

Lopez Laphitz, R. and J.C. Semple. 2015. A multivariate morphometric analysis of the *Solidago chilensis* complex in South America and related taxa in North America (Asteraceae: Astereae). Ann. Missouri Bot. Gard. 100: 423–441.

Morton, J.K, J. Venn and J.C. Semple. 2018. Chromosome number determinations in *Solidago* (Asteraceae: Astereae). Rhodora 119: 341–348.

Nesom, G.L. 1989a. New species of Mexican *Solidago* (Compositae: Astereae). Phytologia 67: 142–147.

Nesom, G.L. 1989b. Taxonomy of *Solidago velutina* (Asteraceae: Astereae) with a new related species from Mexico. Phylologia 67: 297–303.

Nesom, G.L. 1989c. The *Solidago canadensis* (Asteraceae: Astereae) complex in Texas with a new species from Texas and Mexico. Phytologia 67: 441–450.

Nesom, G.L. 1991. *Solidago durangensis* (Asteraceae: Astereae), a new species from Mexico. Phytologia 70: 58–59.

Nesom, G.L. 1993. Taxonomic infrastructure of *Solidago* and *Oligoneuron* (Asteraceae: Astereae) and observations on their phylogenetic position. Phytologia 75: 1–44.

Semple, J.C. 1985. Chromosome number determinations in Fam. Compositae tribe Astereae. Rhodora 87: 517–527.

Semple, J.C. 2018. On *Solidago macvaughii* (Asteraceae: Astereae), a rare Mexican endemic in the *Tortifoliae* groups of *S.* subsect. *Triplinervia*e. Phytoneuron 2018-35: 1–6.

Semple, J.C. and J.B. Beck. 2021. A revised infrageneric classification of *Solidago* (Asteraceae: Astereae). Phytoneuron 2021-10: 1–6.

Semple, J.C. and J.G. Chmielewski. 2022. Cytogeography of *Solidago* ser. *Canadenses* (Asteraceae: Astereae): *S. brendae*, *S. canadensis*, *S. elongata*, *S. fallax*, *S. lepida*, *S. rupestris*, *S. shortii*, and *S. turneri*. Phytoneuron 2022-57: 1–17.

Semple, J.C. and R.E. Cook. 2004. Chromosome number determinations in fam. Compositae, Tribe Astereae. VII. Mostly eastern North American and some Eurasian taxa. Rhodora 106: 253–272.

Semple, J.C. and R. Lopez Laphitz. 2016. On *Solidago gypsophila* and *S. pringlei* (Asteraceae: Astereae), rare and not so rare Mexican endemics: A multivariate study of the *Tortifolia* group of *S.* subsect. *Triplinervia*e. Phytoneuron 2016-29: 1–20.

Semple, J.C., J. Zhang and ChunSheng Xiang. 1993. Chromosome numbers in Fam. Compositae, Tribe Astereae. V. Eastern North American taxa. Rhodora 95: 234–253.

Semple, J.C., G.S. Ringius, C. Leeder, and G. Morton. 1984. Chromosome numbers of goldenrods, *Euthamia* and *Solidago* (Compositae: Astereae). II. Additional counts with comments on cytogeography. Brittonia 36: 280–292. Addendum — Brittonia 37: 121–121. 1985.

Semple, J.C., R.E. Cook, G.H. Morton, J.B. Beck, and R. Lopez Laphitz. 2019. Chromosome number determinations in Fam. Compositae, Tribe Astereae. IX. North American taxa. II. Rhodora 121: 37–53.

Semple, J.C., H. McMinn-Sauder, M. Stover, A. Lemmon, E. Lemmon, and J.B. Beck. 2023 in press. Goldenrod herbariomics: Hybrid-sequence capture reveals the phylogeny of *Solidago*. Amer. J. Bot. 110.

Torrey, J. and A. Gray. 1842. *Solidago* Pp. 195–231, Flora of North America. Vol. 2. Part 2. Wiley & Putnam, New York.

Turner, B.L. and Z. Zhao. 1992. In Documented chromosome number 1992:2. Miscellaneous U. S. A. and Mexican species, mostly Astereae. Sida 15: 147–150.

Ward, D.E. and R.W. Spellenberg. 1986. Chromosome counts of angiosperms of western North America. Phytologia 61: 119–125.

Weedin, J.F. and A.M. Powell. 1980. In Chromosome number reports LXIX. Taxon 30: 716–718.