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A MULTIVARIATE STUDY OF *SOLIDAGO* SECT. *ARGUTAE* (ASTERACEAE: ASTEREAE)

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ABSTRACT

Solidago sect. *Argutae* includes 11 species based on the results of a series of multivariate morphometric analyses performed to discover additional technical traits useful in separating species. *Solidago arguta*, *S. boottii*, *S. faucibus*, *S. harrisii*, *S. ludoviciana*, *S. patula*, *S. salicina*, *S. sphacelata*, *S. tarda*, *S. vaseyi* and *S. verna* are distinct and species rank is appropriate; some taxa are morphologically more distinct than others. Previous treatments have grouped some of these under a more broadly defined *S. arguta*.

Solidago sect. *Argutae* (Mackenzie) Nesom includes 11 species native to the eastern USA and adjacent Canada and placed in three subsections (Semple & Beck 2021). A summary of basionyms and combinations is presented in Table 1. Cronquist (1980) recognized 5 species, with *S. arguta* including var. *arguta*, var. *bootii* (Hook.) Palmer & Steyerm., var. *caroliniana* A. Gray, and var. *harrisii* (E.S. Steele) Cronq.; he treated 3 other species as close to species other than *S. arguta*. Semple and Cook (2006) recognized 7 species with infraspecific taxa in several species and included *S. brachyphylla* Chapm. ex Torr. & Gray, which Semple and Beck (2021) placed in *S.* sect. *Venosae* (G. Don) Nesom. Semple (2021 frequently updated) has recognized 11 species: *S. arguta* Ait. sensu stricto (Figs. 1-2), *S. boottii* Hook. (Figs. 3-4), *S. faucibus* Wieboldt (Figs. 5-7), *S. harrisii* Steele (Figs. 8-9), *S. ludoviciana (*A. Gray) Small (Figs. 10-11), *S. tarda* Mackenzie (Figs. 12-13), *S. vaseyi* Heller (Figs. 14-15), and *S. verna* M.A. Curtis (Figs. 16-17) in *S.* subsect. *Argutae* (Mackenzie in Small) Nesom; S. *patula* Muhl. (Figs. 18-19) and *S. salicina* Ell. (Figs. 20-21) in *S.* subsect. *Patulae* Semple & Beck; and *S. sphacelata* Raf. (Figs. 22-23) in *S.* subsect. *Brachychaeta* (Torr. & Gray) Semple & J.B. Beck. Early studies of the *S. arguta* complex by G.H. Morton (1973, 1974) provided critical guidance during research over multiple decades by the first author's lab on *S. arguta* and relatives.

Table 1. Accepted combinations, basionyms, and synonyms in *Solidago* sect. *Argutae*.

Solidago sect. *Argutae* (Mackenzie in Small) Semple & J.B. Beck, Phytoneuron 2021-10: 4. 2021. *Solidago* (sp.-group) *Argutae* Mackenzie in Small, Man. SE. Fl. 1345, 1347. 1933. *Solidago* subsect. *Argutae* (Mackenzie in Small) Nesom, Phytologia 75: 9. 1993. **TYPE**: *Solidago arguta* Ait.

Solidago subsect. *Argutae* (Mackenzie in Small) Nesom, Phytologia 75: 10. 1993. *Solidago* ser. *Argutae* (Mackenzie in Small) Nesom, Phytologia 75: 10. 1993. *Solidago* (sp.-group) *Argutae* Mackenzie in Small, Man. SE. Fl. 1345, 1347. 1933. **TYPE**: *Solidago arguta* Ait.

1. *Solidago arguta* Ait., Hort. Kew. 3: 213. 1789.
   Solidago muhlenbergii Torr. & Gray, Fl. N. Amer. 2(2): 214. 1842.
2. *Solidago boottii* Hook., Comp. Bot. Mag. 1: 97. 1835. *Solidago arguta* Ait. var. *boottii* (Hook.) Palmer & Steyerm., Ann. Missouri Bot. Gard. 22: 659. 1935. Rhodora 40: 133. 1938. *Solidago boottii* Hook. var. *boottii* (Hook.) Cronq., Rhodora 49: 79. 1947. *Solidago arguta* Ait. subsp. *boottii* (Hook.) G. Morton, Phytologia 28: 1. 1974.
3. *Solidago faucibus* Wieboldt in Wieboldt & Semple, Sida 20: 1596. 2003.

4. *Solidago harrisii* E.S. Steele, Contr. U.S. Natl. Herb. 13: 369. 1911. *Solidago arguta* Ait. var. *harrisii* (E.S. Steele) Cronq., Brittonia 29: 324. 1977.
5. *Solidago ludoviciana* (A. Gray) Small, Fl. S.E. U.S. 1199, 1339. 1903. *Solidago boottii* Hook. var. *ludoviciana* A. Gray, Proc. Amer. Acad. Arts 17: 195. 1882.
   Solidago strigosa Small. Fl. SE. U.S. 1198, 1339. 1903. *Solidago arguta* Ait. var. *strigosa* (Small) Steyerm. Rhodora 62: 131. 1960.
6. *Solidago tarda* Mackenzie ex Small, Man. S.E. Fl. 1355. 1933.
7. *Solidago vaseyi* Heller, Muhlenbergia, 1: 7. 1900 (nom. nov. for *S. arguta* var. *caroliniana* A. Gray 1884).
   Solidago arguta Ait. var. *caroliniana* A. Gray in A. Gray et al., Syn. Fl. N. Amer. 1(2): 155. 1884. Non *S. caroliniana* (L.) B.S.P. (1888). *Solidago boottii* var. *caroliniana* (A. Gray) Cronq., Rhodora 49: 79. 1947. *Solidago arguta* Ait. subsp. *caroliniana* (A. Gray) G. Morton, Phytologia. 28: 1. 1974.
   Solidago arguta Ait. subsp. *pseudoyadkinensis* G. Morton, Phytologia 28: 1. 1974.
8. *Solidago verna* M.A. Curtis ex Torr. & Gray, Fl. N. Amer. 2(2): 205. 1842.

Solidago subsect. *Brachychaeta* (Torr. & Gray) Semple & J.B. Beck, Phytoneuron 2021-10: 4. 2021. *Brachychaeta* Torr. & A. Gray, Fl. N. Amer. 2: 194. 1842. *Solidago* ser. *Brachychaeta* (Torr. & Gray) Nesom, Phytologia 75: 10. 1993. **TYPE**: *Brachychaeta cordata* (Short & Peter) Torr. & A. Gray = *Solidago sphacelata* Raf.

9. *Solidago sphacelata* Raf., Ann. Nat. 14. 1820. *Brachychaeta sphacelata* (Raf.) Britt., Bull. Torrey Bot. Club 20: 4484. 1893.
   Brachyris ovatifolia DC., Prodr. 5: 313. 1836.
   Solidago cordata Short & Peter, Transylvania J. Med. 28: 599. 1836. *Brachychaeta cordata* (Short & Peter) Torr. & Gray, Fl. N. Amer. 2: 195. 1841.

Solidago subsect. *Patulae* Semple & J.B. Beck, Phytoneuron 2021-10: 4. 2021. **TYPE**: *S. patula* Muhl.

10. *Solidago patula* Muhl. ex Willd., Sp. Pl. 3. 2059. 1803.
    Solidago frankii Hochst. & Steud. [in distrib.] ex A. Gray, Synop. Fl. N. Amer. 1,2: 152. 1884.
    Solidago patula Muhl. var. *macra* Farwell, Rep. Mich. Acad. Sci. 17: 171. 1916.
11. *Solidago salicina* Ell., Sketch. Bot. S. Carolina 2: 389. 1824.
    Solidago patula Muhl. var. *strictula* Torr. & Gray, Fl. N. Amer. 2: 213. 1841. *Solidago patula* Muhl. subsp. *strictula* (Torr. & A. Gray) Semple, Sida 20: 1612. 2003.

All members of *Solidago* sect. *Argutae* share a number of morphological traits. Stem height is variable with all species including individuals at least a meter tall. Stem height on average was shortest in *S. sphacelata* (mean of 54 cm tall; shortest 8 cm tall) and *S. verna* (mean of 69 cm tall; shortest 59 cm tall), and the tallest plant was a specimen of *S. tarda* from Alabama at 215 cm tall with average stem heights ranging for most species between 90-110 cm. Basal rosette and lower stem leaves are the largest produced but range from narrowly long-petiolate with large cordate coarsely serrate blades (*S. sphacelata*) to winged short-petiolate and broadly tapering large to small variously serrate blades that are still the largest leaves produced. Basal rosette leaves can be 30 or more cm long and 11 cm wide (*S. faucibus*) to less than 5 cm long (*S. verna*) and rarely only about 1 cm wide (*S. vaseyi*). Mid and upper stem leaves are always reduced progressively upward on the stem to sometimes as little as approximately 1 cm long (*S. ludoviciana*, *S. vaseyi*), but can still be short petiolate in *S. sphacelata*. Inflorescences are always secund conical in general shape but varied greatly in lower branch length and branch density. The narrowest and most congested inflorescences occurred in some individuals of *S. patula* and *S. salicina*, while the most open and sparsely branched inflorescences occurred in multiples species of *S.* subsect. *Argutae* with lower branches sometimes 40-60 cm long. The smallest inflorescences are about 10 cm long in most species but as short as just 3 cm in an individual of *S. sphacelata*. Involucre height correlates with ploidy level with the smallest in several diploid species (about 2.5 mm tall; mean for all 5.3 mm tall, N=729) and the tallest occurring in *S. faucibus* a decaploid (mean involucre height of 7.8 mm). Phyllaries are always imbricate with the outer ones ranging from about 2/5th to 3/5th the length of the involucre and mostly narrowly to broadly lanceolate with obtusely to acutely rounded apices. The phyllaries of *S. sphacelata* are generally the most ovate while the those of *S. faucibus* are the broadest and sometimes oblanceolate with 3 pronounced veins. The number of rays per head range from 0-15 with means of less than 2 to more than 5 per head and an overall mean of 3.2. The length of the ray floret lamina has a mean length of 2.1 mm long (extremes of ca 5 mm in individuals of *S. vaseyi*, *S. verna*, and *S. salicina*). The number of disc florets has a mean of 8.6 and a range of 6-13. Ovary/cypselae bodies are glabrous to distally or completely moderately strigulose.

There have been differences of opinion on names and ranks for taxa in *Solidago* sect./subsect. *Argutae*. Cronquist (1980) recognized a morphologically diverse *S. arguta* with four varieties here treated at the species level. Nesom (2009) noted that the name *Solidago dispersa* Small (1898) had priority over *S. ludoviciana* because the types of the two names belonged in the same species. Gary Morton in 1970 annotated the type of *S. dispersa* as a possible hybrid between *S. arguta* subsp. *boottii* and *S. ulmifolia*. Semple annotated the type as *S.* ×*dispersa* Small pro sp. in 2012. The lax nature of the branches in the inflorescence of the type of *S. dispersa* is atypical for *S. ludoviciana*, while as Nesom (2009) noted much of the morphology is in line with that of *S. ludoviciana*. We continue to use the name *S. ludoviciana* for the species because of the uncertainty of the parentage of the type of *S. dispersa*.

All species of *Solidago* sect. *Argutae* occur only in the eastern USA and adjacent Canada, mostly in partially to densely wooded habitats. *Solidago arguta* is a northern species occurring in deciduous forests from southern Maine to southern Ontario south to eastern Tennessee and northern North Carolina and disjunct in southern Missouri, while *S. vaseyi* (synonym: *S. arguta* var. *caroliniana*) is southern in forests from southern Virginia to northern Florida and eastern Louisiana and disjunct in southern Missouri (Fig. 24). *Solidago boottii* occurs mostly west of the Mississippi River from Missouri south to eastern Texas, Louisiana and southwestern Mississippi and scattered locations across the southeastern US (Fig. 25). *Solidago faucibus* occurs in narrow steep valleys in the mountains in mesic deciduous forests and hardwood-hemlock stands in western Virginia, southern West Virginia, eastern Kentucky, and disjunct in northwestern South Carolina (Fig. 26). *Solidago harrisii* is native to shale barren habitats in two disjunct areas centering around western Virginia and West Virginia and adjacent states and centering around east central Kentucky (Fig. 27). *Solidago ludoviciana* occurs in dry open woods, edges of woods near roads, and on railroad embankments in southwestern Arkansas, southeastern Oklahoma, eastern Texas, and Louisiana (Fig. 28). *Solidago tarda* occurs in widely scattered locations from southern New Jersey and southeastern Pennsylvania south to much of Alabama with large gaps in the central portion of the range (Fig. 29). *Solidago verna* occurs in wet sandy pinelands and along roadsides on the coastal plain of North Carolina and on the eastern Piedmont in North Carolina and northern South Carolina (Fig. 30). *Solidago patula* occurs in wetter soils in woods, seeps and bogs from New Hampshire to Wisconsin south to northern Georgia and Alabama and in scattered locations in the Midwest to southeastern Missouri (Fig. 31). *Solidago salicina* occurs in low wet ground, swamp margins, and wet meadows in multiple disjunct locations from southeastern Virginia to western Florida and eastern Texas and north to southwestern Missouri (Fig. 32). *Solidago sphacelata* occurs in deciduous forests and rocky outcrops from Virginia to southern Indiana south to northern Georgia, Alabama, and northeastern Mississippi (Fig. 33).

Solidago sect. *Argutae* includes diploids, tetraploids, hexaploids, and decaploids. *Solidago arguta*, *S. patula*, *S. salicina*, *S. sphacelata*, and *S. verna* are known only at the diploid level $2n$=18 (Beaudry & Chabot 1959; Beaudry 1963, 1969; Morton 1981; Semple et al. 1981, 1984; Semple 1985; Semple & Chmielewski 1987; Semple et al. 1992, 1993; Semple & Cook 2004; Morton, Venn & Semple 2018; unpublished data). *Solidago boottii*, *S. harrisii*, *S. ludoviciana* and *S. vaseyi* (reported mostly under the synonym *S. arguta* var. *caroliniana*) are known to include diploids and tetraploids 2n=36 (Beaudry 1963; Morton 1973; Anderson et al. 1974; Semple et al. 1984; Semple & Chmielewski 1987; Semple et al. 1993; Semple & Cook 2004; Semple, et al. 2015; Morton, Venn & Semple 2018; Semple et al. 2019; unpublished data). *Solidago tarda* is known to include hexaploids 2*n*=54 (Anderson et al. 1974). *Solidago faucibus* is known to be decaploid 2*n*=90 (Wieboldt & Semple 2003).

No multivariate study of all 11 species of *Solidago* subsect. *Argutae* has been published previously. Morton (Ph.D. 1973) included multiple analyses of flavonoid profiles and numerous chromosome numbers for the taxa he recognized, including his unpublished species *pseudoyadkinensis*, and also discussion of morphological variation within and among taxa, but he did not present multivariate morphometric analyses in his doctoral thesis on the *S. arguta* complex and did not include *S. patula*, *S. salicina*, and *S. sphacelata*.

MATERIALS AND METHODS

In total, 154 specimens from BOON, GH, LSU, MO, the J.K. Morton personal herbarium (now deposited in TRT), NCU, NY, USF, VPI, and WAT in MT (Thiers, continuously updated) were scored and included in the analyses: *Solidago arguta* (32 specimens including 16 specimens of var. *caroliniana* = *S. vaseyi*), *S. boottti* (19 specimens), *S. faucibus* (15 specimens), *S. harrisii* (12 specimens), *S. ludoviciana* (14 specimens), *S. patula* (14 specimens), *S. salicina* (11 specimens), *S. sphacelata* (19 specimens), *S. tarda* (9 specimens) and *S. verna* (9 specimens). These were selected from more than 800 specimens examined of sect. *Argutae* sensu Semple and Beck (2021) and Semple (2021). For each specimen, 18 vegetative and 15 floral traits were scored when possible: 1-5 replicates per character depending upon availability of material and whether or not the trait was meristic (Table 1). The presence/absence of short scabrous hairs on leaves (adaxial surface), the presence/absence of strigose-villous hairs on mid stem adaxial main veins, and the numbers and distribution of small strigose hairs on ovary/cypselae body were noted and used in identifications. Basal rosette leaves were often not present. Lower stem leaves were sometimes not present. Mean values were used in the analyses, while raw values were used to generate ranges of variation for each trait. All traits scored are listed in Table 2.

All analyses were performed using SYSTAT v.10 (SPSS 2000). Details on the methodology were presented in Semple et al. (2016) and are not repeated here. Six analyses were performed. In the <u>first analysis</u>, *Solidago arguta* (including var. *caroliniana), S. bootttii, S. faucibus, S. harrisii, S. ludoviciana, S. patula, S. salicina, S. sphacelata, S. tarda,* and *S. verna* were included in a COMPLETE discriminant analysis. In the <u>second analysis</u>, all 10 species plus *S. vaseyi* (synonym: *S. arguta* var. *caroliniana*) were included in a STEPWISE discriminant analysis. In the <u>third analysis</u> of just the *S. argutae* group, *S. arguta* (including var. *caroliniana*), *S. boottii*, *S. faucibus*, *S. harrisii*, *S. ludoviciana*, *S. tarda*, and *S. verna* were included in a STEPWISE discriminant analysis. In the <u>fourth analysis</u> of just the *S. arguta* group, all seven species plus *S. vaseyi* (*S. arguta* var. *caroliniana*) were included in a STEPWISE analysis. In the <u>fifth analysis</u>, *S. arguta* var. *arguta* and *S. vaseyi* (*S. arguta* var. *caroliniana*) were included in a STEPWISE discriminant analysis. In the <u>sixth analysis</u>, the two species of the *S. patula* group, *S. patula* and *S. salicina*, were included in a STEPWISE discriminant analysis. Numerous preliminary analyses were run over multiple years as sample sizes expanded and taxa were added to the study. In one of these preliminary studies, the numbers of hairs on proximal and distal halves of more than 100 ovary/cypsela bodies were counted in numerous samples of *S. arguta* var. *arguta* and what was treated at the time as *S. arguta* var. *caroliniana* but is now treated as *S. vaseyi*.

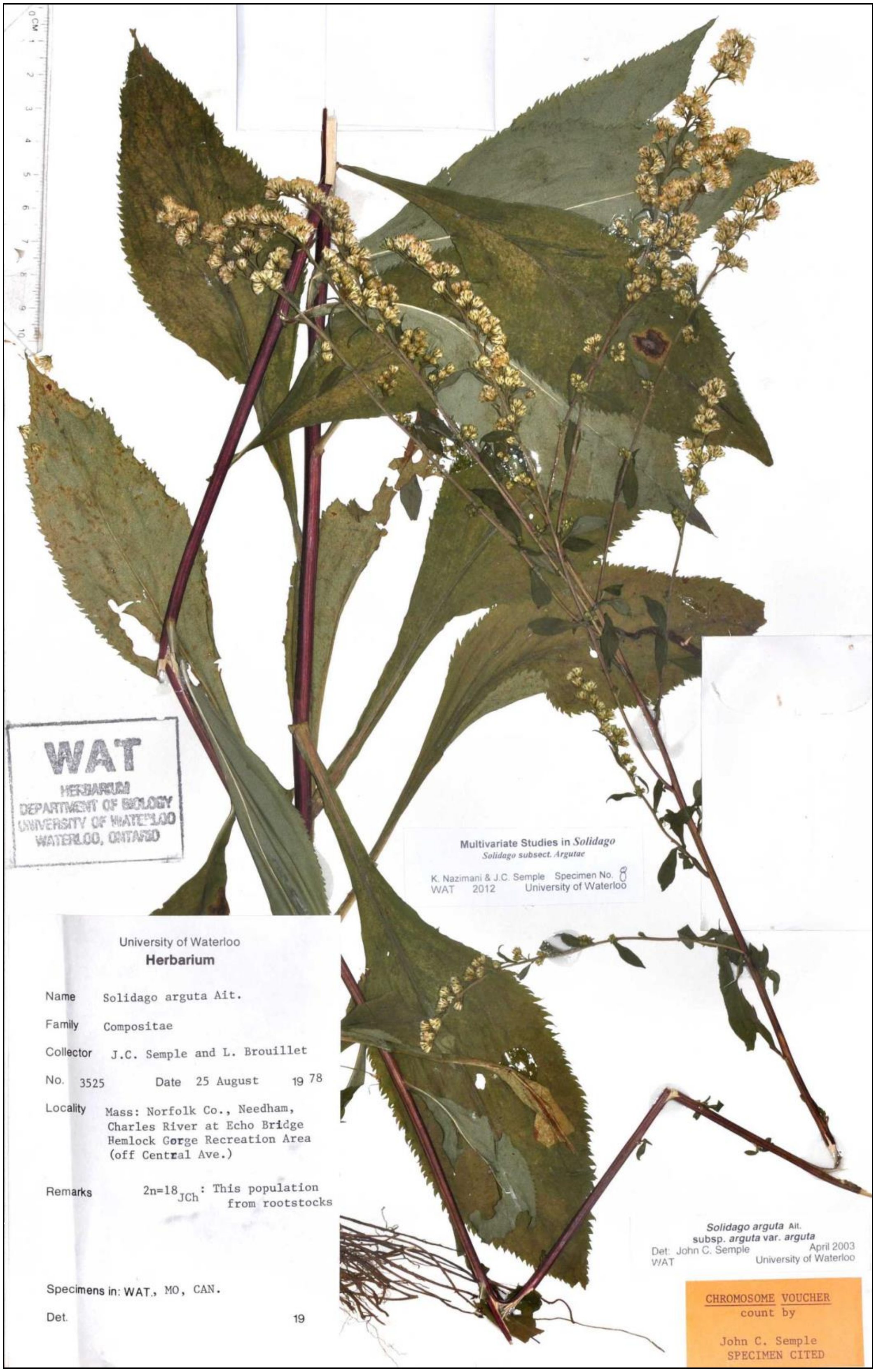

Figure 1. Morphology of *Solidago arguta*: *Semple & Brouillet 3525* (WAT), Norfolk Co., Massachusetts.

Figure 2. Details of the morphology of *Solidago arguta*. **A-B.** Lower and mid stems, *Semple& Keir 4936* (WAT) and *Semple 6883* (WAT). **C.** Lower stem leaf, *Semple & Brouillet 3525* (WAT). **D-E.** Mid stem leaf abaxial vein and margin serrations, *Semple & Suripto 9485* (WAT). **F.** Heads, *Semple & Keir 4936* (WAT). **G.** Cypsela, *Semple & Keir 4936* (WAT). Scale bars = 1 mm in A-B, D-G; = 1 cm in C.

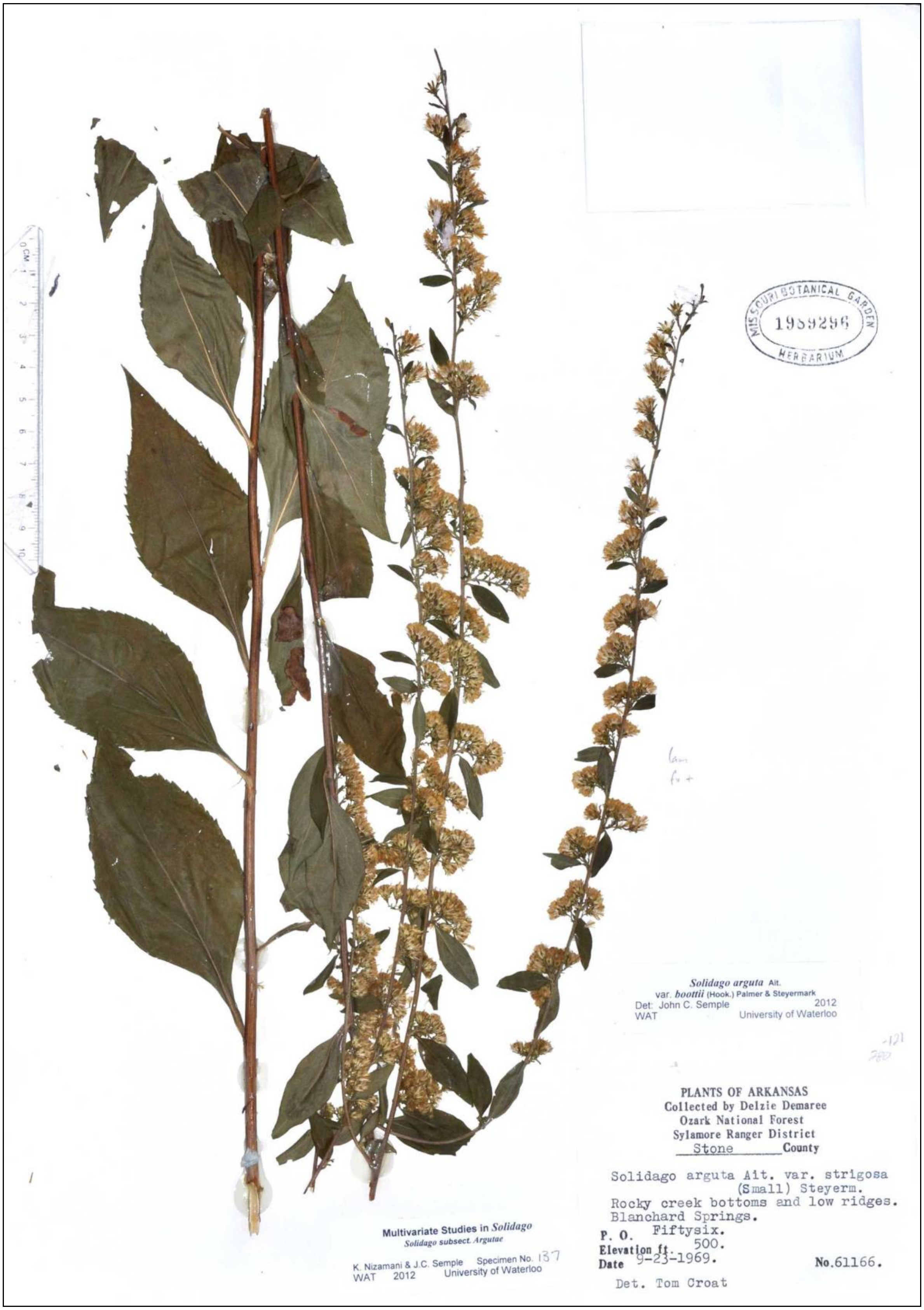

Figure 3. Morphology of *Solidago boottii*: *Demaree 61166* (MO), Stone Co., Arkansas.

Figure 4. Details of the morphology of *Solidago boottii*. **A-B.** Lower mid stems, *Redfearn at el 1740* (MO) and *Thomas et al. 69104* (WAT). **C.** Mid stem leaves, *Demaree 61166* (MO). **D-E.** Mid stem leaf abaxial veins with short and long hairs, *Palmer 26430 (MO)* and *Thomas et al. 69104* (WAT). **F.** Heads, *Thomas et al 69104* (WAT). **G.** Cypsela, *Thomas et al 69104* (WAT). Scale bars = 1 mm in A-B, D- G; = 1 cm in C.

Figure 5. Morphology of *Solidago faucibus*: *Wieboldt et al. 8422* (VPI), Leslie Co., Kentucky.

Figure 6. Morphology of *Solidago faucibus*, lower stem: *Wieboldt et al. 8422* (VPI), Leslie Co., Kentucky.

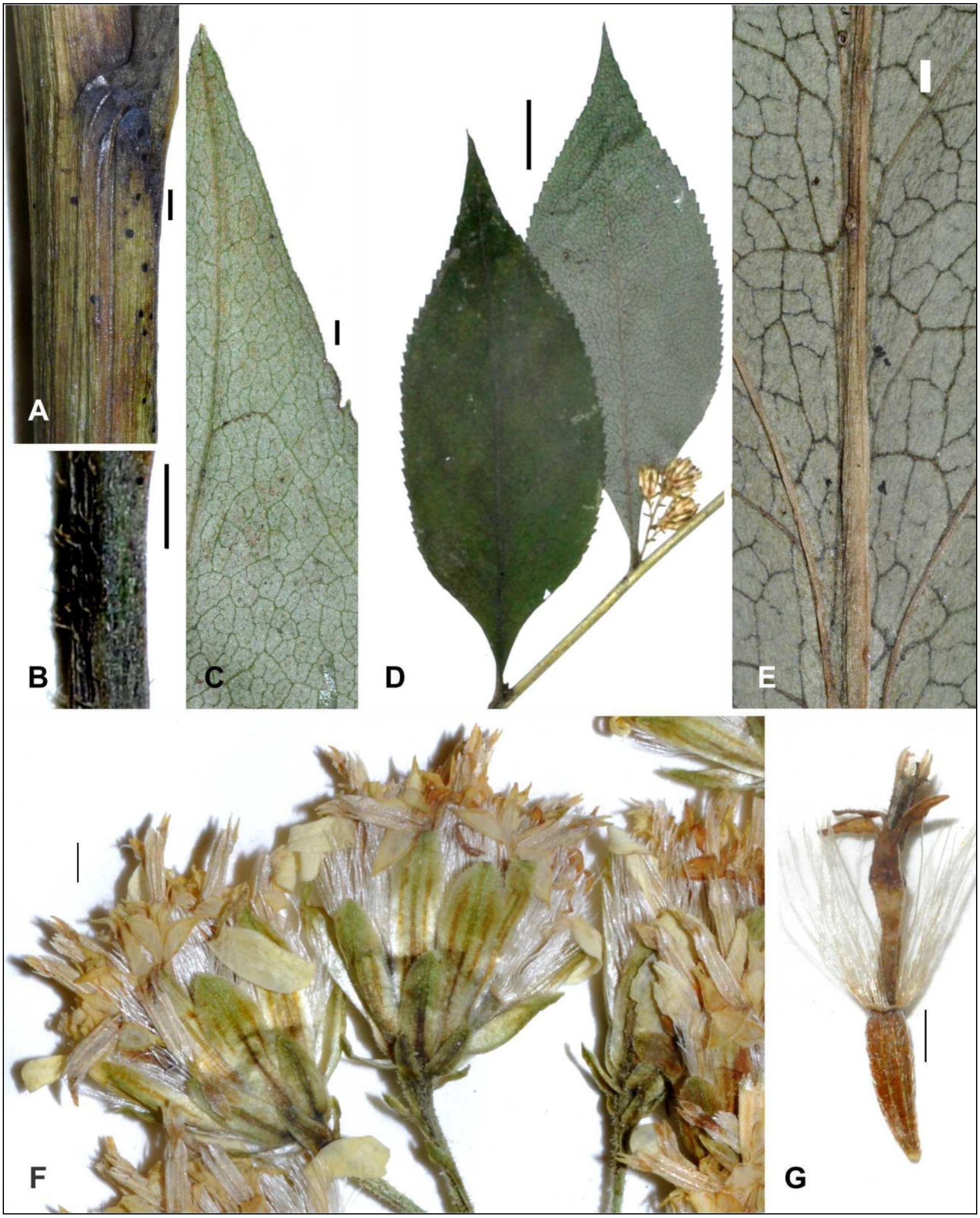

Figure 7. Details of the morphology of *Solidago faucibus*. **A-B.** lower stem and stem in inflorescence, *Wieboldt 8417* (VPI) and *Semple & Suripto 9619* (WAT). **C.** Basal rosette leaf adaxial tip margin, *Wieboldt 11085* (WAT). D. Upper stem leaves, *Wieboldt 7913-1* (VPI). **E.** Mid stem leaf adaxial veins, *Wieboldt 8417* (VPI). **F.** Heads, *Wieboldt 11082* (WAT). **G.** Cypsela, *Wieboldt 11081* (WAT). Scale bars = 1 mm in A-C, E-G; = 1 cm in D.

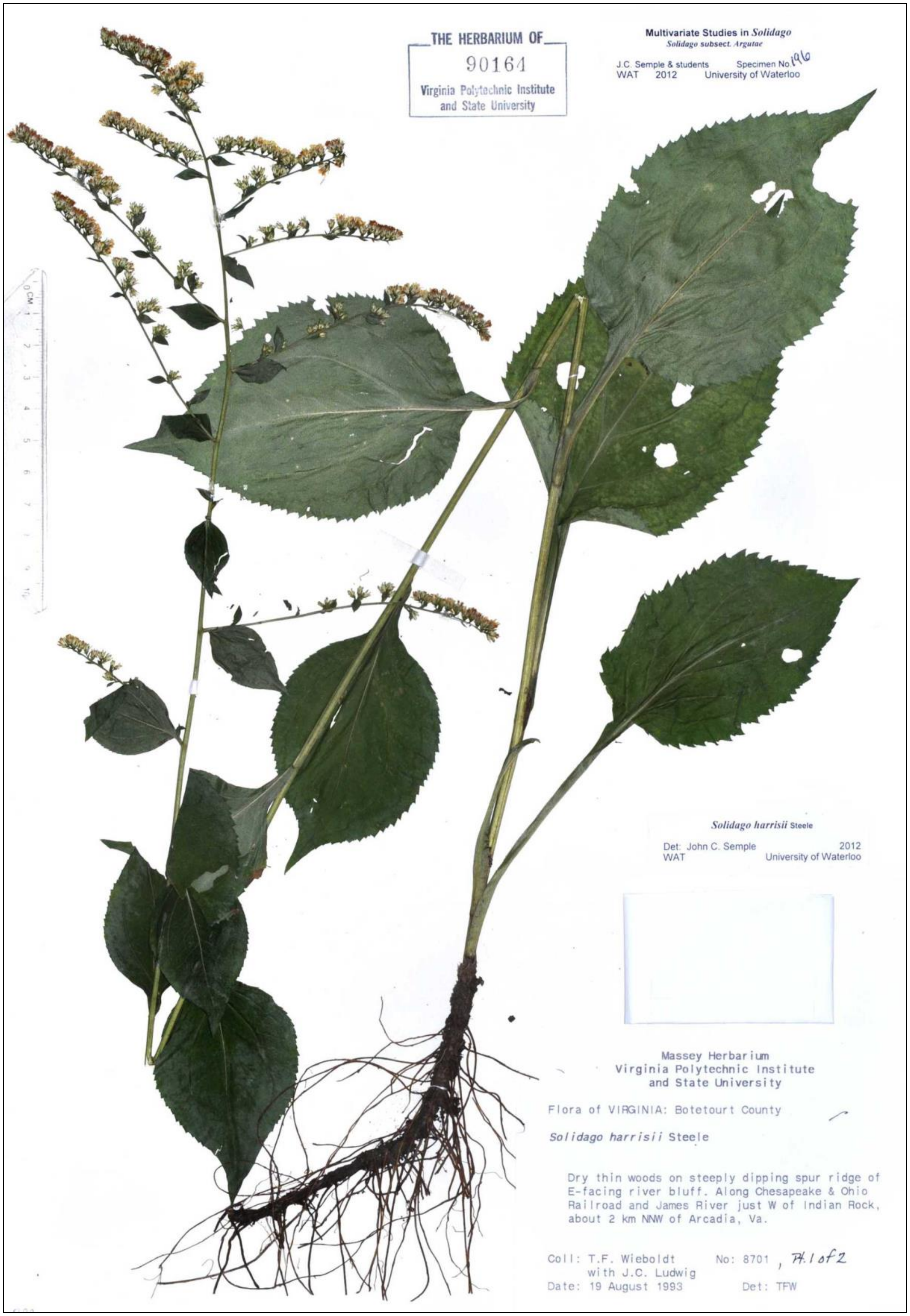

Figure 8. Morphology of *Solidago harrisii*: *Weiboldt & Ludwig 8701* (VPI), Botetouri Co., Virginia.

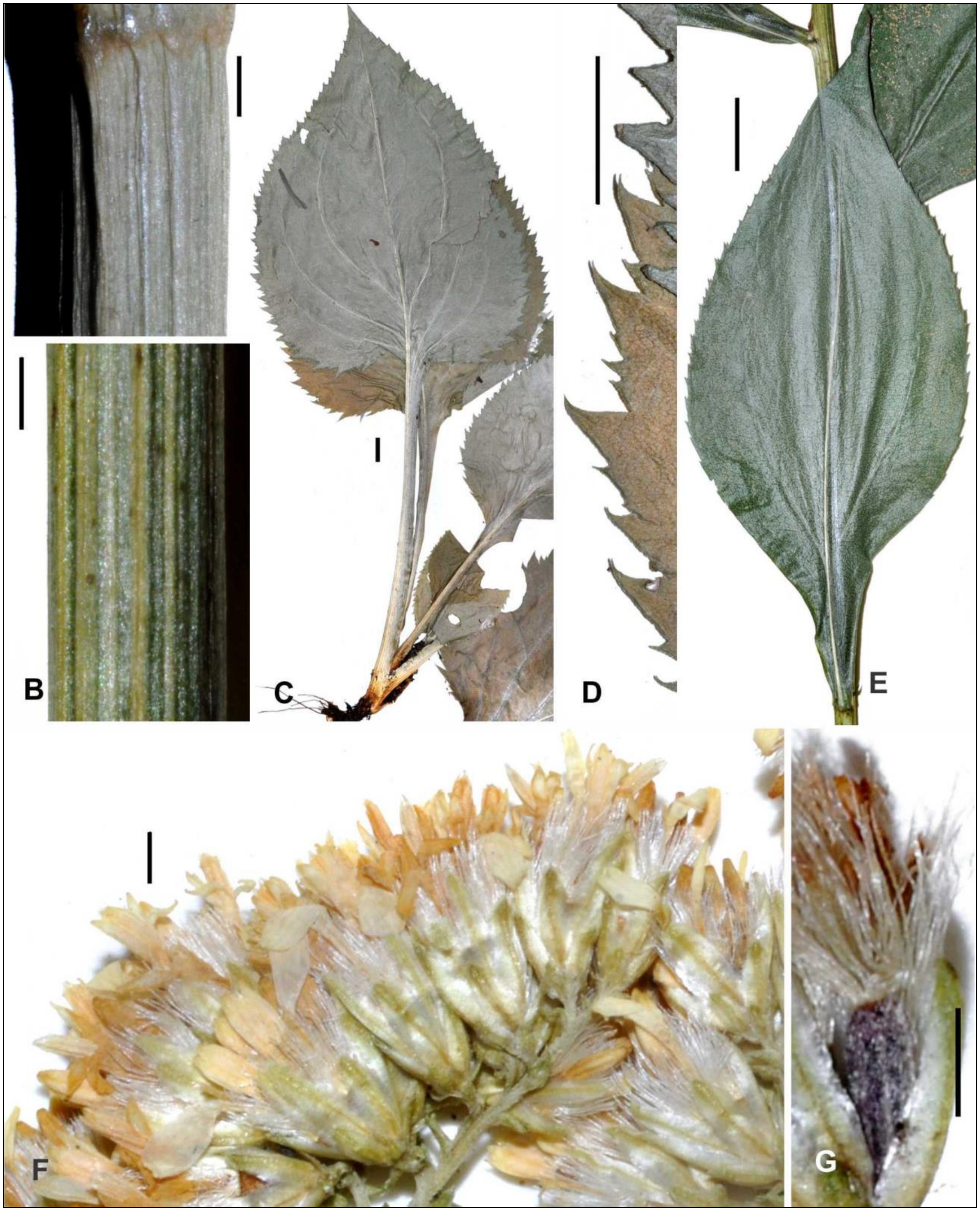

Figure 9. Details of the morphology of *Solidago harrisii*. **A-B.** Lower and mid stems, *Campbell s.n.* (KY) and *Wieboldt et al. 6826* (VPI). **C-D**. Basal rosette leaves and margin details, *Campbell s.n.* (KY). **E.** Mid stem leaf adaxial face, *Wieboldt et al. 6826* (VPI). **F.** Heads, *Uttal 103011* (VPI). **G.** Cypsela, *Wieboldt et al 8438* (WAT). Scale bars = 1 mm in A-B, F-G; = 1 cm in C-E.

Figure 10. Morphology of *Solidago ludoviciana*: *Eggert s.n.* (MO), Bowie Co., Texas.

Figure 11. Details of the morphology of *Solidago ludoviciana*. **A-B.** Lower mid stem and mid stem, *Semple & Suripto 10074* (WAT) and *Eggert s.n.* (NY). **C.** Lateral basal rosette, *Palmer 31714* (MO). **D.** Upper mid stem leaf adaxial face, *Semple & Suripto 10074* (WAT). **E.** Upper stem leaves, *Eggert s.n.* (MO). F. Heads, *Semple & Suripto 10074* (WAT). G. Cypsela, *Eggert s.n.* (MO). Scale bars = 1 mm in A-B, F-G; = 1 cm in C and D.

Figure 12. Morphology of *Solidago tarda*: *Morton 5136* (NY), Cape May Co., New Jersey.

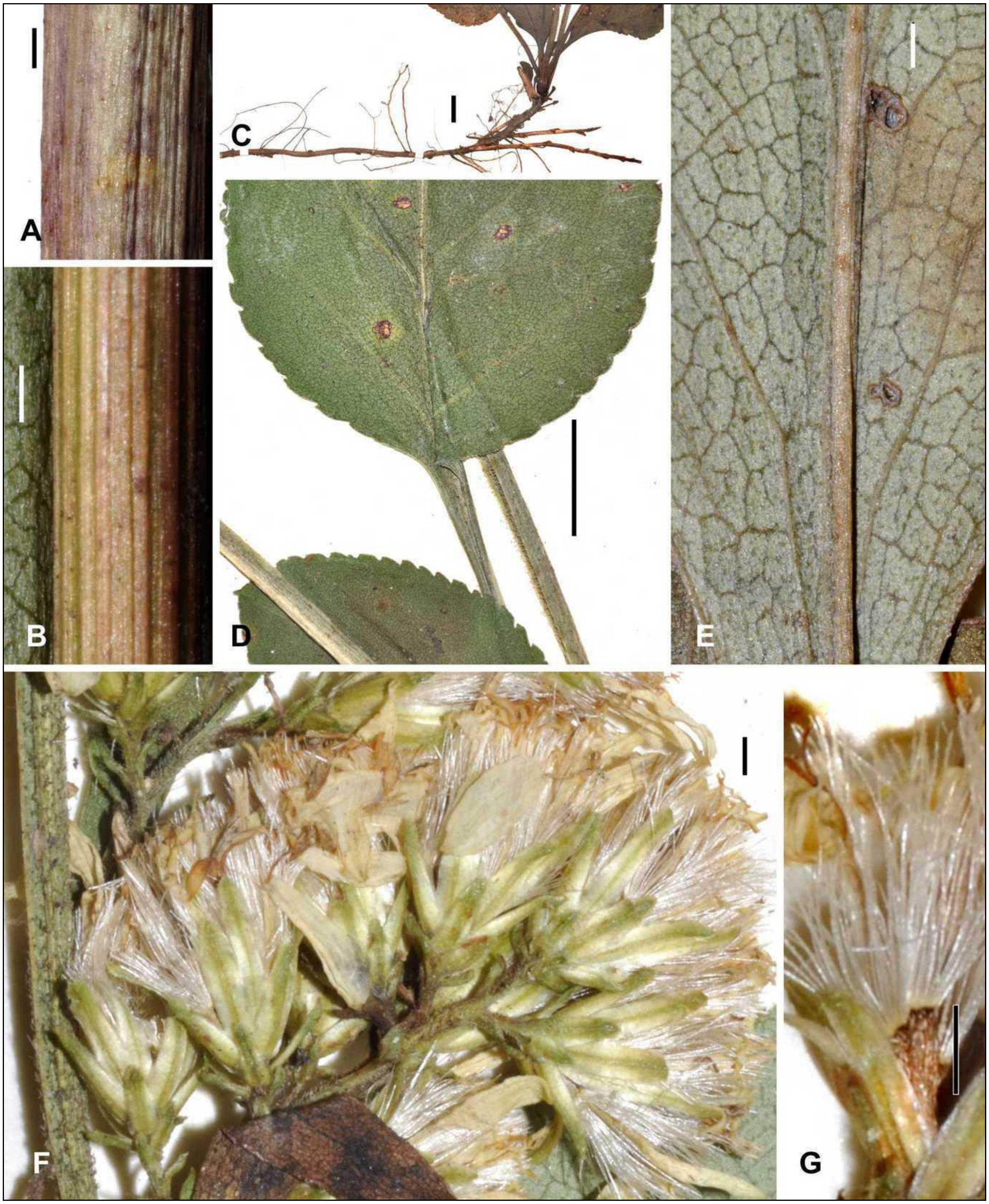

Figure 13. Details of the morphology of *Solidago tarda*. **A-B.** Lower and mid stems, *Morton 8272* (NY) and *Morton 8272* (NY). **C.** Rhizome, *Morton 8272* (NY). **D.** Lower stem leaf blade base, *Morton 5136* (NY). **E.** Lower stem leaf blade abaxial face, *Morton 5136* (NY). **F.** Heads, *Morton 8272* (NY). **G.** Cypsela, *Morton 8272* (NY). Scale bars = 1 mm in A-B, E-G; = 1 cm in C and D.

Figure 14. Morphology of *Solidago vaseyi*: *Semple & B. Semple 11202* (WAT), Cherokee Co., Alabama.

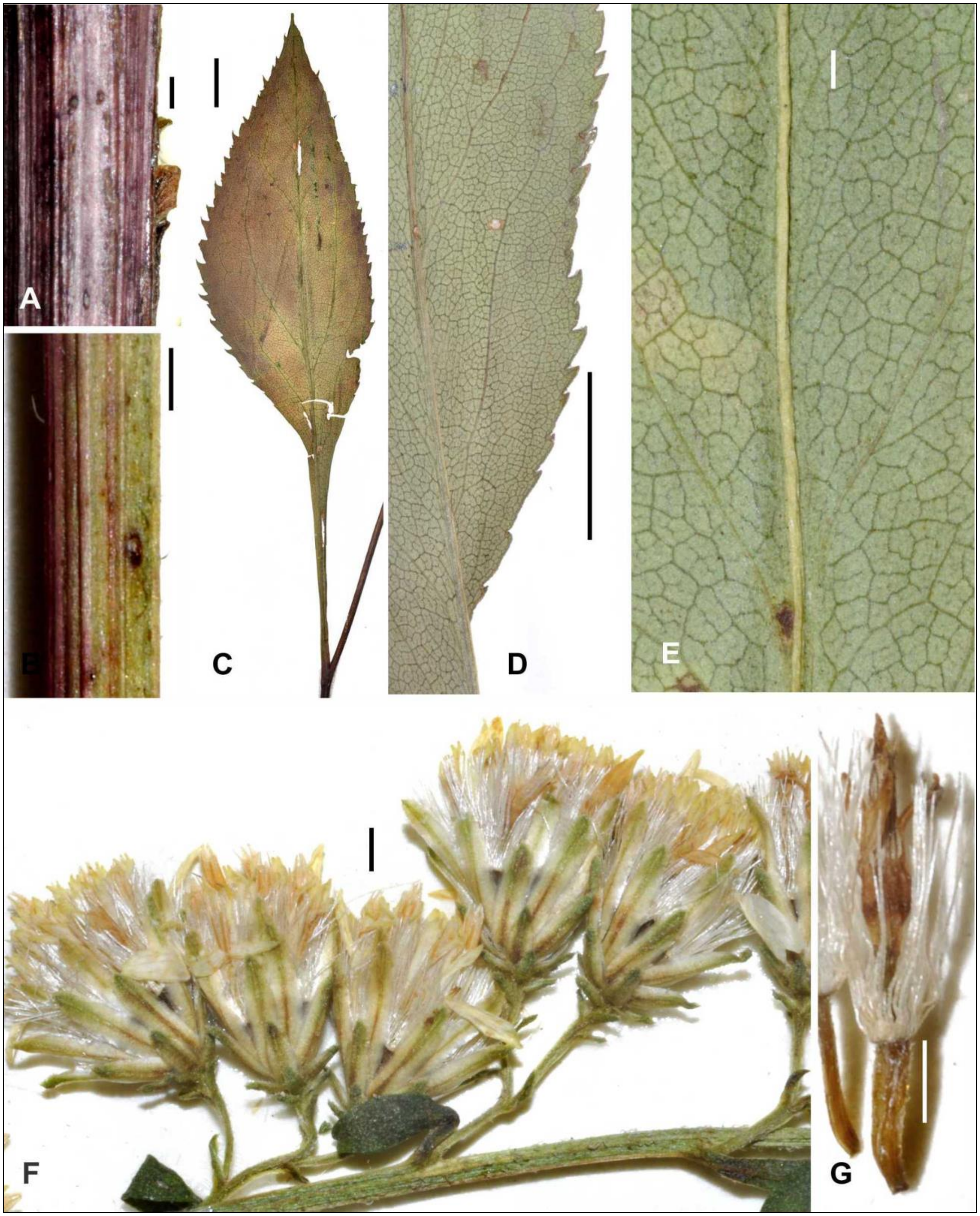

Figure 15. Details of the morphology of *Solidago vaseyi*. **A-B.** Lower and mid stems, *Semple & Chmielewski 5931* (WAT) and *Semple & Suripto 9444* (WAT). **C-D.** Lower stem leaf and adaxial face margin, *Semple & Chmielewki 6207* (WAT) and *Poindexter 05-1212* (WAT). **E.** Mid stem leaf, *Semple & Suripto 9792* (WAT). **F.** Heads, *Semple & B. Semple 11192* (WAT). **G.** Cypsela, *Semple & B. Semple 11192* (WAT). Scale bars = 1 mm in A-B, E-G; = 1 cm in C and D.

Figure 16. Morphology of *Solidago verna*: *Currie & Nelson 11600* (WAT), Moore Co., North Carolina.

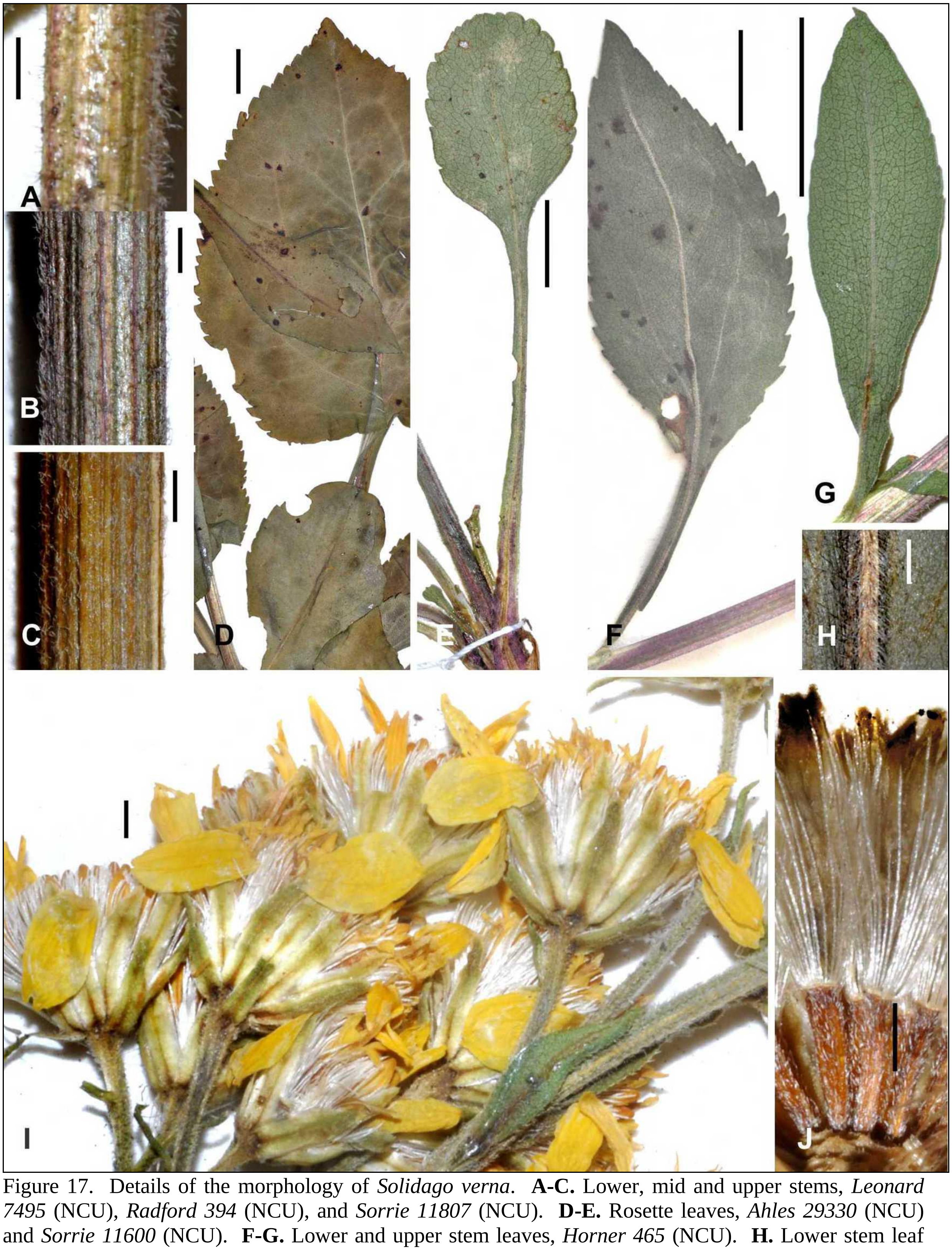

Figure 17. Details of the morphology of *Solidago verna*. **A-C.** Lower, mid and upper stems, *Leonard 7495* (NCU), *Radford 394* (NCU), and *Sorrie 11807* (NCU). **D-E.** Rosette leaves, *Ahles 29330* (NCU) and *Sorrie 11600* (NCU). **F-G.** Lower and upper stem leaves, *Horner 465* (NCU). **H.** Lower stem leaf abaxial mid vein, *Ahles 29330* (NCU). **I.** Heads, *Sorrie 11807* (NCU). **J.** Cypsela, *Radford 4101* (NCU). Scale bars = 1 mm in A-C, H-J; = 1 cm in D-G.

Figure 18. Morphology of *Solidago patula*: *Semple & Suripto 9686* (WAT), Yancey Co., North Carolina.

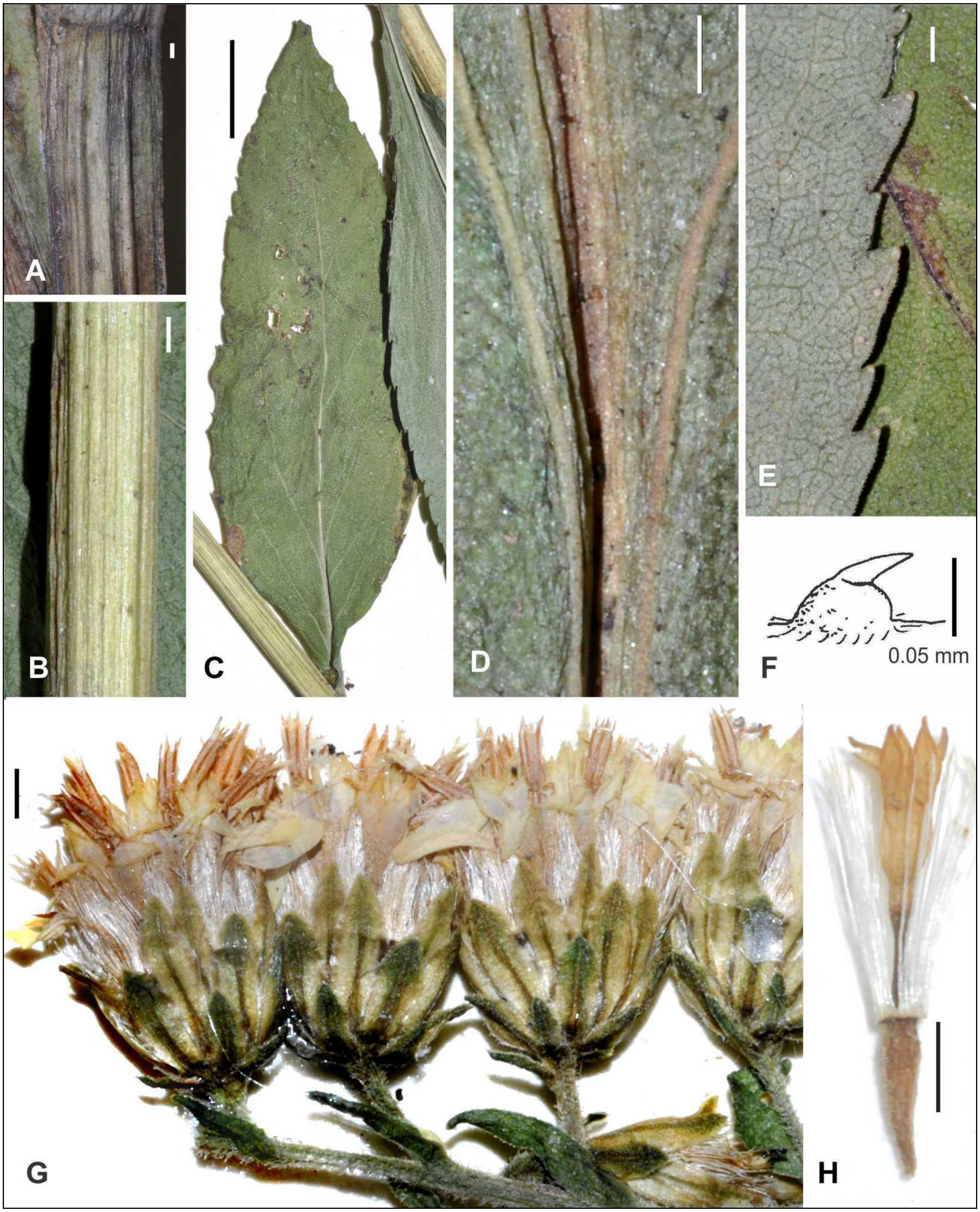

Figure 19. Details of the morphology of *Solidago patula*. **A-B**. Lower and mid stems, *Semple 11132* (WAT) and *Semple & Brouillet 3661* (WAT). **C.** Mid stem leaf, adaxial face, *Semple 2389* (WAT). **D-E.** Mid stem leaf abaxial veins and margin, *Semple 11132* (WAT). **F.** Small scabrous hair, adaxial leaf surface, scale indicated. **G.** Heads, *Semple & Horsburgh 10575* (WAT). **G.** Cypsela, *Semple & Zhang 10589* (WAT). Scale bars = 1 mm in A-B, D-E, G and H; = 1 cm in C.

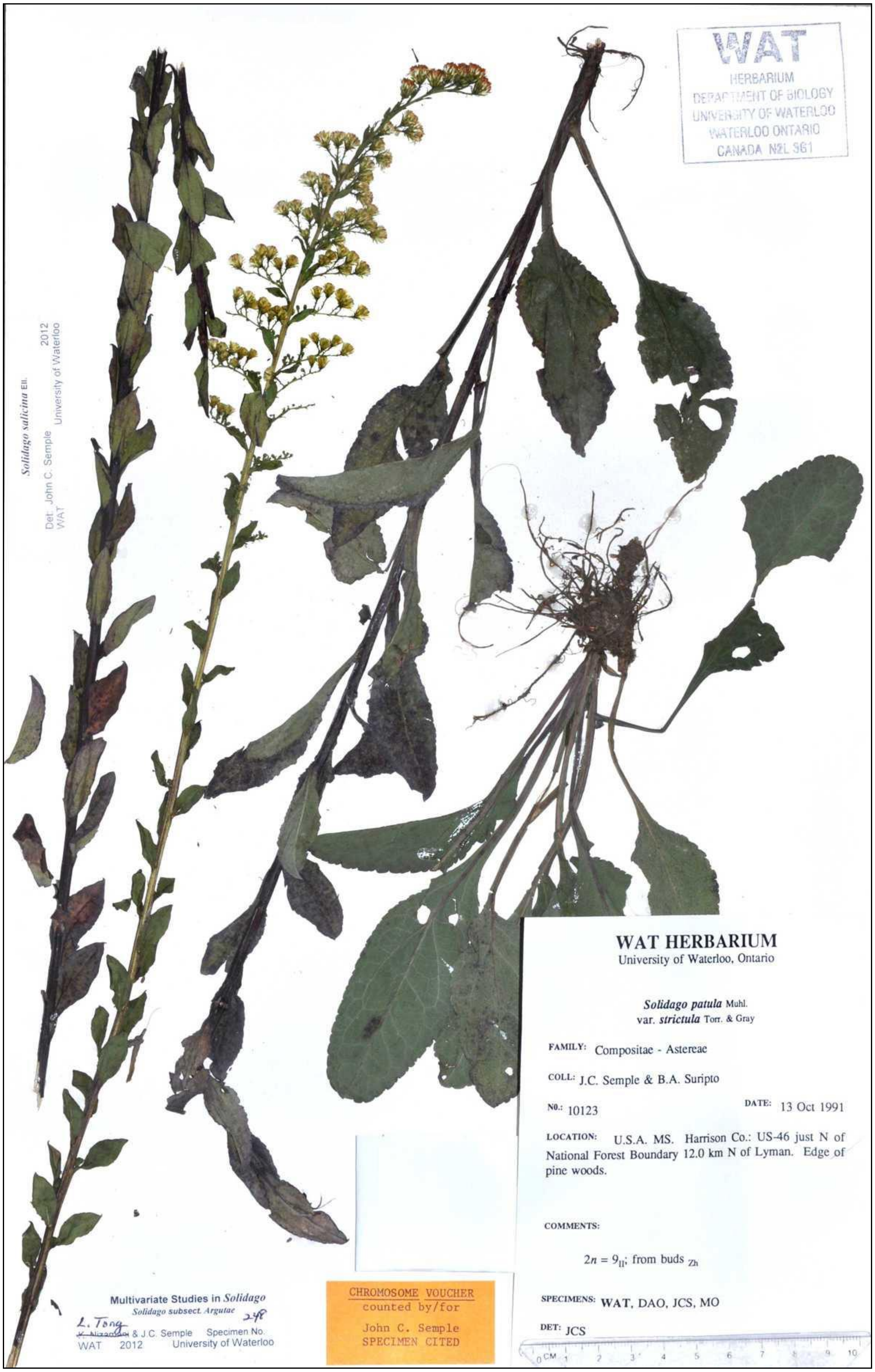

Figure 20. Morphology of *Solidago salicina*: *Semple & Suripto 10123* (WAT), Harrison Co., Mississippi.

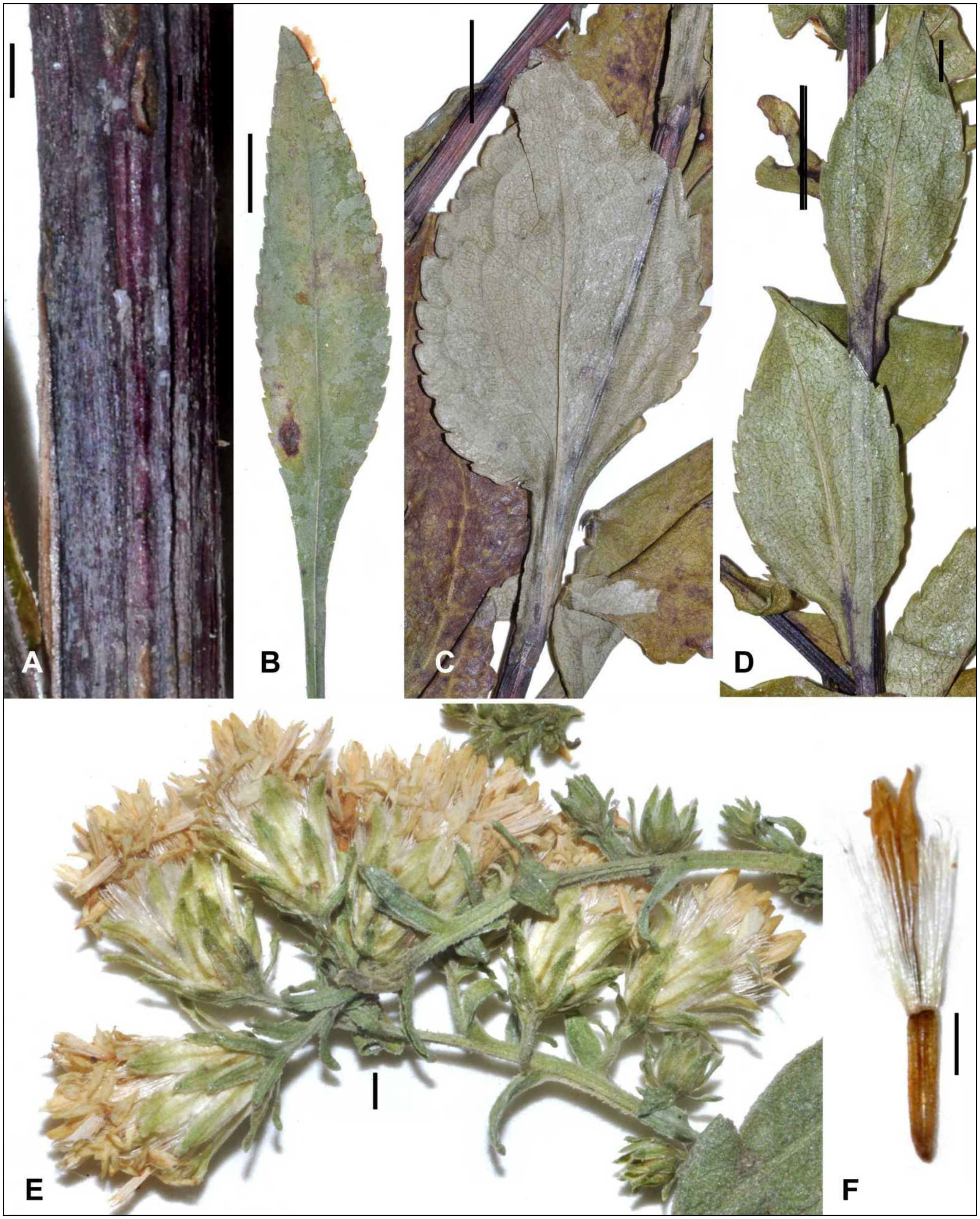

Figure 21. Details of the morphology of *Solidago salicina*. **A.** Lower stem, *Semple & Suripto 10123* (WAT). **B.** Lower stem leaf blade, *Cronquist 4880* (GH). **C.** Lower mid stem leaf, *Godfrey 68383* (GH). D. Upper stem leaves, abaxial faces, *Godfrey 68383* (GH). **E.** Heads, *Thomas et al. 108382* (WAT). **F.** Cypsela, *Thomas et al. 108382* (WAT). Scale bars = 1 mm in A, E and F; = 1 cm in B -D.

Figure 22. Morphology of *Solidago sphacelata*: *Friesner 101551* (NY), Brown Co., Indiana.

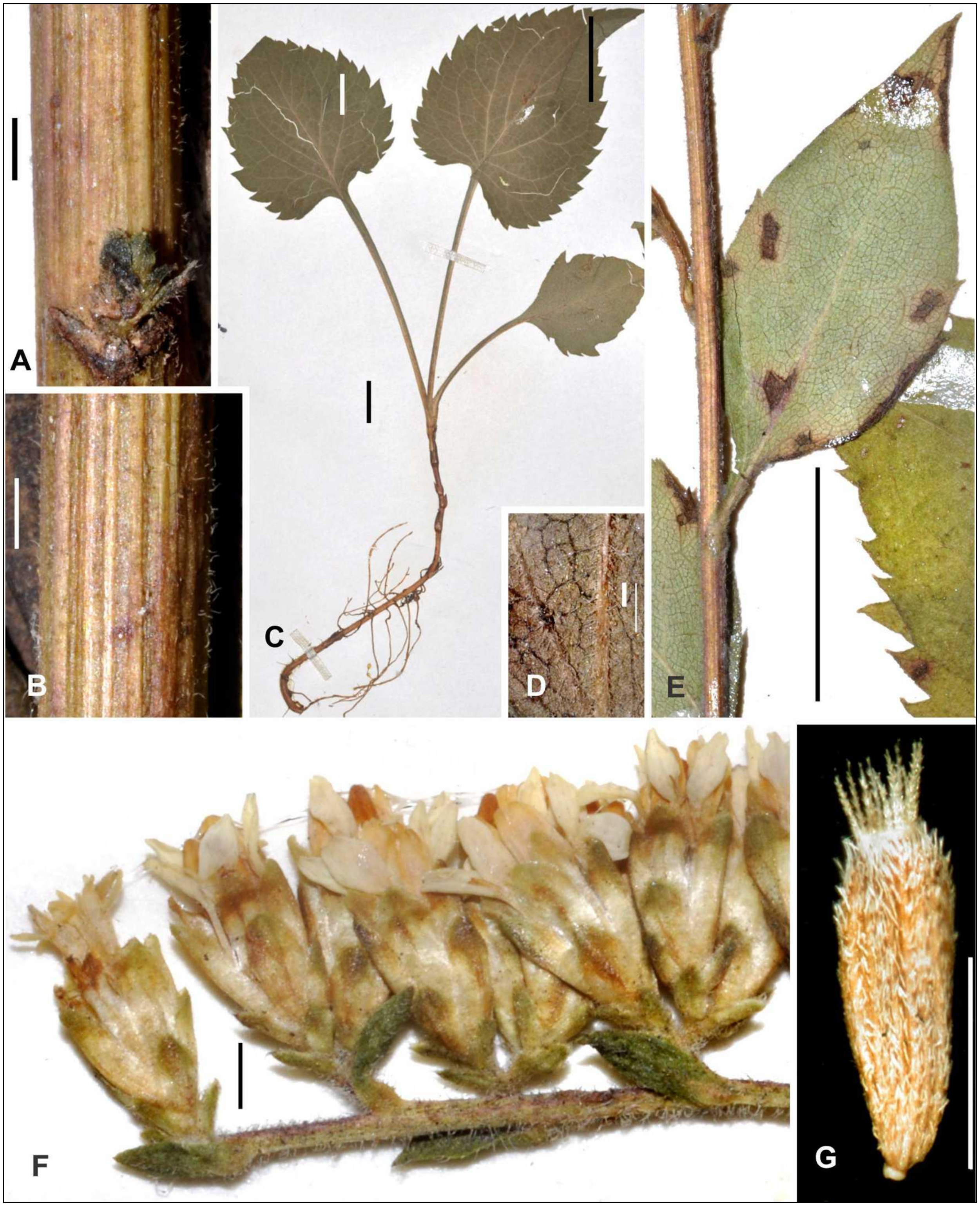

Figure 23. Details of the morphology of *Solidago sphacelata*. **A-B.** Mid stem, *Semple et al. 3019* (WAT). **C.** Rosette, *Biltmore Herb. 991b* (NY). **D.** Lower stem leaf abaxial veins, Eggleston 5210 (NY). **E.** Mid stem leaf , *Ruth s.n.* (NY). **F.** Heads, *Morton 4048* (NY). **G.** Cypsela, *Semple et al. 3019* (WAT). Scale bars = 1 mm in A-B, D, F and G; = 1 cm in C and E.

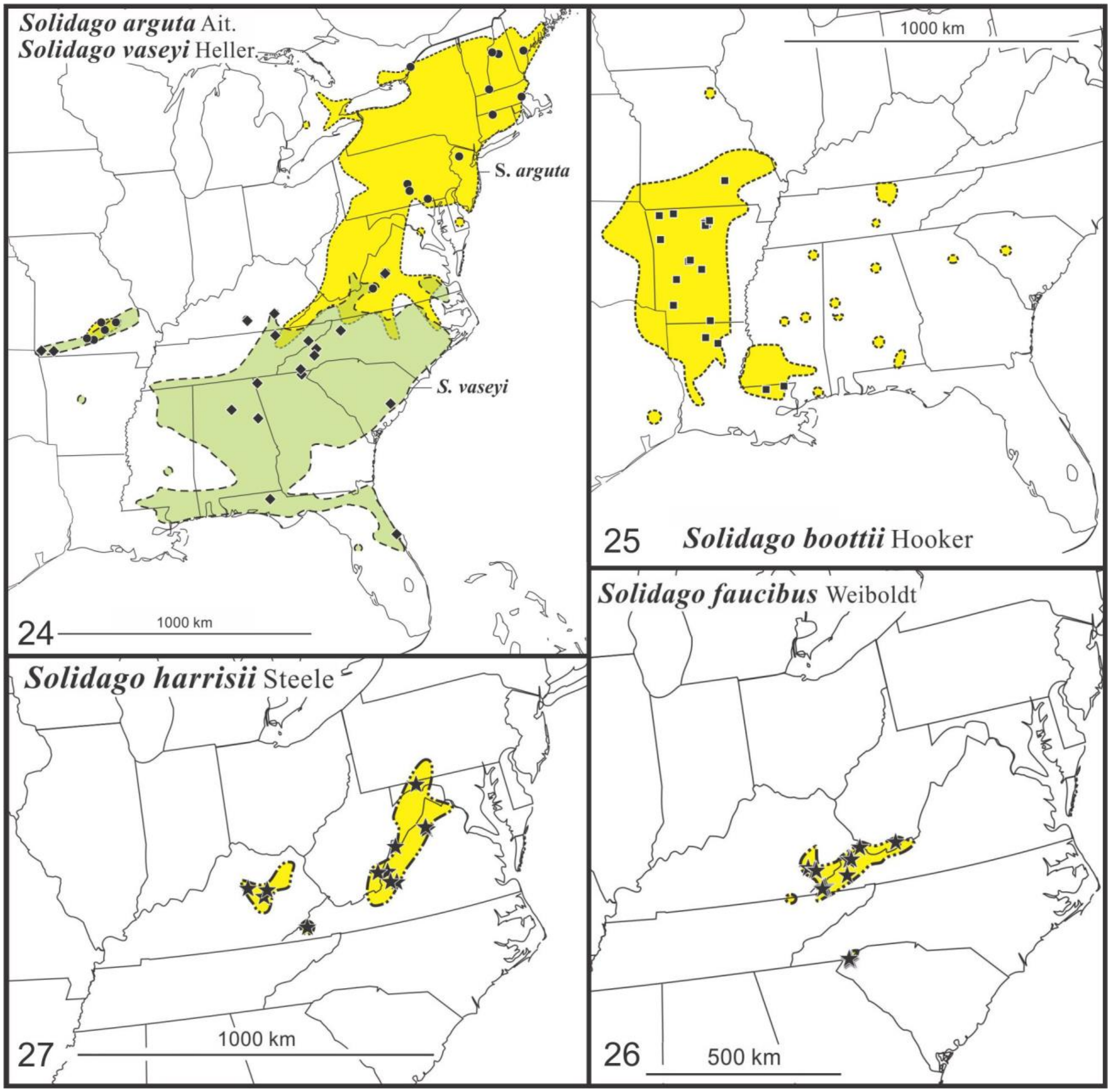

Figure 24. Ranges of distribution of *Solidago arguta* and *S. vaseyi* and locations of specimens included in the analyses.

Figure 25. Range of distribution of *Solidago boottii* and locations of specimens included in the analyses.

Figure 26. Range of distribution of *Solidago faucibus* and locations of specimens included in the analyses.

Figure 27. Range of distribution of *Solidago harrisii* and locations of specimens included in the analyses.

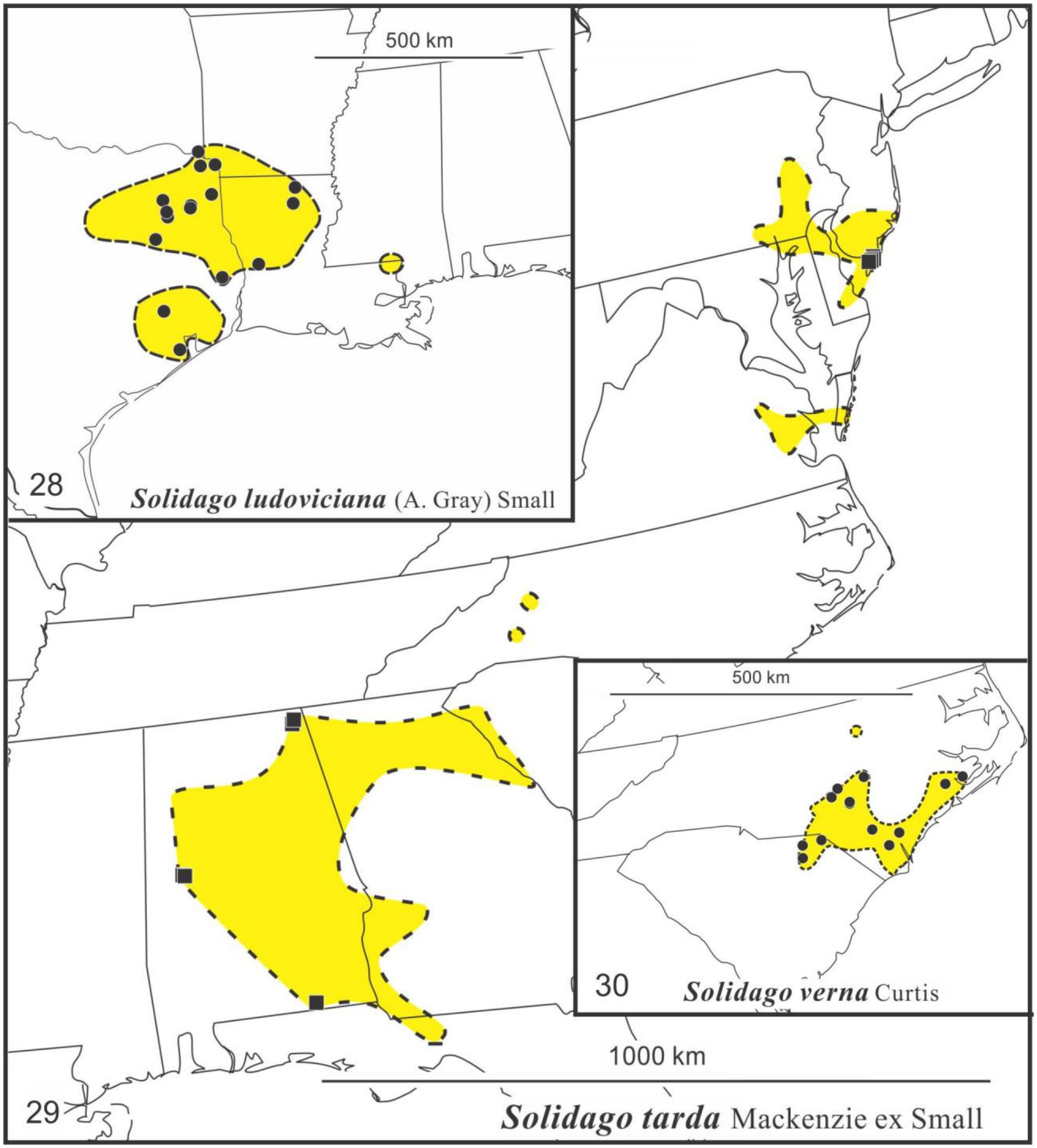

Figure 28. Range of distribution of *Solidago ludoviciana* and locations of specimens included in the analyses in Arkansas, southeastern Oklahoma, Texas and Louisiana.

Figure 29. Range of distribution of *Solidago tarda* and locations of specimens included in the analyses from Pennsylvania to Alabama and western Florida.

Figure 30. Range of distribution of *Solidago verna* and locations of specimens included in the analyses in North Carolina and adjacent South Carolina.

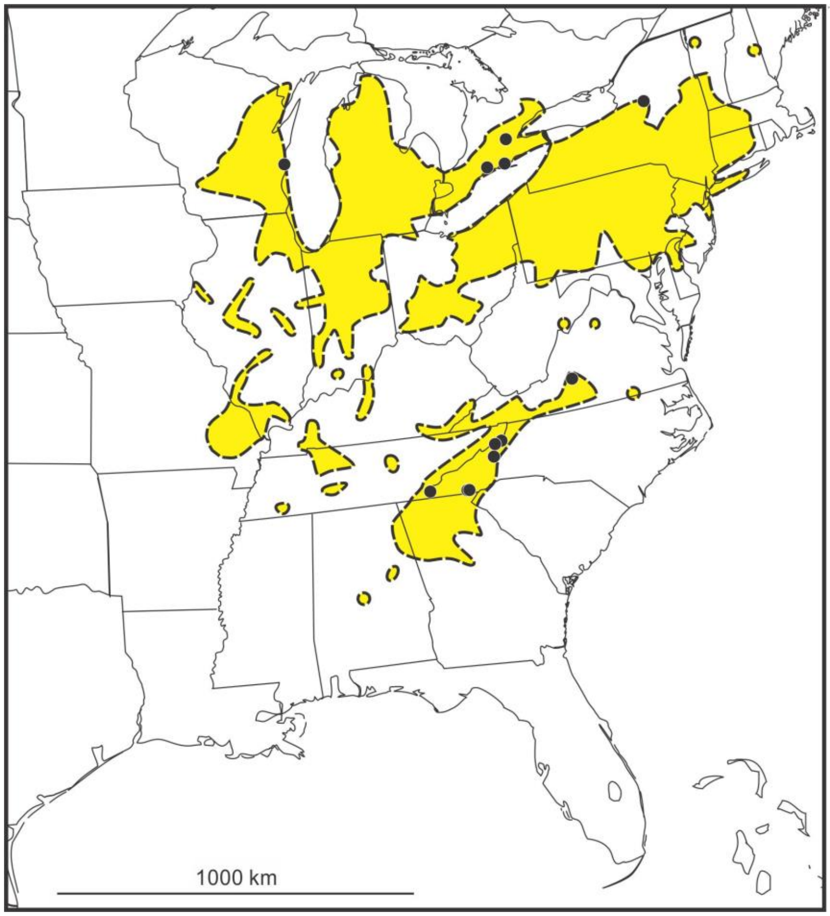

Figure 31. Range of distribution of *Solidago patula* and locations of specimens included in the analyses.

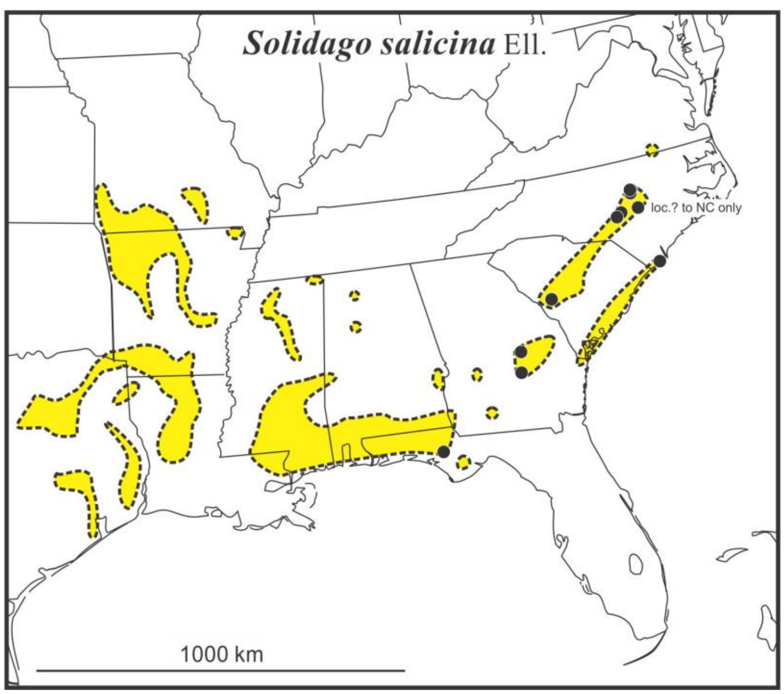

Figure 32. Range of distribution of *Solidago salicina* and locations of specimens included in the analyses.

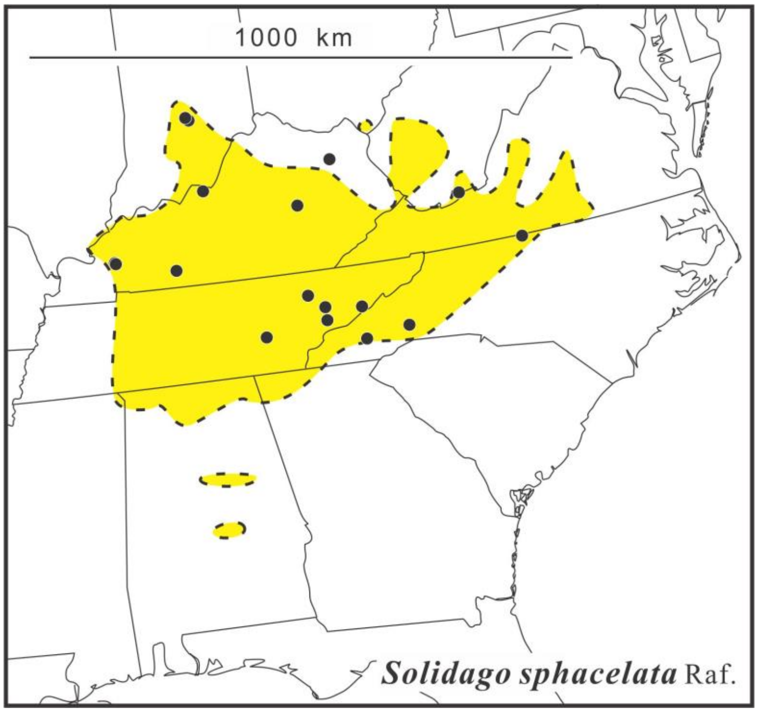

Figure 33. Range of distribution of *Solidago sphacelata* and locations of specimens included in the analyses.

Table 2. Traits scored for the multivariate analyses of 261 specimens of *Solidago* subsect. *Squarrosae*.

Abbreviation	**Description of trait scored**
STEMHT	Stem height measured from the stem base to tip (cm)
BLFLN	Basal rosette leaf length including petiole (mm)
BLFPETLN	Basal rosette leaf petiole length (not scored if winged margins broad)
BLFWD	Basal rosette leaf width measured at the widest point (mm)
BLFWTOE	Basal rosette leaf measured from the widest point to the end (mm)
BLFSER	Basal rosette leaf-number of serrations on 1 side of margin
LLFLN	Lower leaf length measured from the leaf base to tip (mm)
LLFWD	Lower leaf width measured at the widest point (mm)
LLFWTOE	Lower leaf measured from the widest point to the end (mm)
LLFSER	Lower leaf dentation-number of serrations of lower leaf
MLFLN	Mid leaf length measured from the leaf base to tip (mm)
MLFWD	Mid leaf width measured at the widest point (mm)
MLFWTOE	Mid leaf measured from the widest point to the end (mm)
MLFSER	Mid leaf dentation-number of serrations of mid leaf
ULFLN	Upper leaf length measured form the leaf base to tip (mm)
ULFWD	Upper leaf width measured at the widest point (mm)
ULFWTOE	Upper leaf measured from the widest point to the end (mm)
ULFSER	Upper leaf dentation-number of serrations of upper leaf
CAPL	Length of inflorescence (cm)

CAPW	Width of inflorescence (cm)
CAPBLN	Length of longest 5 inflorescence branches (cm)
INVOLHT	Involucre height (mm)
OPHYLN	Outer phyllary length (mm)
IPHYLN	Inner phyllary length (mm)
RAYNUM	Number of ray florets per head
RLAMLN	Ray strap length top of the corolla tube to the tip of the strap (mm)
RLAMPWD	Ray strap width measured at the widest point (mm)
RACHLN	Ray floret cypsela body length at anthesis (mm)
RPAPLN	Ray floret pappus length at anthesis (mm)
DCORLN	Disc floret corolla length from the base to tip of the corolla lobes (mm)
DLOBLN	Disc floret corolla lobe length lobe (mm)
DACHLN	Disc floret achene length at anthesis (mm)
DPAPLN	Disc floret pappus length at anthesis (mm)

RESULTS

The Pearson correlation matrix yielded $r > |0.7|$ for most pairs of leaf traits reducing the number to be used to mid stem leaf length and upper stem leaf width. Basal rosette leaves were often absent and were not included in the discriminant analyses: basal leaf length, petiole length, and length from widest point to tip were all highly correlated. Lower leaves were sometimes absent and lower leaf traits were excluded from discriminant analyses but were used in partially defining a priori groups. Ray floret pappus body length at anthesis correlated highly with disc floret pappus length and only the latter trait was included in discriminant analyses. Inflorescence length and width traits were highly variable in all species and were not included in the analyses.

Analysis 1: Ten species a priori groups analysis

In the STEPWISE discriminant analysis 153 specimens of ten species level a priori groups (*Solidago arguta* including var. *caroliniana*, *S. boottii*, *S. faucibus*, *S. harrisii*, *S. ludoviciana*, *S. patula*, *S. salicina*, *S. sphacelata*, *S. tarda*, and *S. verna*), the following seven traits were selected for as best separating the groups and are listed in order of decreasing F-to-remove values: disc floret pappus length at anthesis (21.74), involucre height (14.45), mid stem leaf length (7.61), ray floret lamina length (6.79), number of disc florets (5.74), disc corolla lobe length (4.94), and upper leaf width (4.57). Wilks's lambda, Pillai's trace, and Lawley-Hotelling trace tests of the null hypothesis that all groups were samples of one group had probabilities of $p = 0.000$ that the null hypothesis was true. The F-matrix for the discriminant analysis is presented in Table 3. F-values based on Mahalanobis distances between group centroids indicated the largest separation was between *S. ludoviciana* and *S. sphacelata* (51.913), and the least separations were between *S. patula* and *S. salicina* (0.644), *S. arguta* and *S. boottii* (2.431), and *S. ludoviciana* and *S. tarda* (2.458).

In the Classificatory Discriminant Analysis of the ten species level a priori groups (*Solidago arguta* including var. *caroliniana*, *S. boottii*, *S. faucibus*, *S. harrisii*, *S. ludoviciana*, *S. patula*, *S. salicina*, *S. sphacelata*, *S. tarda*, and *S. verna*), percents of correct a posteriori assignment to the same a priori group ranged from 38-100%. The Classification matrix and Jackknife classification matrix are presented in Table 43. Results are presented in order of decreasing percents of correct placement.

Table 3. Between groups F-matrix for the three a priori group analysis (df = 10 146).

Group	***arguta***	***boottii***	***faucibus***	***harrisii***	***ludo-viciana***	***patula***	***salicina***	***sphacelata***	***tarda***
boottii	2.431								
faucibus	14.298	14.745							
harrisii	5.981	6.881	8.644						
ludoviciana	12.996	9.595	19.980	19.976					
patula	4.188	6.586	20.203	11.317	11.850				
salicina	3.077	3.796	16.862	9.168	9.255	0.644			
sphacelata	36.920	33.575	38.489	12.919	51.913	29.627	25.846		
tarda	7.436	4.498	14.393	14.078	2.458	6.848	4.770	38.046	
verna	22.519	18.355	25.709	25.449	11.957	14.303	11.408	46.129	5.534

Wilks' lambda = 0.0194 df = 7 9 143; Approx. F= 112.5122 df = 63 777 prob = 0.0000

All 19 specimens of the *S sphacelata* a priori group (100%) were assigned a posteriori to the *S. sphacelata* group; 16specimens with 100% probability, 2 specimens with 99% and 94% probabilities, and 1 specimen with 85% probability. All of the 15 specimens of *S. faucibus* (100%) were assigned a posteriori to the *S. faucibus* group: 9 specimens with 90-100% probability, 2 specimens with 89% and 85% probabilities, 1 specimen with 79% probability, 1 specimen with 58% probability (21% to *S. ludoviciana*; *Wieboldt 5825-A1* VPI from Scott Co., Virginia), and 2 specimens with 48% probability (21% to *S. ludoviciana*, 14% to *S. arguta*, and 10% to *S. boottii*; *Wieboldt 5893-C1* VPI from Lee Co., Virginia) and 45% probability (31% to *S. arguta*, and 10% to *S. boottii*; *Wieboldt 7913-1* VPI from Buchanan Co., Virginia). Eleven of the 12 specimens of the *S. harrisii* a priori group (92%) were assigned a posteriori to the *S. harrisii* group: 5 specimens with 94-99% probability, 2 specimens with 87% and 80% probability, 2 specimens with 77% and 71% probabilities, 1 specimen with 68% probability, and 1 specimen with 51% probability (35% to *S. arguta*, and 7% to *S. boottii*; *Uttal 103011* VPI from Greenbrier Co., West Virginia). One specimen of the *S. harrisii* a priori group was assigned a posteriori to *S. arguta* with 31% probability (25% to *S. patula*, 25% to *S. salicina*, 10% to *S. boottii* and 7% to *S. ludoviciana*; *Harris s.n.* KY from Highland Co., Virginia). Eight of the 9 specimens of the *S. verna* a priori group (89%) were assigned a posteriori to the *S. verna* group: 4 specimens with 99-100% probability, 1 specimen with 82% probability, 2 specimens with 77% and 70% probabilities, and 1 specimen with 57% probability (29% to *S. harrisii*, 16% to *S. boottii*, and 5% to *S. arguta*; *Sorrie 11807* NCU from Harnett Co., North Carolina; the stem and leaves have the short hairy indument typical for the species). One specimen of the *S. verna* a priori group was assigned a posteriori to *S. tarda* with 58% probability (36% to *S. tarda*; *Godfrey 49159* NCU from Johnston Co., North Carolina; the specimen has the short hairy indument typical for the species). Twelve of the 14 specimens of the S. *ludoviciana* a priori group (86%) were assigned a posteriori to the *S. ludoviciana* group: 3 specimens with 91-93% probability, 4 specimens with 84-89% probability, 3 specimens with 70-75% probability, and 2 specimens with 65% and 62% probabilities. Two specimens of the *S. ludoviciana* a priori group were assigned a posteriori to other species: 1 specimen to *S. arguta* with 44% probability (16% to *S. salicina*, 11% to *S. boottii* and *S. harrisii*, 10% to *S. patula*, and 5% to *S. ludoviciana*; *Semple & Suripto 10074* WAT from Fort Bend Co., Texas) and to *S. patula* with 36% probability (35% to *S. salicina*, 9% to *S. tarda*, and 65% to *S. arguta*; *Lindheimer 84* MO from Texas). Ten of the 14 specimens of the *S. patula* a priori group (71%) were assigned a posteriori to the *S. patula* group: 2 specimens with 81-82% probability, 1 specimen with 71% probability, 2 specimens with 40% probability (22% to *S. salicina* and l6% to *S. arguta*; *Semple & Horsburgh 10575* WAT from Haldimand-Norfolk Reg. Mun., Ontario) and 50% probability (40% to *S. salicina* and 8% to *S. arguta*; *Fernald & Lewis 14750* GH from Brunswick Co., Virginia), and 4 specimens with 41% probability (30% to *S. salicina*, 17% to *S. arguta*, and 12% to *S. boottii*; *Morton & Venn NA10947* WAT from Sheboygan Co., Wisconsin), 40% probability (40% to *S. arguta*, 11% to *S. salicina*, and 5% *S. harrisii*; *Smith s.n.* GH from Macon Co., North Carolina), 39% probability (35% to *S. arguta*, 16% to *S. salicina*, and 7% to *S. boottii*; *Semple & Zhang 10589* WAT from Elgin Co., Ontario), and 32% probability (26% to *S. salicina*, and 16% to *S. arguta* and *S. boottii*; *Semple & Brouillet 3661* WAT from Oneida Co., New York). Four specimens of the *S. patula* a priori group with typical fine scabrous leaf indument were assigned a posteriori to other species: 3 specimens to *S. salicina* with 64% probability (22% to *S. patula* and 5% to *S. arguta* and *S. boottii*; *Semple 2389* WAT from Brant Co., Ontario), 57% probability (35% to *S. patula*; *Lewis 2322* GH from Brunswick Co., Virginia), and 46% probability (19% to *S. arguta*, 18% to *S. boottii*, and 13% to *S. patula*; *Semple 11132* WAT from Avery Co., North Carolina); and 1 specimen to *S. verna* with 47% probability (31% to *S. salicina* and 8% to *S. patula; Curtis s.n*. GH from Bedford Co., Virginia). Six of the 9 specimens of the *S. tarda* a priori group (67%) were assigned a posteriori to the *S. tarda* group: 3 specimens with 80-85% probability, 1 specimen with 73% probability, 1 specimen with 61% probability, and 1 specimen with 49% probability (28% to *S. verna*, 11% to *S. ludoviciana*, 7% to *S. patula* and 5% to *S. salicina*; *Morton 5136* NY from Cape May Co., New Jersey). Three specimens of the *S. tarda* a priori group were assigned to other species: 2 specimens to *S. boottii* with 51% probability (25% to *S. tarda* and 12% to S. arguta; *Morton 4323* NY from Tuscaloosa Co., Alabama) and 39% (30% to *S. tarda*, 14% to *S. arguta*, and 7% to *S. ludoviciana* and *S. salicina*; *Morton 4323* NY second sheet from Tuscaloosa Co., Alabama); and 1 specimen to *S. salicina* with 46% probability (16% to *S. patula*, 15% to *S. tarda* and 7% to *S. arguta* and *S. boottii*; *Morton 8272* NY from Cape May Co., New Jersey). Eleven of the 18 specimens of the *S. boottii* a priori group (61%) were assigned a posteriori to the *S. boottii* group: 6 specimens with 70-78% probability, 2 specimens with 55% probability (25% to *S. arguta*, 9% to *S. salicina*, and 8% to *S. harrisii*; *Demaree 6218* MO from Pike Co., Arkansas) and 50% probability (33 to *S. harrisii*, and 16% to *S. arguta*; *Williams 62189* LSU from Benton Co., Arkansas), and 2 specimens with 44% (22% to *S. salicina*, 18% to *S. arguta*, and 6% to *S. patula*; *Demaree 64009* MO from Crawford Co., Arkansas) and 29% probability (20% to *S. arguta*, 18% to *S. tarda*, 17% to *S. salicina*, and 14% to *S. patula*; *Allen 1442* LSU from St. Helena Par., Louisisana). Seven specimens of the *S. boottii* a priori group were assigned a posteriori to other species: 4 specimens to *S. arguta* with 44% probability (40% to *S. boottii*, and 5% to *S. patula* and *S. salicina*; 126; *Moore 5410* LSU from Lincoln Par., Louisisana), 43% probability (30% to *S. boottii*, 15% to *S. salicina*, and 8% *S. patula*; *Demaree 59538* MO from Logan Co., Arkansas), 42% probability (39% to *S. boottii*, 10% *S. salicina*, and 6% *S. patula*; *Greenman 4438* MO from Hampstead Co., Arkansas), and 40% probability (29% to *S. patula*, 18% to *S. salicina*, and 10% to *S. harrisii*; *Urbatsch et al. 6036* LSU from Washinton Par., Louisiana); 1 specimen to *S. ludoviciana* with 94% probability (*Bush 15246* MO from Carroll Co., Arkansas); 1 specimen to *S. faucibus* with 41% probability (28% to *S. harrisii*, 19% to *S. arguta*, and 5% to *S. salicina*; *Palmer 26430* MO from Logan Co., Arkansas); and 1 specimen to *S. tarda* with 27% probability (22% to *S. patula*, 18% to *S. salicina*, 16% to *S. arguta*, and 15% to *S. harrisii*; *Thomas & Thomas 108499* WAT from Ouachita Par., Louisiana). Six of the 11 specimens of the *S. salicina* a priori group (55%) were assigned a posteriori to the *S. salicina* group: 1 specimen with 67% probability, 1 specimen with 54% probability (41% to *S. patula*; *Cronquist 4880* NY from

Laurens Co., Georgia; neotype of the species), and 3 specimens with 45% probability (29% to *S. harrisii*, 13% to *S. arguta*, and 11% to *S. patula*; *Curtis s.n.* GH from North Carolina), 33% probability (22% to *S. boottii*, 19% to *S. arguta*, 13% to *S. patula*, and 12% to *S. harrisii*; *Godfrey 6732* GH from Wake Co., North Carolina), and 26% probability (24% to *S. boottii*, 19% to *S. arguta*, 13% to *S. harrisii*, and 9% to *S. patula*; *Godfrey 68383* GH from Bay Co., Florida). Five specimens of the *S. salicina* a priori group with typical fine scabrous leaf hairs for the species were assigned a posteriori to other species: 2 specimens to *S. patula* with 59% probability (26% to *S. salicina* and 14% to *S. arguta*: *Godfrey 12057* GH from Brunswick Co., North Carolina) and 56% probability (26% to *S.* arguta, 9% to *S. salicina*, and 7% to *S. ludoviciana*; *Thomas et al. 108382* WAT from Monroe Par., Louisiana); 1 specimen to *S. arguta* with 54% probability (37% to *S. patula*; *Godfrey s.n.* GH from Wake Co., North Carolina); 1 specimen to *S. boottii* with 38% probability (31% to *S.* salicina, 11% to *S.* arguta, 9% to *S. harrisii*, and 7% to *S. arguta*; *Godfrey 50794* GH from Wheeler Co., Georgia); and 1 specimen to *S. ludoviciana* with 41% probability (18% to *S. boottii*, 17% to *S. arguta*, 11% to *S. salicina*, and 6% to *S. harrisii*; *Semple & Suripto 10123* WAT from Harrison Co., Mississippi). Twelve of the 32 specimens of the *S. arguta* a priori group (38%; including var. *caroliniana*) were assigned a posteriori to the *S. arguta* group: 1 specimen with 62% probability, 1 specimen with 52% probability, 4 specimens with 40-47% probability, and 3 specimens with 31-39%. Twenty of the 32 specimens of the *S. arguta* a priori group were assigned a posteriori to other species; the details are not presented.

Two dimensional plots of CAN1 versus CAN3 and CAN1 versus CAN2 canonical scores for 153 specimens of *Solidago arguta* including var. *caroliniana*, *S. boottii*, *S. faucibus*, *S. harrisii*, *S. ludoviciana*, *S. patula*, *S. salicina*, *S. sphacelata*, *S. tarda*, and *S. verna* are presented in Fig. 34. Eigenvalues on the first three axes were 2.833, 1.763 and 0.873.

Table 4. Linear and jackknife classification matrices from the Classificatory Discriminant Analysis of ten a priori species groups; a posteriori placements to groups in rows.

Group	***arguta***	***boottii***	***faucibus***	***harrisii***	***ludo-viciana***	***patula***	***salicina***	***sphacelata***	***tarda***	***verna***	**% correct**
arguta	12	5	2	5	0	3	4	0	1	0	38
boottii	4	11	2	0	1	0	0	0	1	0	61
faucibus	0	0	1	0	0	0	0	0	0	0	100
harrisii	1	0	15	11	0	0	0	0	0	0	92
ludoviciana	1	0	0	0	12	1	0	0	0	0	86
patula	0	0	0	0	0	10	3	0	0	1	71
salicina	1	1	0	0	1	2	5	0	0	1	45
sphacelata	0	0	0	0	0	0	0	19	0	0	100
tarda	0	2	0	0	0	0	1	0	6	0	67
verna	0	0	0	0	1	0	0	0	0	8	89
Totals	19	19	18	16	15	16	13	19	8	10	71

Jackknifed classification matrix

Group	***arguta***	***boottii***	***faucibus***	***harrisii***	***ludo-viciana***	***patula***	***salicina***	***sphacelata***	***tarda***	***verna***	**% correct**
arguta	11	5	2	5	0	4	4	0	1	0	34
boottii	4	10	1	1	1	0	0	0	1	0	56
faucibus	1	0	14	0	0	0	0	0	0	0	93
harrisii	1	0	0	11	0	0	0	0	0	0	92
ludoviciana	1	0	0	0	12	1	0	0	0	0	86
patula	2	0	0	0	0	7	4	0	0	1	50
salicina	1	3	0	0	1	4	1	0	0	1	9
sphacelata	0	0	0	0	0	0	0	19	0	0	100
tarda	0	2	0	0	1	0	1	0	4	1	44
verna	0	0	1	0	1	0	0	0	0	7	78
Totals	21	20	18	17	16	16	10	19	6	10	63

Analysis 2: Eleven species a priori groups analysis

In the STEPWISE discriminant analysis 159 specimens of 11 species level a priori groups (*Solidago arguta*, *S. boottii*, *S. faucibus*, *S. harrisii*, *S. ludoviciana*, *S. patula*, *S. salicina*, *S. sphacelata*, *S. tarda*, *S. vaseyi* and *S. verna*), the following eight traits were selected as best separating the groups and are listed in order of decreasing F-to-remove values: disc floret pappus length at anthesis (18.22), involucre height (14.16), mid stem leaf width (7.77), ray floret lamina length (6.45), number of ray florets (6.23), disc corolla lobe length (5.21), number of disc florets (4.20), and upper leaf width (4.07). Wilks's lambda, Pillai's trace, and Lawley-Hotelling trace tests of the null hypothesis that all groups were samples of one group had probabilities of p = 0.000 that the null hypothesis was true. The F-matrix for the discriminant analysis is presented in Table 5. F-values based on Mahalanobis distances between group centroids indicated the largest separations were between *S. ludoviciana* and *S. sphacelata* (46.094), and the least separations were between *S. patula* and *S. salicina* (0.567), *S. boottii* and *S. vaseyi* (1.522), *S. arguta* and *S. salicina* (2.250) and *S. arguta* and *S. patula* (2.528).

In the Classificatory Discriminant Analysis of the eleven species level a priori groups (*Solidago arguta*, *S. boottii*, *S. faucibus*, *S. harrisii*, *S. ludoviciana*, *S. patula*, *S. salicina*, *S. sphacelata*, *S. tarda*, *S. vaseyi* and *S. verna*), percents of correct a posterori assignment to the same a priori group ranged from 63-100%. The Classification matrix and Jackknife classification matrix are presented in Table 6. Results are presented in order of decreasing percents of correct placement. <u>All 19 specimens of the *S. sphacelata* a priori group</u> (100%) were assigned a posteriori into the *S. sphacelata* group; 18 specimens with 92-100% probability and 1 specimen with 83% probability. <u>All fifteen of the specimens of the *S. faucibus* a priori group</u> (100%) were assigned a posteriori to the *S. faucibus* group; 11 specimens with 90-100% probability, 1 specimen with 83% probability, 1 specimen with 73% probability, 2 specimens with 67% and 63% probabilities, and 1 with 58% probability (29% to *S. vaseyi*; *Wieboldt 11085* WAT from Pickens Co., South Carolina). <u>Eleven of the 12 specimens of *S. harrisii* a priori group</u> (92%) were assigned a posteriori to the *S. harrisii* group: 4 specimens with 96-99% probability, 3 specimens with 81-88% probability, 3 specimens with 77-79% probability, and 1 specimen with 59% probability (16% to *S. vaseyi* and 13% to *S. arguta*;

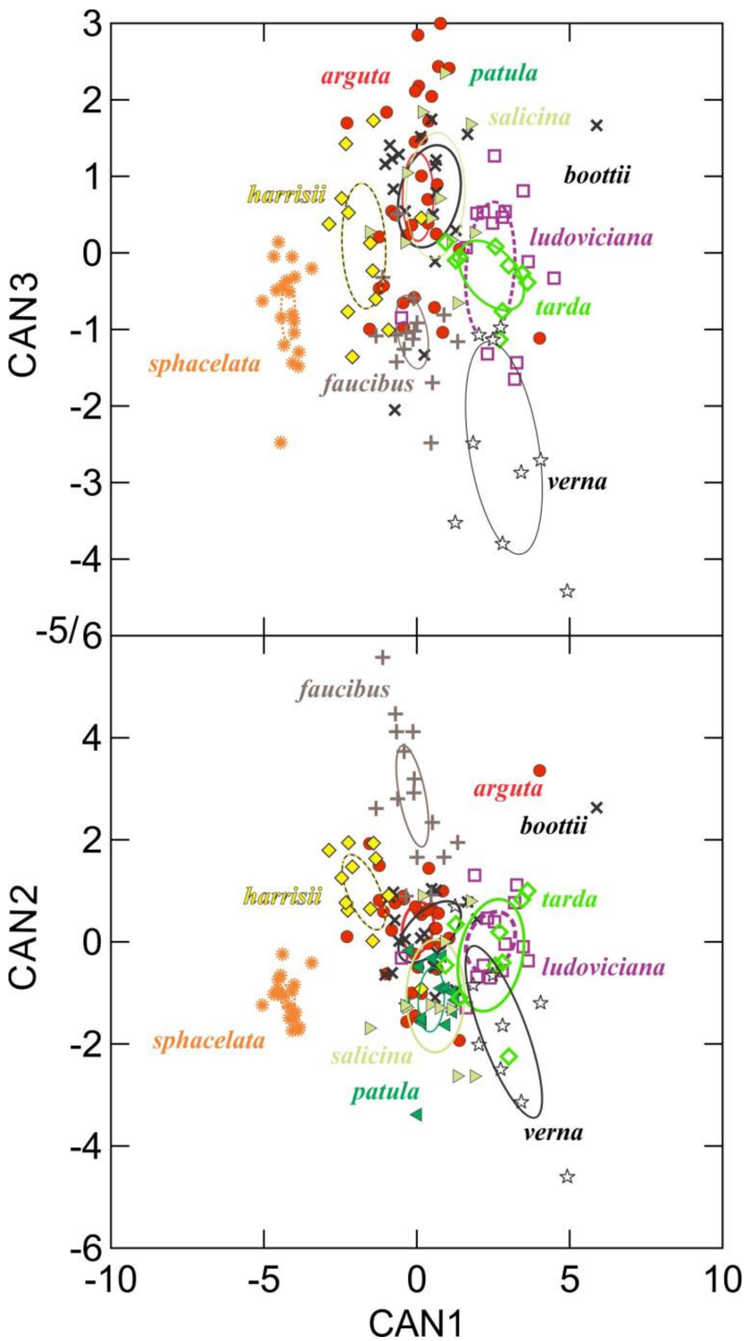

Figure 34. Plot of canonical scores (CAN1 vs CAN3 and CAN1 vs CAN2) for 138 specimens of *Solidago* subsect. *Argutae*: *S. arguta* including var. *caroliniana* (red dots), *S. boottii* (black +s), *S. faucibus* (brown +s), *S. harrisii* (yellow diamonds), *S. ludoviciana* (open magenta squares), *S. patula* (left oriented green triangles), *S. salicina* (right oriented light green triangles), *S. sphalcelata* (orange starburst), *S. tarda* (bright green outlined diamonds), and *S. verna* (black outlined stars).

Uttal 103011 VPI from Greenbrier Co., West Virginia). One specimen of the *S. harrisii* a priori group was assigned a posteriori to *S. salicina* with 32% probability (30% to *S. patula*, 19% to *S. arguta*, 6% to *S. vaseyi*, and 5% to *S. boottii*; *Harris s.n.* KY from Alleghany Co., Maryland). Eight of the 9 specimens of *S. verna* a priori group (92%) were assigned a posteriori to the *S. verna* group: 4 specimens with 99-99% probability, 1 specimen with 86% probability, 2 specimens with 75% and

Table 4. Between groups F-matrix for the eleven a priori species groups analysis.

Group	***arguta***	***boottii***	***faucibus***	***harrisii***	***ludo-viciana***	***patula***	***salicina***	***sphacelata***	***tarda***	***vaseyi***
boottii	6.128									
faucibus	12.648	14.392								
harrisii	5.232	7.060	7.619							
ludoviciana	14.275	8.527	18.194	18.135						
patula	2.528	7.433	17.973	9.875	11.833					
salicina	2.250	4.830	14.894	7.972	9.393	0.567				
sphacelata	26.817	31.201	33.201	11.364	46.094	26.175	22.676			
tarda	8.506	6.362	12.618	12.660	3.708	6.756	4.716	32.951		
vaseyi	7.448	1.522	11.346	6.763	7.430	7.668	6.117	25.936	7.813	
verna	20.545	19.136	22.686	22.943	11.978	13.802	10.944	40.224	4.841	18.626

Wilks' lambda = 0.01072 df = 8 10 142; Approx. F= 11.2924 df = 80 8641 prob = 0.0000

72% probabilities, and 1 specimen with 52% probability (34% to *S. ludoviciana* and 9% to *S. sphacelata*; *Leonard 7495* NCU from Pender Co., North Carolina). One specimen of the *S. verna* a priori group was assigned to *S. tarda* with 81% probability (*Godfrey 49159* NCU from Johnston Co., North Carolina). Twelve of the 14 specimens of the *S. ludoviciana* a priori group (86%) were assigned a posteriori to the *S. ludoviciana* group: 8 specimens with 92-100%, 2 specimens with 87% and 81%, 1 specimen with 77%, and 1 specimen with 54% (41% to *S. sphacelata*; *Taylor & Taylor23641* from McCurtain Co., Oklahoma). Two specimens of the *S. ludoviciana* a priori group were assigned a posteriori to other species: 1 specimen with 40% to *S. patula* (40% to *S. salicina*, 8% to *S. tarda*; *Lindheimer 84* MO from Texas) and 1 specimen with 29% to *S. salicina* (20% to *S. harrisii*, 19% to *S. arguta*, and 16% to *S. patula*; *Semple & Suripto 10074* WAT from Fort Bend Co., Texas). Eleven of the 16 specimens of the *S. vaseyi* a priori group (69%) were assigned a posteriori to the *S. vaseyi* group: 1 specimen with 96% probability, 2 specimens with 73% and 70% probabilities, 2 specimens with 69% and 63% probabilities, 2 specimens with 56% probability (30% to *S. boottii*; *Semple & Chmielewski 6207* WAT from Rabun Co., Georgia; tetraploid) and 53% probability (38% to *S. boottii*; *Semple & B. Semple 11182* WAT from Campbell Co., Tennessee; tetraploid), and 3 specimens with 46% probability (26% to *S. harrrisii*, 13% to *S. boottii*, and 9% to *S. faucibus*; Bush *65* MO from Barry Co., Missouri; main veins of leaves not hairy), 45% probability (*Semple & Suripto 9444* WAT from Adair Co., Kentucky; tetraploid), and 38% probability (35% to *S. boottii* and 9% to *S. salicina*; Semple *& Suripto 9613* WAT from Laurel Co., Kentucky; tetraploid). Five specimens of the *S. vaseyi* a priori group were assigned to other species: 2 specimens to *S. harrisii* with 79% probability (*Semple & B. Semple 11138* WAT from Augusta Co., Virginia; identity changed to *S. harrisii*, diploid) and 67% probability (23% to *S. vaseyi*; *Kellogg s.n.* MO from McDonald Co., Missouri; leaf veins not hairy); 2 specimens to *S. ludoviciana* with 65% probability (29% to *S. tarda*; *Semple et al. 2538* WAT from Volusia Co., Florida; diploid) and 44% probability (*Semple & Suripto 9692* WAT from Buncombe Co., North Carolina); and 1 specimens to *S. boottii* with 54% probability (25% to *S.* arguta and 11% to *S. vaseyi*; *Semple et al. 11875* WAT from Cocke Co., Tennessee; mid stem leaf veins glabrous, cypselae moderately strigose on distal half). Twelve of the 18 specimens of the *S. boottii* a priori group (67%) were assigned a posteriori to the *S. boottii* group: 5 specimens with 72-78% probability, 2 specimens with 65% and 60% probabilities, 1 specimen with 56% probability (23% to *S. vaseyi*, and 19% to *S. harrisii*; *Williams 62189* LSU from

Benton Co., Arkansas), and 2 specimens with 48% probability (46% to *S. vaseyi*; *Greenman 4438* MO from Hempstead Co., Arkansas), and 39% probability (*Demaree 59538* MO from Logan Co., Arkansas). Five specimens of the *S. vaseyi* a priori group were assigned to other species (all 5 had hairy abaxial leaf midveins): 4 specimens to *S. vaseyi* with 70% probability (27% to *S. boottii*; *Moore 5410* LSU from Lincoln Par., Louisiana), 46% probability (40% to *S. boottii*; *Allen 1442* LSU from St. Helena Par., Louisisana), 38% probability (31% to *S. faucibus*, and 21% to *S. harrisii*; *Palmer 26430* MO from Logan Co., Arkansas), and 37% probability (19% to *S. boottii*, 17% to *S. patula*, 15% to *S. arguta*, and 10% to *S. salicina*: *Urbatsch et al. 6036* LSU from Washington Par., Louisana); 1 specimen to *S. ludoviciana* with 99% probability (*Bush 15246* MO from Carroll Co., Arkansas); and 1 specimens to *S. patula* with 27% probability (27% to *S. tarda*, 24 % to *S. salicina*, and 10% to *S arguta*; *Thomas & Thomas 108499* WAT from from Ouachita Par., Louisiana). Nine of the 14 specimens of the *S. patula* a priori group (64%) were assigned a posteriori to the *S. patula* group: 2 specimens with 77% probability and 71% probability, 1 specimens with 65% probability, 2 specimens with 57% probability (23% to *S. salicina*; *Semple & Horsburgh 10575* WAT from Haldimand-Norfolk Reg. Mun., Ontario) and 57% probability (32% to *S. arguta* and 12% to *S. salicina*; *Semple & B. Semple 11230* WAT from Macon Co., North Carolina), and 4 specimens with 47% probability (28% to *S. arguta* and 14% to *S. salicina*; *Smith s.n.* GH from Macon Co., North Carolina), 46% probability (31% to *S. salicina* and 9% to *S. vaseyi*; *Fernald & Lewis 14750* GH from Brunswick Co., Virginia), 45% probability (33% to *S. salicina* and 17% to *S. arguta*; *Morton & Venn NA10947* WAT from Sheboygan Co., Wisconsin), and 32% probability (*Semple & Brouillet 3661* WAT from Oneida Co., New York). Five specimens of the *S. patula* a priori group were assigned to other species (all 5 had finely scabrous adaxial leaf surfaces): 4 specimens to *S. salicina* with 61% probability (22% to *S. patula* and 8% to *S. boottii*; *Semple 2389* WAT from Brant Co., Ontario), 55% probability (24% to *S. arguta* and 15% to *S. patula*; *Semple 11132* WAT from Avery Co. North Carolina), 54% probability (34% to *S. patula* and 11% to *S. arguta*; *Lewis 2322* GH from Brunswick Co., Virginia), and 42% probability (31% to *S. verna* and 11% to *S. patula*, and 9% to *S. tarda*; *Curtis s.n.* GH from North Carolina); and 1 specimen to *S. vaseyi* with 31% probability (21% to *S. patula*, 21% to *S. arguta*, and 19% to *S. boottii*, 9% to *S. salicina*; *Semple & Zhang 10589* WAT from Elgin Co., Ontario). Seven of the 11 specimens of the *S. salicina* a priori group (64%) were assigned a posteriori to the *S. salicina* group: 1 specimen with 71% probability, 2 specimens with 66% and 63% probabilities, 2 specimens with 51% probability (42% to *S. patula*; *Cronquist 4880* NY from Laurens Co., Georgia; neotype of the species) and 50% probability (32% to *S. arguta* and 12% to *S. salicina*; *Godfrey 50794* GH from Wheeler Co., Georgia), and 2 specimens with 37% probability (18% to *S. harrisii*, 15% to *S.. tarda*, 11% to *S. patula*, and 7% to *S. boottii*; *Godfrey 68383* GH from Bay Co., Florida) and 24% probability (*Semple & Suripto 10123* WAT from Harrison Co., Mississippi). Four specimens of the *S. salicina* a priori group were assigned to other species: 2 specimens to *S. arguta* with 74% probability (21% to *S. patula*; *Godfrey s.n.* GH from Wake Co., North Carolina) and 56% probability (30% to *S. patula* and 14% to *S. salicina*; *Godfrey 12057* GH from Brunswick Co., North Carolina); 1 specimen to *S. patula* with 45% (44% to *S. arguta* and 7% to *S. salicina*; *Thomas et al. 108382* WAT from Monroe Par., Louisiana), and 1 specimen to *S. boottii* with 40% probability (19% to *S. salicina*, 17% to *S. vaseyi*, 9% to *S. harrisii*, and 7% to *S. arguta*; ; *Godfrey 6732* GH from Wake Co., North Carolina). Nine of the 16 specimens of the *S. arguta* a priori group (63%) were assigned a posteriori to the *S. arguta* group: 1 specimen with 90% probability, 1 specimen with 86% probability, 1 specimen with 74% probability, 2 specimens with 63% and 60% probabilities, 2 specimens with 59% probability (19% to *S. salicina* and 18% to *S. patula*; *Semple & Brouillet 3459* WAT from Grafton Co., New Hampshire) and 53% probability (19% to *S. boottii* 16% to *S. harrisii*, and 8% to *S. salicina*; *Semple & Brouillet 3619* WAT from Hartford Co., Connecticut; diploid), and 3

Table 5. Linear and jackknife classification matrices from the Classificatory Discriminant Analysis of eleven a priori species groups; a posteriori placements to groups in rows.

Group	***arguta***	***boottii***	***faucibus***	***harrisii***	***ludo-viciana***	***patula***	***salicina***	***sphacelata***	***tarda***	***vaseyi***	***verna***	**% correct**
arguta	10	0	0	2	0	2	1	0	0	1	0	63
boottii	0	12	0	0	1	0	0	0	1	4	0	67
faucibus	0	0	15	0	0	0	0	0	0	0	0	100
harrisii	0	0	0	11	0	0	1	0	0	0	0	92
ludoviciana	0	0	0	0	12	0	2	0	0	0	0	86
patula	0	0	0	0	0	9	4	0	0	1	0	64
salicina	2	1	0	0	0	1	7	0	0	0	0	64
sphacelata	0	0	0	0	0	0	0	19	0	0	0	100
tarda	0	2	0	0	1	0	0	0	6	0	0	67
vaseyi	0	1	0	2	2	0	0	0	0	11	0	69
verna	0	0	0	0	0	0	0	0	1	0	8	89
Totals	12	15	15	15	16	12	15	19	8	17	8	78

Jackknifed classification matrix

Group	***arguta***	***boottii***	***faucibus***	***harrisii***	***ludo-viciana***	***patula***	***salicina***	***sphacelata***	***tarda***	***vaseyi***	***verna***	**% correct**
arguta	6	0	0	2	0	2	3	0	0	2	0	38
boottii	0	10	1	0	1	0	0	0	1	5	0	56
faucibus	0	0	14	0	0	0	0	0	0	1	0	93
harrisii	0	0	0	11	0	0	1	0	0	0	0	92
ludoviciana	0	0	0	0	11	0	2	0	1	0	0	79
patula	2	0	0	0	0	4	6	0	0	1	1	29
salicina	3	1	0	1	0	2	2	0	1	0	1	18
sphacelata	0	0	0	0	0	0	0	19	0	0	0	100
tarda	0	2	0	0	1	0	1	0	3	0	2	33
vaseyi	0	1	1	2	2	0	0	0	0	10	0	63
verna	0	0	1	0	1	0	0	0	1	0	6	67
Totals	11	15	17	16	16	8	15	19	7	19	10	63

specimens with 43% probability (32% to *S. salicina* and 2% to *S. patula*; *Semple & Suripto 9489* WAT from Perry Co., Pennsylvania), 40% probability (30% to *S. vaseyi*, 14% to *S. patula*, and 7% to *S. harrisii*; *Steyermark 23580* MO from Howell Co., Missouri) and 33% probability (31% to *S. salicina*, 17% to *S. patula*, and 8% to *S. tarda*; *Semple 6883* WAT from Windham Co., Vermont). Six specimens of the *S. arguta* a priori group were assigned to other species: 2 specimens to *S. harrisii* with 56% probability (19% to *S.* arguta, 11% to *S. faucibus*, and 8% to *S. vaseyi*; *Steyermark 12879* MO from Reynolds Co., Missouri) and 43% probability (35% to *S.* vaseyi and 9% to *S. arguta*; *Kellogg 1314* MO from Dent Co., Missouri); 2 specimens to *S. patula* with 52% probability (43% to *S. arguta*; *Semple & Suripto 9485* WAT from Juniata Co., Pennsylvania) and 41% probability (38%

to *S. salicina* and 20% to *S. arguta*; *Semple & Keir 9484* WAT from Cumberland Co., Maine); 1 specimen to *S. vaseyi* with 47% probability (15% to *S. faucibus*, 14% to *S. harrisii*, and 12% to *S. arguta; Redfearn at el. 1740* MO from Shannon Co., Missouri); and 1 specimen to *S. salicina* with 46% probability (27% to *S. patula*and 16% to *S. arguta*; *Redfearn et al. 650* MO from Shannon Co., Missouri).

Two dimensional plots of CAN1 versus CAN3 and CAN1 versus CAN2 canonical scores for 153 specimens of *Solidago arguta*, *S. boottii*, *S. faucibus*, *S. harrisii*, *S. ludoviciana*, *S. patula*, *S. salicina*, *S. sphacelata*, *S. tarda*, *S. vaseyi*, and *S. verna* are presented in Fig. 35. Eigenvalues on the first three axes were 4.144, 1.592 and 1.212.

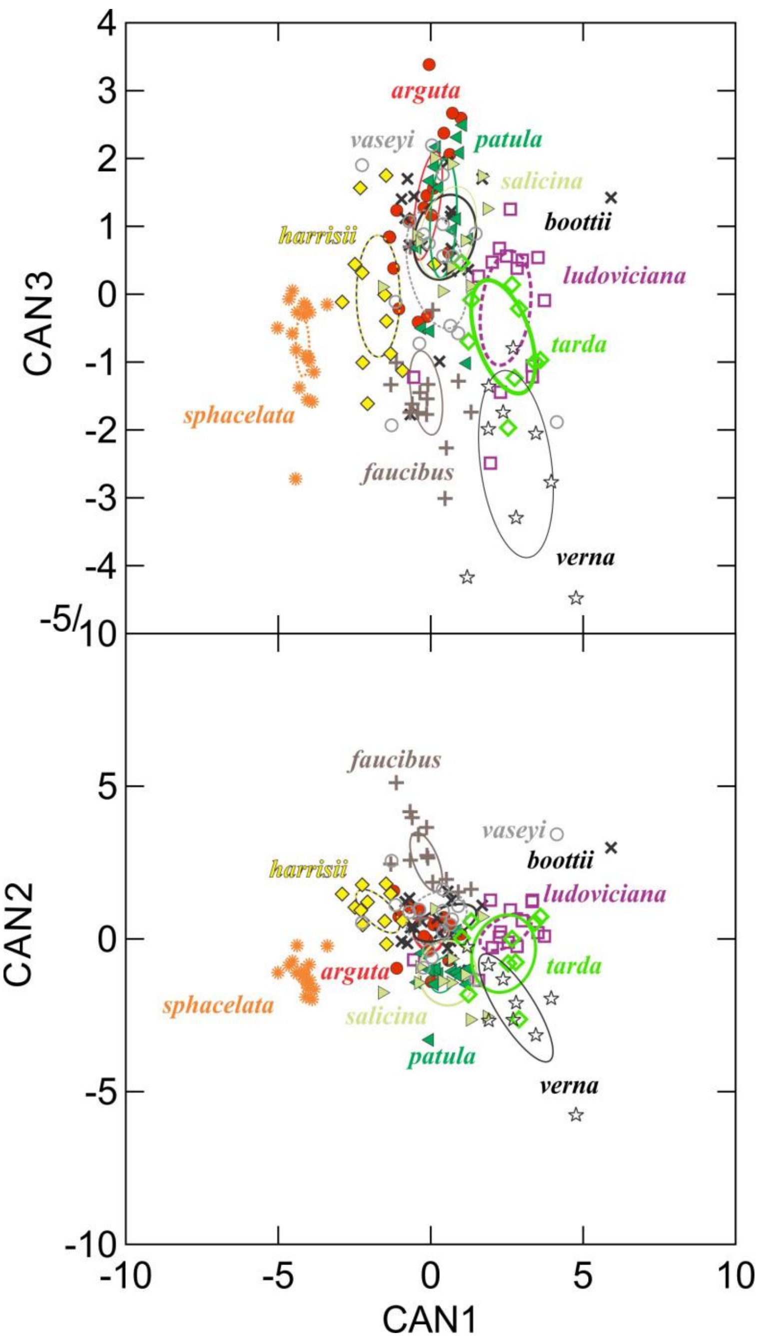

Figure 35. Plot of canonical scores (CAN1 vs CAN3 and CAN1 vs CAN2) for 153 specimens of *Solidago* subsect. *Argutae*: *S. arguta* (red dots), *S. boottii* (black +s), *S. faucibus* (brown +s), *S. harrisii* (yellow diamonds), *S. ludoviciana* (open magenta squares), *S. patula* (left oriented green triangles), *S. salicina* (right oriented light green triangles), *S. sphalcelata* (orange starburst), *S. tarda* (bright green outlined diamonds), *S. vaseyi* (gray circles), and *S. verna* (black outlined stars).

Analysis 3: Seven species a priori groups analysis

In the STEPWISE discriminant analysis of 109 specimens of seven species level a priori groups (*S. arguta* including var. *caroliniana/S. vaseyi*, *S. boottii*, *S. faucibus*, *S. harrisii*, *S. ludoviciana*, *S. tarda*, and *S. verna*), the following seven traits were selected as best separating the groups and are listed in order of decreasing F-to-remove values: involucre height (14.92), ray floret lamina length (14.07), disc floret corolla lobe length (6.78), disc floret pappus length at anthesis (6.53), mid stem leaf length (6.37), upper stem leaf width (5.24), and number of ray florets (4.87). Wilks's lambda, Pillai's trace, and Lawley-Hotelling trace tests of the null hypothesis that all groups were the samples of one group had probabilities of p = 0.000 that the null hypothesis was true. The F-matrix for the discriminant analysis is presented in Table 7. F-values based on Mahalanobis distances between group centroids indicated the largest separation was between *S. arguta* and *S. verna* (23.603), and the least separations were between *S. arguta* and *S. boottii* (2.853) and *S. ludoviciana* and *S. tarda* (3.876).

Table 7. Between groups F-matrix for the seven species a priori groups analysis (df = 6 97).

Group	***arguta***	***boottii***	***faucibus***	***harrisii***	***ludo-viciana***	***tarda***
boottii	2.853					
faucibus	11.221	14.033				
harrisii	4.671	5.517	8.498			
ludoviciana	10.044	8.182	14.373	14.355		
tarda	7.915	5.996	10.681	10.522	3.876	
verna	23.603	19.241	20.775	20.816	15.036	5.341

In the Classificatory Discriminant Analysis of 109 specimens of the seven species level a priori groups (*S. arguta* including var. *caroliniana/S. vaseyi*, *S. boottii*, *S. faucibus*, *S. harrisii*, *S. ludoviciana*, *S. tarda*, and *S. verna*), percents of correct a posterori assignment to the same a priori group ranged from 61-93%. The Classification matrix and Jackknife classification matrix are presented in Table 8. Results are presented in order of decreasing percents of correct placement. <u>Thirteen of the 14 specimens of the *S. ludoviciana* a priori group</u> (93%) were assigned a posteriori into the *S. ludoviciana* group; 6 specimens with 91-98% probability, 2 specimens with 85-86% probability, 2 specimens with 76% probability, 1 specimen with 60% probility, and 2 specimens with 48% probability (44% to *S. tarda*; *Taylor & Taylor 23641* from McCurtain Co., Oklahoma) and 37% probability (33% to *S. tarda* and 25% to *S. arguta*; *Lindheimer 84* MO from Texas). One specimen of the *S. ludoviciana* a priori group was assigned to *S. arguta* with 36% probability (24% to *S. tarda:*, 20% to *S. ludoviciana*, 12% to *S. harrisii*, and 5% to *S. boottii*; *Semple & Suripto 10074* WAT from Fort Bend Co., Texas; the specimen has a damaged inflorescence). <u>Eight of the 9 specimens of the *S. verna* a priori group</u> (89%) were assigned a posteriori to the *S. verna* group; 6 specimens with 93-100% probability, 1 specimen with 87% probability, and 1 specimen with 64% probability. One specimen of the *S. verna* a priori group was assigned to *S. tarda* with 84% probability (8% to *S. ludoviciana* and 6% to *S. boottii*; *Godfrey 49159* NCU from Johnston Co., North Carolina). <u>Ten of the 12 specimens of the *S. harrisii* priori group</u> (83%) were assigned a posteriori to the *S. harrisii* group: 4 specimens with 90-98% probability, 3 specimens with 80-83% probability, 1 specimen with 66% probability, and 1 specimen with 43% probability (33% to *S. arguta* and 23% to *S. faucibus*; *Wieboldt et al. 6826* VPI from Wise Co., Virginia). Two specimens of the *S. harrisii* a priori group were assigned a posteriori to *S. arguta*: 1 specimen with 55% (34% to *S. harrisii* and 8% to *S. boottii*;

Uttal 103011 VPI from Greenbrier Co., West Virginia) and 1 specimen with 51% probability (24% to *S. ludoviciana*, 13% to *S. boottii*, and 7% to *S. harrisii*; *Harris s.n.* KY from Alleghany Co., Maryland). Twelve of the 15 specimens of the *S. faucibus* a priori group (80%) were assigned a posteriori to the *S. faucibus* group: 7 specimens with 99-100% probability, 4 specimens with 82-86% probability, and 1 specimen with 46% probability (27% to *S. ludoviciana* and 21% to *S. tarda*; *Wieboldt 5825-A1* VPI from from Scott Co., Virginia). Three specimens of the *S. faucibus* a priori group were assigned a posteriori to other species: 1 specimen to *S. ludoviciana* with 45% (23% to *S. faucibus*, 15% to *S. tarda*, and 13% to *S. arguta*; *Wieboldt 5893-C1* VPI from Lee Co., Virginia), 1 specimen to *S arguta* with 37% probability (35% to *S. faucibus*, 13% to *S. tarda*, and 6% to *S. ludoviciana*; *Wieboldt 7913-1* VPI from Buchanan Co., Virginia), and 1 specimen to *S. tarda* with 36% probability (36% to *S. verna*, and 24% to *S. faucibus*; *Wieboldt 11083* VPI from Pickens Co., South Carolina). Six of the 9 specimens of the *S. tarda* a priori group (67%) were assigned a posteriori to the *S. tarda* group: 3 specimens with 91-92% probability, 2 specimens with 81% probability, and 1 specimen with 44% probability (38% to *S. boottii* and 16% to *S. ludoviciana*; *Somers s.n.* NY from Geneva Co., Alabama). Three specimens of the *S. tarda* a priori group were assigned a posteriori to other species: 1 specimen to *S. verna* with 90% (10% to *S. tarda*; *Morton 8272* NY from Cape May Co., New Jersey); and 2 specimens to *S. boottii* with 78% probability (24% to *S. ludoviciana*, 13% to *S. boottii*, and 7% to *S. harrisii*; *Morton 4323* NY from Tuscaloosa Co., Alabama, second sheet) and 49% probability (20% to *S. arguta*, 19% to *S. tarda and 11% to S. ludoviciana*; *Morton 4323* NY from Tuscaloosa Co., Alabama). Twenty-one of the 32 specimens of the *S. arguta* a priori group (66%) were assigned a posteriori to the *S. arguta* group: 1 specimen with 97% probability, 2 specimens with 80-81% probability, 4 specimen with 70-76% probability, 4 specimens with 60-68% probability, 6 specimens with 54% probability (41% to *S. boottii*; *Cook et al. C-550* WAT from Buncombe Co., North Carolina), 53% probability (39% to *S. boottii*; *Sauleda 5977A* WAT from Morris Co., New Jersey), 52% probability (16% to *S. boottii*, 16% to *S. harrisii*, and 16% to *S. tarda*; *Morton & Venn NA6562* WAT from Bedford Co., Virginia), 52% probability (17% to *S. boottii*, 12% to *S. ludoviciana*, 11% to *S. faucibus*, and 5% to *S. harrisii*; *Semple & B. Semple 11192* WAT from Blount Co., Alabama; tetraploid), 50% probability (38% to *S. boottii*; *Semple & Suripto 9613* WAT from Laurel Co., Kentucky; tetraploid) and 50% probability (34% to *S. boottii* and 11% to *S. harrisii*; *Kellogg 1314* MO from Dent Co., Missouri), and 4 specimens with 46% probability (34% to *S. boottii* and 11% to *S. harrisii*; *Steyermark 23636* MO from Douglas Co., Missouri), 43% probability (35% to *S. boottii* and 14% to *S. ludoviciana*; *Semple & Suripto 9706* WAT from Wilkes Co., North Carolina), 39% probability (31% to *S. harrisii* and 9% to *S. faucibus*; *Bush 65* MO from Barry Co., Missouri), and 33% probability (32% to *S. ludoviciana*, 17% to *S. tarda*, and 13% to *S. harrisii*; *Semple 6883* WAT from Windham Co., Vermont). Eleven specimens of the *S. arguta* a priori group were assigned a posteriori to other species: 3 specimens to *S. harrisii* with 75% probability (15% to *S. arguta* and 9% to *S. boottii*; *Kellogg s.n.* MO from McDonald Co., Missouri), 71% probability (18% to *S. boottii* and 11% to *S. arguta*; *Semple & B. Semple 11138* WAT from Augusta Co., Virginia; identity changed to *S. harrisii*, diploid), and 44% probability (42% to *S. boottii* and 13% to *S. arguta*; *Semple & Brouillet 3619* WAT from Hartford Co., Connecticut; diploid); 5 specimens to *S. boottii* with 64% probability (27% to *S. arguta*; *Semple & Chmielewski 6207* WAT from Rabun Co., Georgia; tetraploid), 50% probability (46% to *S. arguta*; *Semple et al. 11875* WAT from Cocke Co., Tennessee), 49% probability (42% to *S. arguta*; *Semple & B. Semple 11182* WAT from Campbell Co., Tennessee; tetraploid), 36% probability (*Semple & Suripto 9792* WAT from Berkeley Co., South Carolina; diploid with lower stem leaves ca. 3.5 cm broad), and 35% probability (35% to *S. ludoviciana* and 26% to *S. arguta*; *Semple & Suripto 9692* WAT from Buncombe Co., North Carolina); 1 specimen to *S. ludoviciana* with 49% probability (40% to *S. tarda*;

Semple et al. 2538 WAT from Volusia Co., Florida; diploid); and 1 specimen to *S. faucibus* with 47% probability (30% to *S. arguta* and 12% to *S. boottii*; *Semple & Chmielewski 5931* WAT from Nelson, Virginia). Eleven of the 18 specimens of the *S. boottii* a priori group (61%) were assigned a posteriori to the *S. boottii* group: 3 specimens with 82-84% probability, 4 specimens with 73-77% probability, 1 specimen with 62% probability, 1 specimen with 57% probability (21% to *S. arguta* and 17% to *S harrisii*; *Allen 1442* LSU from St. Helena Par., Louisisana), and 2 specimens with 46% probability (42% to *S. harrisii* and 12% to *S. arguta*; *Williams 62189* LSU from Benton Co., Arkansas) and 45% probability (36% to *S. harrisii* and 11% to *S. arguta*; *Redfearn at el. 1740* MO from Shannon Co., Missouri). Seven specimens of the *S. boottii* a priori group were assigned a posteriori to other species; 1 specimen to *S. ludoviciana* with 99% probability (*Bush 15246* MO from Carroll Co., Arkansas; adaxial leaf midvein distally densely long hairy); 5 specimens to *S. arguta* with 70% probability (21% to *S. boottii* and 9% to *S. harrisii*; *Urbatsch et al. 6036* LSU from Washington Par., Louisiana), 59% probability (39% to *S. boottii; Greenman 4438* MO from Hempstead Co., Arkansas), 55% probability (41% to *S. boottii*; *Demaree 59538* MO from Logan Co., Arkansas), and 46% probability (43% to *S. boottii* and 9% to *S. harrisii*; *Moore 5410* LSU from Lincoln Par., Louisiana); and 1 specimen to *S. tarda* with 31% probability (29% to *S. arguta*, 22% to *S. boottii*, and 16% to *S. harrisii*; *Thomas & Thomas 108499* WAT from from Ouachita Par., Louisiana).

Table 7. Linear and jackknife classification matrices from the Classificatory Discriminant Analysis of seven a priori groups; a posteriori placements to groups in rows.

Group	***arguta***	***boottii***	***faucibus***	***harrisii***	***ludoviciana***	***tarda***	***verna***	**% correct**
arguta	21	5	2	3	1	0	0	66
boottii	5	11	0	0	1	1	0	61
faucibus	1	0	12	0	1	0	1	80
harrisii	2	0	0	10	0	0	0	83
ludoviciana	1	0	0	0	13	0	0	93
tarda	0	2	0	0	0	6	1	67
verna	0	0	0	0	0	1	8	89
Totals	30	18	14	13	16	8	10	74

Jackknifed classification matrix

Group	***arguta***	***boottii***	***faucibus***	***harrisii***	***ludoviciana***	***tarda***	***verna***	**% correct**
arguta	17	6	3	3	3	0	0	53
boottii	5	8	1	2	1	1	0	44
faucibus	1	0	12	0	1	1	0	80
harrisii	3	0	0	9	0	0	0	75
ludviciana	1	0	1	0	10	2	0	71
tarda	0	3	0	0	0	5	1	56
verna	0	0	0	0	0	2	7	78
Totals	27	17	17	14	15	11	8	62

Two dimensional plots of CAN1 versus CAN3 and CAN1 versus CAN2 canonical scores for 109 specimens of *S. arguta* (including var. *caroliniana/S. vaseyi*), *S. boottii*, *S. faucibus*, *S. harrisii*, *S. ludoviciana*, *S. tarda*, and *S. verna* presented in Fig. 37. Eigenvalues on the first three axes were 2.288, 1.175 and 0.360.

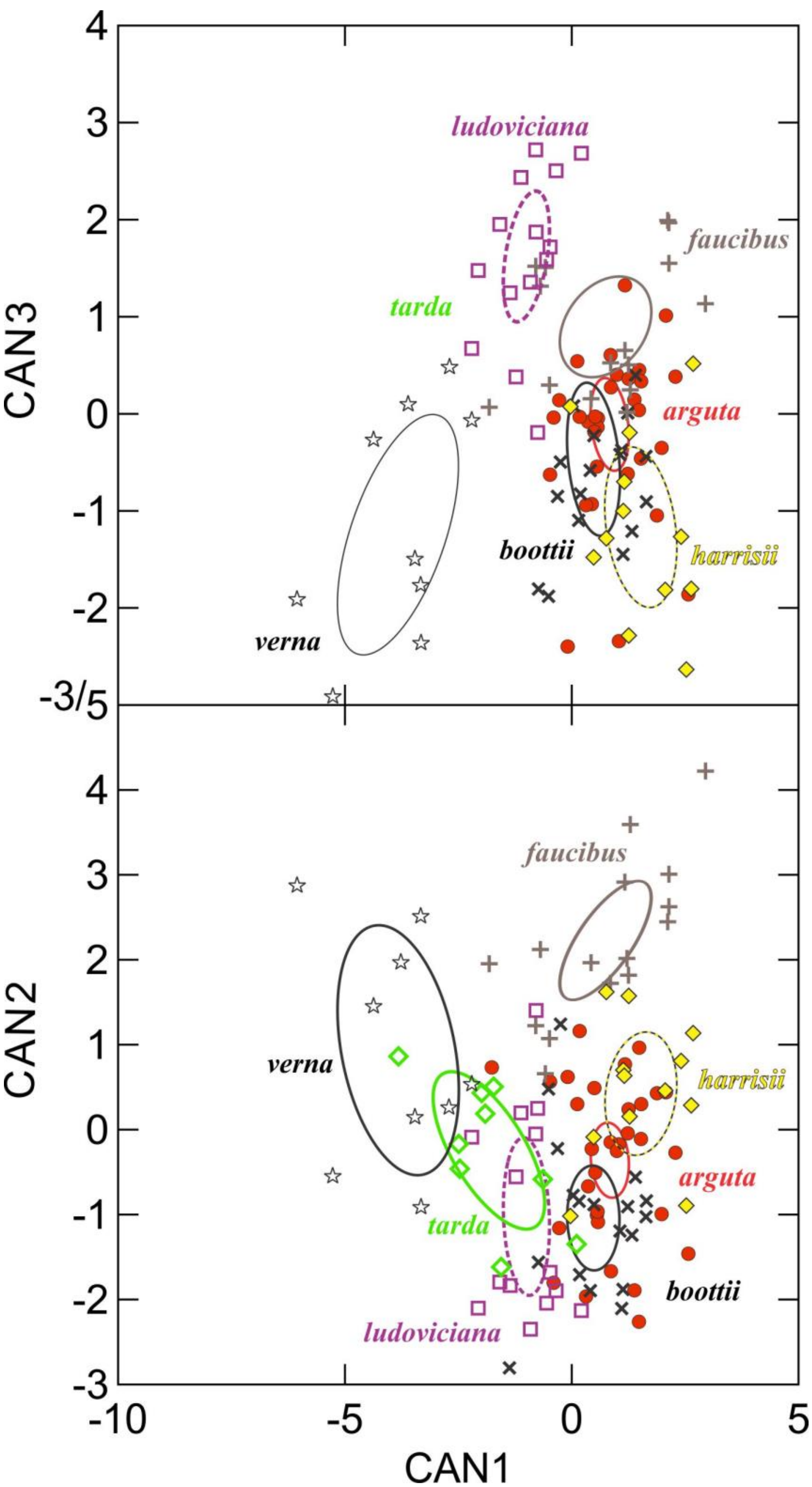

Figure 36. Plot of canonical scores (CAN1 vs CAN3 and CAN1 vs CAN2) for 109 specimens of *Solidago* subsect. *Argutae*: *S. arguta* (red dots), *S. boottii* (black +s), *S. faucibus* (brown +s), *S. harrisii* (yellow diamonds), *S. ludoviciana* (open magenta squares), *S. tarda* (bright green outlined diamonds), and *S. verna* (black outlined stars).

Analysis 4: Eight species a priori groups

In the STEPWISE discriminant analysis of 109 specimens of eight species level a priori groups (*S. arguta*, *S. boottii*, *S. faucibus*, *S. harrisii*, *S. ludoviciana*, *S. tarda*, *S. vaseyi*, and *S. verna*), the following seven traits were selected as best separating the groups and are listed in order of decreasing F-to-remove values: involucre height (13.22), ray floret lamina length (12.19), number of ray florets (7.46), mid stem leaf length (7.36), disc floret corolla lobe lengths (6.25), disc floret pappus length at anthesis (5.75), and upper stem leaf width (4.92). Wilks's lambda, Pillai's trace, and Lawley-Hotelling trace tests of the null hypothesis that all groups were the samples of one group had probabilities of p = 0.000 that the null hypothesis was true. The F-matrix for the discriminant analysis is presented in Table 9. F-values based on Mahalanobis distances between group centroids indicated the largest separation was between *S. arguta* and *S. verna* (21.882), and the least separation was between *S. boottii* and *S. vaseyi* (1.441).

Table 8. Between groups F-matrix for the eight species a priori groups analysis (df = 8 94).

Group	***arguta***	***boottii***	***faucibus***	***harrisii***	***ludo-viciana***	***tarda***	***vaseyi***
boottii	7.642						
faucibus	11.123	14.097					
harrisii	5.763	5.699	8.412				
ludoviciana	12.971	8.103	14.481	14.493			
tarda	8.217	6.132	10.572	10.412	4.078		
vaseyi	7.703	1.441	9.504	4.827	6.818	7.421	
verna	21.882	19.091	20.585	20.642	14.959	5.322	19.398

Wilks' lambda = 0.0321 df = 7 7 101; Approx. F= 9.6133 df = 49 486 prob = 0.0000

In the Classificatory Discriminant Analysis of 109 specimens of the eight species level a priori groups (*S. arguta*, *S. boottii*, *S. faucibus*, *S. harrisii*, *S. ludoviciana*, *S. tarda*, *S. vaseyi*, and *S. verna*), percents of correct a posterori assignment to the same a priori group ranged from 56-89%. The Classification matrix and Jackknife classification matrix are presented in Table 10. Results are presented in order of decreasing percents of correct placement. Eight of 9 specimens of the *S. verna* a priori group (89%) were assigned a posteriori into the *S. verna* group; 6 specimens with 92-100% probability, 1 specimen with 89% probability, and 1 specimen with 61% probability. One specimen of the *S. verna* a priori group was assigned to *S. tarda* with 87% probability (7% to *S. vaseyi* and 6% to *S. arguta*; *Godfrey 49159* NCU from Johnston Co., North Carolina; has the stem and leaf indument typical of *S.* verna and bloomed in May). Twelve of the 14 specimens of the *S. ludoviciana* a priori group (86%) were assigned a posteriori to the *S. ludoviciana* group; 6 specimens with 90-98% probability, 2 specimens with 89% and 83% probabilities, 2 specimens with 77-78% probability, 1 specimen with 64% probability, and 1 specimen with 50% probability (43% to *S. tarda*; *Taylor & Taylor 23641*). Two specimens of the *S. ludoviciana* a priori group were assigned to *S. tarda* with 37% probability (28% to *S. arguta*, 26% to *S. ludoviciana*, and 5% to *S. vaseyi*; *Lindheimer 84* MO from Texas) and 27% probability (18% to *S. arguta* and *S. ludoviciana*, 15% to *S. vaseyi*, 14% to *S. tarda*, and 5% to *S. boottii*; *Semple & Suripto 10074* WAT from Fort Bend Co., Texas; the specimen has a damaged inflorescence). Ten of the 12 specimens of the *S. harrisii* a priori group (83%) were assigned a posteriori to the *S. harrisii* group: 3 specimens with 91-88% probability, 2 specimens with 80-81% probability, 2 specimens with 77-78% probability, 1 specimen with 66% probability, and 1 specimen with 40% probability (32% to *S. arguta* and 22% to *S. faucibus*; *Wieboldt et al. 6826* VPI from Wise Co., Virginia). Two specimens of the *S. harrisii* a priori group were assigned a posteriori to the other species: 1 specimen to *S. vaseyi* with 37% probability (36% to *S. harrisii*, 15% to *S. arguta*, and 8% to *S. boottii*; *Uttal 103011* VPI from Greenbrier Co., West Virginia); and 1 specimen to *S arguta* with 36% probability (20% to *S. ludoviciana*, 17% to *S. vaseyi*, 12% to *S. boottii*, and 6% to *S. tarda*; *Harris s.n.* KY from Alleghany Co., Maryland). Twelve of the 15 specimens of the *S. faucibus* a priori group (80%) were assigned a posteriori to the *S. faucibus* group: 6 specimens with 94-100% probability, 5 specimens with 81-85% probability, and 1 specimen with 47% probability (26% to *S. ludoviciana* and 21% to *S. boottii*; *Wieboldt 5825-A1* VPI from from Scott Co., Virginia). Three specimens of the *S. faucibus* a priori group were assigned a posteriori to the other species: 1

specimen to *S. ludoviciana* with 44% probability (21% to *S. faucibusi*, 17% to *S. vaseyi*, and 13% to *S. tarda*; *Wieboldt 5893-C1* VPI from Lee Co., Virginia); 1 specimen to *S. verna* with 38% probability (32% to *S. tarda*, and 22% to *S. faucibus*; *Wieboldt 11083* VPI from Pickens Co., South Carolina); and 1 specimen to *S. vaseyi* with 35% probability (20% to *S. ludoviciana*, 17% to *S. vaseyi*, 12% to *S. boottii*, and 6% to *S. tarda*; *Wieboldt 7913-1* VPI from Buchanan Co., Virginia). Twelve of the 16 specimens of the *S. arguta* a priori group (75%) were assigned a posteriori to the *S. arguta* group: 7 specimens with 941-100% probability, 2 specimens with 86% probability, 1 specimen with 64% probability, and 2 specimens with 46% probability (19% to *S. ludoviciana*, 17% to *S. tarda*, and 5% to *S. vaseyi*; *Semple 6883* WAT from Windham Co., Vermont) and 39% probability (29% to *S.* vaseyi, 11% to *S. boottii*, 7% to *S. tarda*, and 5% to *S. faucibus* and *S. harrisii Redfearn et al. 650* MO from Shannon Co., Missouri). Four specimens of the *S. arguta* a priori group were assigned a posteriori to the other species: 1 specimen to *S. harrisii* with 46% probability (26% to *S. boottii* and 25% to *S. arguta*; *Semple & Brouillet 3619* WAT from Hartford Co., Connecticut; diploid); 2 specimens to *S. vaseyi* with 43% probability (36% to *S. harrisii* and 9% to *S. arguta*; *Kellogg 1314* MO from Dent Co., Missouri) and 39% probability (25% to *S. arguta*, 19% to *S. harrisii*, and 8% to *S. boottii* and *S. faucibus*; *Steyermark 12879* MO from Reynolds Co., Missouri); and 1 specimen to *S. faucibus* with 38% probability (27% to *S. vaseyi*, 15% to *S. arguta*, 12% to *S. harrisii* and 6% to *S. ludoviciana*; *Steyermark 23580* MO from Howell Co., Missouri). Eleven of the 16 specimens of the *S. vaseyi* priori group (69%) were assigned a posteriori to the *S. vaseyi* group: 1 specimen with 92% probability, 1 specimen with 63% probability, 5 specimens with 59% probability (14% to *S. boottii*, 10% to *S. ludoviciana*, and 8% to *S. faucibus*; ; *Semple & B. Semple 11192* WAT from Blount Co., Alabama; tetraploid), 57% probability (35% to *S. boottii Cook et al. C-550* WAT from Buncombe Co., North Carolina), 53% probability (21% to *S. harrisii* 15% to *S. boottii*, and 6% to *S. faucibus*; *Bush 65* MO from Barry Co., Missouri), 52% probability (28% to *S. boottii* and 19% to *S. harrisii*; *Semple & Suripto 9792* WAT from Berkeley Co., South Carolina; diploid with lower stem leaves ca. 3.5 cm broad), and 51% probability (43% to *S. boottii*; *Semple & Chmielewski 6207* WAT from Rabun Co., Georgia; tetraploid), and 3 specimens with 46% probability (23% to *S. boottii* and 22% to *S. arguta*; *Semple & Suripto 9444* WAT from Adair Co., Kentucky; tetraploid), 44% probability (37% to *S. boottii* and 8% to *S. arguta*; *Semple & Suripto 9613* WAT from Laurel Co., Kentucky; tetraploid), and 36% probability (30% to *S. boottii* and *S. ludoviciana*; *Semple & Suripto 9692* WAT from Buncombe Co., North Carolina). Five specimens of the *S. vaseyi* a priori group were assigned a posteriori to the other species: 2 specimens to *S. harrisii* with 72% probability (18% to *S. harrisii* and 8% to *S. vaseyi*; *Semple & B. Semple 11138* WAT from Augusta Co., Virginia; identity changed to *S. harrisii*, diploid) and 61% probability (27% to *S. vaseyi* and 10% to *S. boottii*; *Kellogg 1314* MO from Dent Co., Missouri); 1 specimen to *S. ludoviciana* with 65% probability (25% to *S. tarda*; *Semple et al. 2538* WAT from Volusia Co., Florida; diploid); 1 specimen to *S. boottii* with 47% probability (32% to *S. arguta* and 17% to *S. vaseyi*; *Semple et al. 11875* WAT from Cocke Co., Tennessee;), and 1 specimen to *S. faucibus* with 44% probability (29% to *S. vaseyi* and 12% to *S. boottii*; *Semple & Chmielewski 5931* WAT from Nelson, Virginia). Eleven of the 18 specimens of the *S. boottii* a priori group (61%) were assigned a posteriori to the *S. boottii* group: 4 specimens with 71-77% probability, 3 specimens with 62-66% probability, 1 specimen with 52% probability (30% to *S. vaseyi* and 13% to *S. harrisii*; *Allen 1442* LSU from St. Helena Par., Louisisana), and 2 specimens with 45% probability (33% to *S. harrisii* and 21% to *S. vaseyi*; *Williams 62189* LSU from Benton Co., Arkansas) and 44% probability (27% to *S. harrisii* and 22% to *S. vaseyi*; *Redfearn at el. 1740* MO from Shannon Co., Missouri). Seven specimens of the *S. boottii* a priori group were assigned a posteriori to the other species: 1 specimen to *S. ludoviciana* with 99% probability (*Bush 15246* MO from Carroll Co., Arkansas; adaxial leaf midvein distally densely long hairy); 5 specimens to *S. vaseyi* with 63% probability (29% to *S. boottii*; *Moore 5410* LSU from Lincoln Par., Louisiana), 57% probability (17% to *S. faucibus*, 14% to *S. harrisii*, and 7% to *S. boottii*; *Palmer 26430* MO from Logan Co., Arkansas), 51% probability (38% to *S. boottii* and 10% to *S. arguta*; *Greenman 4438* MO from Hempstead Co., Arkansas), and 46% probability (40% to *S. boottii* and 10% to *S. arguta*;

Demaree 59538 MO from Logan Co., Arkansas); and 1 specimen to *S arguta* with 32% probability (31% to *S. tarda*, 16% to *S. harrisii*, and 5% to *S. vaseyi*; *Thomas & Thomas 108499* WAT from from Ouachita Par., Louisiana). Five of the 9 specimens of the *S. tarda* a priori group (56%) were assigned a posteriori to the *S. tarda* group: 3 specimens with 92-96% probability and 2 specimens with 83% probability. Four specimens of the *S. tarda* a priori group were assigned a posteriori to the other species: 1 specimen to *S. verna* with 88% probability (12% to *S. tarda*; *Morton 8272* NY from Cape May Co., New Jersey); and 3 specimens to *S. boottii* with 69% probability (20% to *S. ludoviciana*, 17% to *S. vaseyi*, 12% to *S. boottii*, and 6% to *S. tarda*; *Morton 4323* NY from Tuscaloosa Co., Alabama, second sheet), 42% probability (35% to *S. vaseyi* and 12% to *S. tarda*; *Morton 4323* NY from Tuscaloosa Co., Alabama), and 40% probability (28% to *S. tarda*, 18 to *S. ludoviciana*, and 14% to *S. vaseyi*; *Somers s.n.* NY from Geneva Co., Alabama).

Table 10. Linear and jackknife classification matrices from the Classificatory Discriminant Analysis of eight species a priori groups; a posteriori placements to groups in rows.

Group	***arguta***	***boottii***	***faucibus***	***harrisii***	***ludoviciana***	***tarda***	***vaseyi***	***verna***	**% correct**
arguta	12	0	1	1	0	0	2	0	75
boottii	1	11	0	0	1	0	5	0	61
faucibus	0	0	12	0	1	0	1	1	80
harrisii	1	0	0	10	0	0	1	0	83
ludviciana	0	0	0	0	12	2	0	0	86
tarda	0	3	0	0	0	5	0	1	56
vaseyi	0	1	1	2	1	0	11	0	69
verna	0	0	0	0	0	1	0	8	89
Totals	14	15	14	13	15	8	20	10	74

Jackknifed classification matrix

Group	***arguta***	***boottii***	***faucibus***	***harrisii***	***ludoviciana***	***tarda***	***vaseyi***	***verna***	**% correct**
arguta	11	1	1	1	0	0	3	0	69
boottii	1	10	0	1	1	0	5	0	56
faucibus	1	0	11	0	1	1	1	1	73
harrisii	2	0	0	9	0	0	1	0	75
ludviciana	0	0	1	0	10	3	0	0	71
tarda	0	3	0	0	0	5	0	1	56
vaseyi	0	2	2	2	2	0	8	0	50
verna	0	0	0	0	1	1	0	7	78
Totals	15	15	15	13	15	12	18	9	65

Two dimensional plots of CAN1 versus CAN3 and CAN1 versus CAN2 canonical scores for 109 specimens of *Solidago arguta*, *S. boottii*, *S. faucibus*, *S. harrisii*, *S. ludoviciana*, *S. tarda*, *S. vaseyi*, and *S. verna* are presented in Fig. 37. Eigenvalues on the first three axes were 2.360, 1.254 and 0.867.

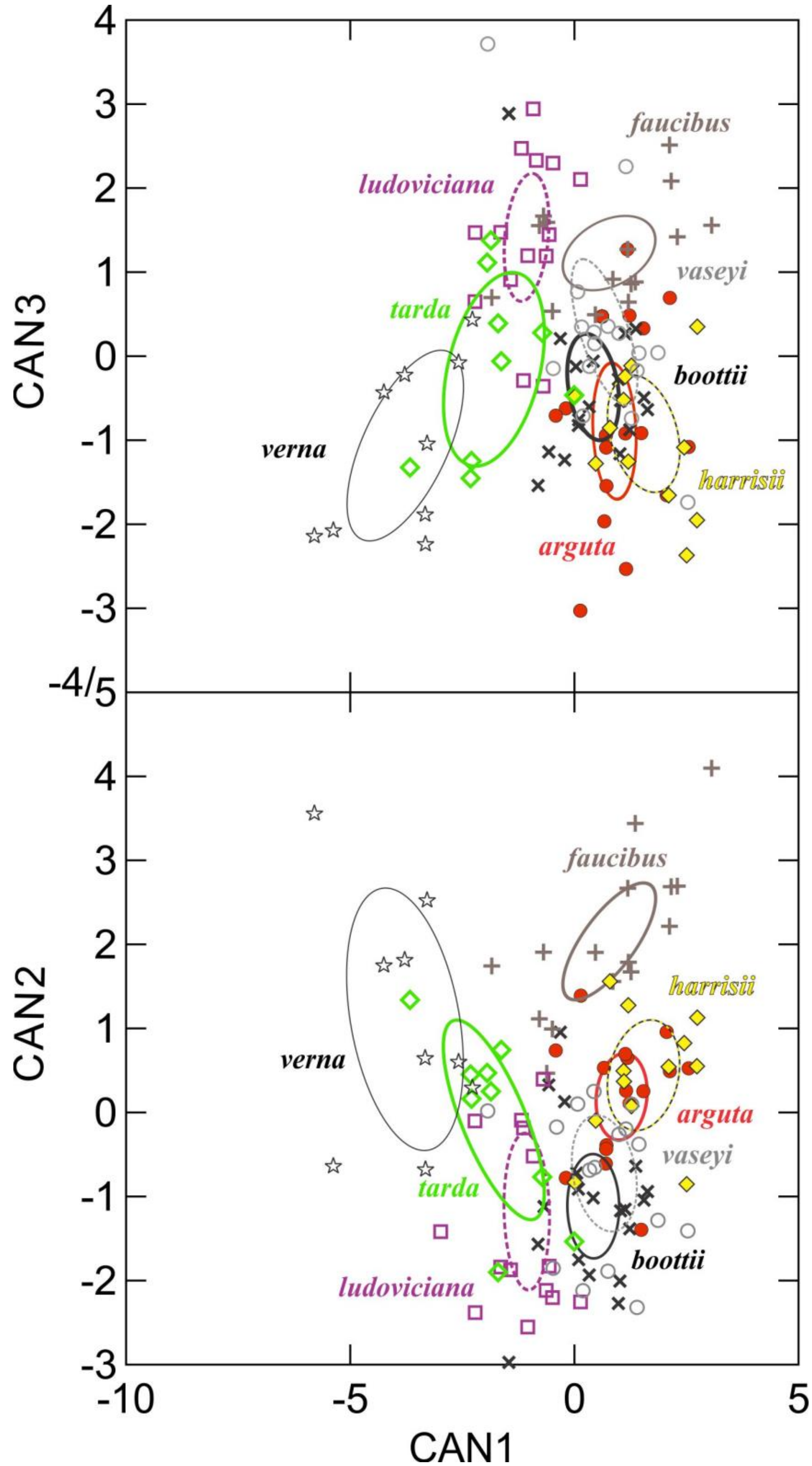

Figure 37. Plot of canonical scores (CAN1 vs CAN3 and CAN1 vs CAN2) for 109 specimens of *Solidago* subsect. *Argutae*: *S. arguta* (red dots), *S. boottii* (black +s), *S. faucibus* (brown +s), *S. harrisii* (yellow diamonds), *S. ludoviciana* (open magenta squares), *S. tarda* (bright green outlined diamonds), *S. vaseyi* (gray circles), and *S. verna* (black outlined stars).

Analysis 5: Two species a priori groups analysis of *S. arguta* and *S. vaseyi*

In the STEPWISE discriminant analysis of 32 specimens of two species level a priori groups (*S. arguta* (var. *arguta*), *S. vaseyi* (synonym: *S. arguta* var. *carolinana*)), the following four traits were selected as best separating the groups and are listed in order of decreasing F-to-remove values: number of ray florets (14.95), mid stem leaf length (8.62), ray floret lamina length (6.13), and upper stem leaf width (4.97). Wilks's lambda, Pillai's trace, and Lawley-Hotelling trace tests of the null hypothesis that all groups were the samples of one group had probabilities of p = 0.000 that the null hypothesis was true. *Solidago arguta* and *S. vaseyi* had an F-to separate value of 11.6 (Wilks' lambda = 0.3648 df = 4 1 30; Approx. F= 11.7537 df = 4 27 prob = 0.0000).

In the Classificatory Discriminant Analysis of the two species level a priori groups (*S. arguta* and *S. vaseyi*), percents of correct a posterori assignment to the same a priori group were 100% for *S. vaseyi* 75% for *S. arguta*. The Classification matrix and Jackknife classification matrix are presented in Table 11. All 16 specimens of the *S. vaseyi* a priori group (100%) were assigned a posteriori into the *S. vaseyi* group; 12 specimens with 90-100% probability, 2 specimens with 87-88% probability, 1 specimen with 71% probability, and 1 specimen with 63% probability. Twelve of the 16 specimens of *S. arguta* a priori group (75%) were assigned a posteriori to the *S. arguta* group; 10 specimens with 90-100% probability, 1 specimen with 87% probability, 1 specimen with 71% probability, and 1 specimen with 63 probability. Four specimens of the *S. arguta* a priori group were assigned to *S. vaseyi* with 64% probability (*Steyermark 12879* MO from Reynolds Co., Missouri), 64% probability (*Kellogg 1314* MO from Dent Co., Missouri), 61% probability (*Semple & Brouillet 3619* WAT from Hartford Co., Connecticut), and 52% probability (*Redfern 650* MO from Shannon Co., Missouri).

A two dimensional plot of CAN1 versus CAN2 canonical scores for 32 specimens of *Solidago arguta* and *S. vaseyi* are presented in Fig. 38. The Eigenvalue on the first axis was 1.741.

Table 11. Linear and jackknife classification matrices from the Classificatory Discriminant Analysis of two a priori species groups; a posteriori placements to groups in rows.

Group	***arguta***	***vaseyi***	**% correct**
arguta	12	4	75
vaseyi	0	16	100
Totals	12	20	88

Jackknifed classification matrix

Group	***arguta***	***vaseyi***	**% correct**
arguta	12	4	75
vaseyi	1	15	94
Totals	13	19	84

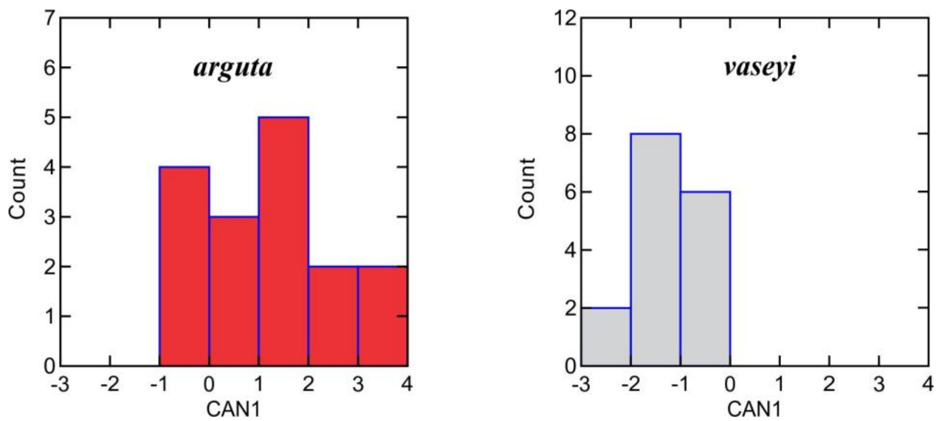

Figure 38. Histograms of the frequencies of CAN1 scores for 32 specimens of *Solidago arguta* and *S. vaseyi*.

Analysis 6: Two species a priori groups *S. patula* and *S. salicina*

In the STEPWISE discriminant analysis of 25 specimens of two species level a priori groups (*S. patula* and *S. salicina*), one trait was selected as best separating the groups: disc floret corolla length (15.6 approx. F to remove). Wilks's lambda, Pillai's trace, and Lawley-Hotelling trace tests of the null hypothesis that all groups were samples of one group had probabilities of p = 0.006 that the null hypothesis was true. *Solidago patula* and *S. salicina* had an F-to separate value of 15.6 (Wilks' lambda = 0.5959 df = 1 1 23; Approx. F= 15.5997 df = 1 23 prob = 0.0006).

In the Classificatory Discriminant Analysis of the two species level a priori groups (*S. patula* and *S. salicina*), percents of correct a posterori assignment to the same a priori group were 79% and 91% respectively. The Classification matrix and Jackknife classification matrix are presented in Table 12. Ten of the 11 specimens of the *S. salicina* a priori group (91%) were assigned a posteriori to the *S. salicina* group; 3 specimens with 91-99% probability, 2 specimens with 82% probability, 2 specimens with 79% and 74% probabilities, 3 specimens with 62-69% probability, and 1 specimen with 52% probability (*Godfrey 50121* from Harnett Co., North Carolina). One specimen of the *S. salicina* a priori group was assigned a posteriori to *S. patula* with 88% probability (*Godfrey 68383* NCU from Bay Co., Florida). Eleven of the 14 specimens of *S. patula* a priori group (79%) were assigned a posteriori to the *S. patula* group; 3 specimens with 91-99% probability, 1 specimen with 82% probability, 2 specimens with 79% and 74% probabilities, 3 specimens with 62-69% probability, and 1 specimen with 58% probability (*Smith s.n.* GH from Macon Co., North Carolina). Three specimens of the *S. patula* a priori group were assigned to *S. salicina* with 74% (*Semple 11576* WAT from Polk Co., Tennessee), 69% (*Lewis 2322* GH from Brunswick Co., Virginia), and 58% (*Curtis s.n.* GH from Bedford Co., Virginia).

Table 11. Linear and jackknife classification matrices from the Classificatory Discriminant Analysis of two a priori species groups; a posteriori placements to groups in rows.

Group	***patula***	***salicina***	**% correct**
patula	11	3	79
salicina	1	10	91
Totals	12	13	84

Jackknifed classification matrix

Group	*patula*	*salicina*	% correct
patula	11	3	79
salicina	1	10	91
Totals	12	13	84

Histograms of CAN1 canonical scores for 25 specimens of *Solidago patula* and *S. salicina* are presented in Fig. 39. The Eigenvalue on the first axis was 0.678.

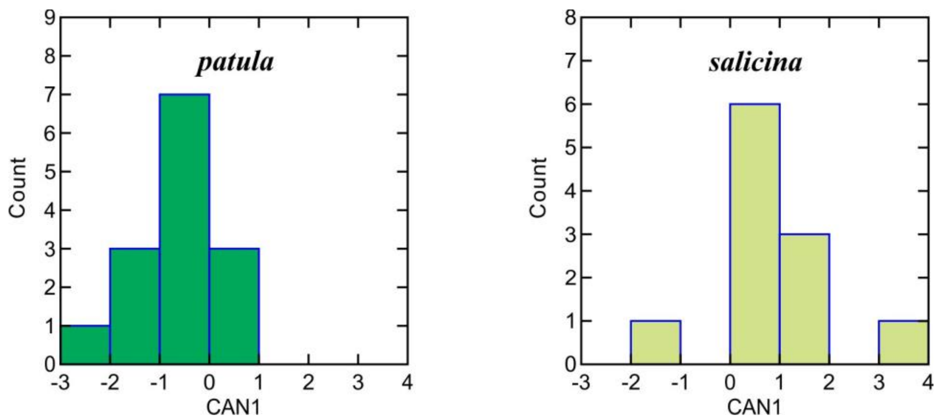

Figure 39. Histograms of the frequencies of CAN1 scores for 25 specimens of *Solidago patula* and *S. salicina*.

DISCUSSION

Species level analyses

The results of the six species level multivariate analyses indicate that *Solidago arguta*, *S. boottii*, *S. faucibus*, *S. harrisii*, *S. ludoviciana*, *S. patula*, *S. salicina*, *S. sphacelata*, *S. tarda*, *S. vaseyi* and *S. verna* are distinct and species rank is most appropriate, although some taxa are more obviously distinct than others. While the eleven species are for the most part morphologically similar and thus belong together within sect. *Argutae*, each has a diagnostic set of traits distinguishing it from the other ten species. When traits often used in keys (e.g., amount and nature of stem and leaf pubescence, presence or absence of well-developed ridges on the stem, habitat features) but not included in the analyses were considered, then most of the specimens that had been assigned a posteriori to a different group than each had been assigned to a priori were easily assigned to their a priori groups. For example, all of the specimens of *S. patula* and *S. salicina* (subsect. *Patulae*) had easy to determine finely scabrous adaxial leaf surfaces and generally strongly ridged stems, which are not traits of the other nine species. However, on the basis of leaf length and width and multiple floral traits specimens of *S. patula* and *S. salicina* were assigned a posteriori to *S. arguta*, *S. boottii* or *S. vaseyi*. Thus, there is considerable overlap in the ranges of technical floral traits even among species that are easily distinguished. Within subsect. *Argutae*, taxa are distinguished on rhizome, leaf pubescence features, and ploidy influenced features, e.g. involucre height, but often share overlapping ranges in technical floral traits that resulted in higher levels of a posteriori assignment to other species. In the era dominated by the floristic works of Arthur Cronquist during which multiple taxa were grouped under a single species as varieties, *S. arguta* included four varieties all treated here as species and even some of the species Cronquist (1980) recognized had first been described as varieties of other species that Cronquist included as varieties under *S. arguta*, e.g., the basionym of *S. ludoviciana* is *S. boottii* var. *ludoviciana*.

The key trait in Flora North America (Semple & Cook 2006) separating *S. arguta* var. *arguta* from *S. arguta* var. *caroliniana* (and var. *boottii* and var. *harrisii*) is the absence of hairs on the ovary/cypsela body in var. *arguta* and the presence of few to many hairs on the distal half of the ovary/cypsela body in var. *caroliniana*. The assignment to var. *caroliniana* could come down to the presence of just a few hairs, which is a small difference. In analyses 1 and 3 with var. *carolinina/S. vaseyi* included in *S. arguta*, a posteriori correct placements of *S. arguta* a priori group specimens to *S. arguta* were 38% and 66%, respectively. However, in analysis 2, only 1 specimen of var. *arguta* was placed a posteriori into var. *caroliniana/S. vaseyi* with 47% probability. In analysis 4, only 2 specimens of var. *arguta* were placed a posteriori into var. *carolinina/S. vaseyi* with 43% and 39% probability. In analysis 2 and 4, none of the var. *caroliniana/S. vaseyi* specimens were placed *a posteriori* into var. *arguta*, but 1 specimen in each analysis was placed in *S. boottii*. In analysis 2 and 4, 4 specimens of *S. boottii* were placed a posteriori into *var. caroliniana*/*S. vaseyi*. Thus, on technical morphological grounds as indicated by F-matrix values in Tables 4 and 8 *S. arguta* var. *caroliniana/S. vaseyi* was more similar to *S. boottii* (F-matrix values of 1.522 and 1.441, respectively) than to *S. arguta* var. *arguta* (F-matrix values of 7.448 and 7.703, respectively). Specimens of *S. arguta* (var. *arguta*) and *S. vaseyi* (*S. arguta* var. *caroliniana*) are less similar morphologically than might be implied by the sometimes minor differences in numbers of cypselae body hairs between the two taxa. Our conclusion is species rank is warranted for *S. vaseyi*, if one treats *S. boottii* and *S. harrisii* as separate species from *S. arguta*, which we do.

The most recently described taxon in sect. *Argutae* is *Solidago arguta* subsp. *pseudoyadkinensis* (Morton 1974). Several collections that came from the range of subsp. *pseudoyakinensis* were included in the analyses but all were treated here as members of *S. vaseyi* (initially in our study as *S. arguta* var. *caroliniana*). In the key to the *S. arguta* complex in his doctoral thesis Morton (1973) emphasized basal and lower stem leaf width in separating out his species level *pseudoyadkinensis* from *S. boottii* and *S. arguta* (and its northern and southern subspecies) and *S. vaseyi*. Our observations early in our study were that *S. arguta* var. *caroliniana* included numerous narrow-leaved specimens outside the range of distribution of subsp. *pseudoyadkinensi*s and thus the two taxa were not separate. The sample selection process ended up precluding the possibility of treating *pseudoyadkinensis* more recently as a separate a priori group because not enough specimens of the *S. vaseyi*/*S. arguta* var. *caroliniana* group as delimited here were from the eastern portion of the range of subsp. *pseudoyadkinensis* in Morton (1973). The first author recently looked at digital images of 68 herbarium collections identified by Gary Morton as *S. arguta* subsp. *pseudoyadkinensis* and all fit into *S. vaseyi* as treated here. It is nonetheless possible that subsp. *pseudoyadkinensis* might warrant recognition as a variety within *S. vaseyi* or as a separate species, if someone in the future undertakes a large study focusing on this particular problem.

Solidago patula and *S. salicina* make up subsect. *Patulae*, defined by the presence of very small scabrous hairs on the adaxial leaf faces. In analysis 1 and 2, specimens of *S. patula* and *S. salicina* were assigned a posteriori to the other species in the subsection and to *S. arguta*, *S. boottii*, *S. ludoviciana*, and *S. verna* of subsect. *Argutae* with probabilities ranging from 64% to as low as 38% in analysis 1 and to *S. vaseyi* with 31% probability in analysis 2. Thus, on technical traits both *S. patula* and *S. salicina* can be similar to members of subsect. *Argutae*. In the field or herbarium, a quick distal to proximal movement of the finger along the adaxial leaf surface will immediately result in some drag on the finger indicating the presence of those small distally-oriented scabrous hairs.

Solidago sphacelata is the most distinct species in sect. *Argutae* on the basis of pappus length, cordate rosette and lower leaf bases, and the general appearance of the involucre with its ovate phyllaries. It is the only species in the section to have ever been placed in a separate genus, which is here treated as subsect. *Brachychaeta.* The inflorescence branching pattern is typical of members of sect. *Argutae*.

Key to species of *Solidago* sect. *Argutae*

1. Pappus bristles ca 1 mm or less long (subsect. *Brachychaeta*) .... **Solidago sphacelata**
1. Pappus bristles >2 mm long.

2. Adaxial leaf surfaces finely scabrous (shark skin texture; subsect. *Patulae*)

3. Plants relatively robust, proximal leaves large, 80–300 × 40–100 mm, sharply serrate; distal leaves relatively few, gradually reduced distally, serrate; northern USA and adjacent Canada and south in mountains/Piedmont, to Alabama, Mississippi, Georgia .... **Solidago patula**
3. Plants more slender and small-leaved, proximal leaves narrower, 50–60 mm wide; distal leaves numerous, much reduced to bracts in array, usually finely serrate to entire; mostly coastal plain and adjacent Piedmont across the southeastern USA .... **Solidago salicina**

2. Adaxial leaf surfaces glabrous to moderately strigose-villose (subsect. *Argutae*).

4. Plants spring blooming; stem moderately to densely strigose-villous .... **Solidago verna**
4. Plants late summer and fall blooming; stems glabrous to sparsely strigose.

5. Shoots arising from long rhizomes.

6. Proximal leaves elliptic to obovate (ovate), acute or obtuse, with narrowly attenuate bases; distal cauline leaves quickly reduced, ascending to appressed; Arkansas, Louisiana and e Texas .... **Solidago ludoviciana**
6. Proximal leaves mostly ovate, acute to acuminate, with truncate to obtuse bases; distal cauline leaves gradually reduced, rarely appressed; e Pennsylvania and New Jersey south to northeastern Mississippi, Alabama, w Georgia, and adjacent Florida .... **Solidago tarda**

5. Shoots arising from woody caudex with short rhizomes.

7. Phyllaries striate, several nerves enlarged; involucres (5.2–)6.5–8.8(–10) mm; Kentucky, West Virginia, w Virginia .... **Solidago faucibus**
7. Phyllaries not striate, only main nerve enlarged (very rarely more striate); involucres 2.5–5.6 mm.

8. Abaxial veins of leaves sparsely to densely hispid-strigose; mostly west of the Mississippi .... **Solidago boottii**
8. Abaxial veins of leaves glabrous to rarely very sparsely strigose.

9. Ovaries/cypsela bodies glabrous to rarely glabrate; Maine and Ontario to North Carolina, disjunct in Missouri.. **Solidago arguta**
9. Ovaries/cypsela bodies sparsely distally strigose (sometimes only a few hairs) to moderate strigose proximally and distally.

10. Leaves relatively firm, lower leaves with ± truncate; (shale barrens) e Kentucky, w Maryland, w Pennsylvania, w Virginia, e West Virginia............ **Solidago harrisii**
10. Leaves less firm, the lower leaves with tapering bases; Virginia to northern Florida, west to Kentucky, Tennessee, Mississippi, and e Louisiana, disjunct in southern Missouri and Arkansas .... **Solidago vaseyi**

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