

**A MULTIVARIATE STUDY OF *SOLIDAGO RUPESTRIS*, *S. CANADENSIS*  
AND *S. GIGANTEA* (ASTERACEAE: ASTEREAE)**

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**ABSTRACT**

In a multivariate analysis, *Solidago rupestris* was determined to be more similar to *S. canadensis* than to *S. gigantea*. In a second analysis, *S. rupestris* was somewhat more similar to the more hairy *S. canadensis* var. *hargeri* than to the less hairy *S. canadensis* var. *canadensis*, which was less similar to var. *hargeri* than to *S. rupestris*.

*Solidago rupestris* Raf. (Ann. Nat. 14. 1820; Figs. 1-3) is a relatively uncommon species over its range, which consists of two disjunct areas bridging the central Appalachian Mts. (Fig 4). In the eastern portion of the range (Pennsylvania, Maryland, Virginia and West Virginia) the species is rare to threatened, while it is more commonly encountered in the western portion of its range (Clark Co., Indiana, much of Kentucky, and west central Tennessee). In both areas, the species tends to be found near rivers on slopes and bluffs and by streams, marshes or meadows.

*Solidago rupestris* has most frequently been treated as a species and as a variety in *S. canadensis* L. Fernald (1950) used key traits of (1) the summit of stem below the inflorescence being densely pilose, (2) the involucre being 2-2.8 mm high, and (3) the leaves being mostly serrate — leading to *S. canadensis* — and (1) the summit of stem below the inflorescence being glabrous or sparsely pilose, (2) the involucre being 2.5-3 mm high, and (3) the inflorescence being loosely pyramidal with elongate secund divergent branches — leading to *S. rupestris*.

Cronquist (1968) accepted the combination *Solidago canadensis* var. *rupestris* (Raf.) Porter (Bull. Torrey Bot. Club 21: 120. 1894), although erroneously cited there as (Raf.) Cronq., and he distinguished var. *rupestris* by its leaves commonly being glabrous beneath and more often subentire and having about 7-11 rays that were 1.2-1.8 mm long versus var. *canadensis* having leaves nearly always puberulent at least on the midrib and abaxial main veins and heads with 10-17 rays that were 1.-1.5 mm long. Gleason and Cronquist (1991) used the same key features to separate *S. rupestris* from *S. canadensis* but noted that stems were glabrous below the middle in *S. rupestris*. They separated *S. gigantea* in their key by its glaucous stems that are glabrous below the inflorescence while *S. shortii*, *S. rupestris*, and *S. canadensis* have non-glaucous stems that are commonly puberulent down to the middle or below.

In their FNA key to *Solidago* subsect. *Triplinerviae*, Semple and Cook (2006) included *S. rupestris* among species distinguished by having rays mostly 2–8 and midcauline leaves lanceolate or linear and sometimes twisted, while *S. canadensis* and *S. gigantea* were included among species distinguished by having rays mostly 8–15 and midcauline leaves lanceolate to oblanceolate, or if linear then not twisted.

*Solidago rupestris* has been reported as diploid  $2n=18$  (one report from Tennessee by Beaudry 1963) and tetraploid (one report from Kentucky by Semple et al. 1993).

*Solidago altissima* L. can be similar to some specimens of *S. rupestris*, but lower stems of *S. altissima* are sparsely to densely short strigose, while those of *S. rupestris* are always glabrous. Thus, it is not likely that specimens of *S. altissima* and *S. rupestris* would be difficult to distinguish.



Figure 1. *Solidago rupestris* (Henshaw s.n., NY) from the Potomac River near Washington, Virginia.





Figure 2. Details of the morphology of *Solidago rupestris*. **A-C.** Lower, mid and upper stems, *Henshaw s.n.* (NY). **D.** Stem in lower inflorescence, *Shacklette et al. 62* (NY). **E.** Upper stem leaf, abaxial surface, *Nash s.n.* (NY). **F.** Middle portion of mid stem leaf, abaxial surface, *Gattinger s.n.* (NY). **G.** Heads, *Gattinger s.n.* (NY). **H.** Cypselae of disc and ray florets, *Chester 87-775* (NY). Scale bar = 1 mm in A-D, G-H; = 1 cm in E-F.





Figure 3. Morphology of *Solidago rupestris*: live plants. **A-B.** Cultivated transplant at APSU, Clarksville, Tennessee. **C.** Inflorescence branch, *Semple et al. 11860* (WAT), Giles Co., Tennessee.

Semple and Beck (2021) included *S. altissima*, *S. canadensis*, and *S. rupestris* in subsect. *Triplinervae* ser. *Canadenses* Semple & Beck and placed *S. gigantea* in subsect. *Serotinae* (Rybd.) Semple & Beck that also included two South America species *S. chilensis* Meyen and *S. microglossa* DC. The taxonomic decisions were based on the polygenomic phylogeny results subsequently presented in Semple et al. (2023). Previously, Nesom (1993) and Semple and Cook (2006) included all three species in subsect. *Triplinerviae* sensu Nesom.

Key traits leading to *Solidago rupestris* that include terms like “sometimes,” “occasionally,” and “mostly” can lead to misidentifications of atypical collections. The occurrence of polyploidy has effects on involucre height that result in larger involucres for tetraploids than diploids. No previous multivariate study of members of subsect. *Triplinerviae* has included *S. rupestris*. The following

analysis was carried out to find alternative traits that might be useful in separating more and less pubescent individuals of *S. rupestris* from *S. canadensis* and *S. gigantea*. Diploids of the latter might be confused with *S. rupestris* even though *S. gigantea* is in a different subsection than *S. rupestris* and *S. canadensis*.

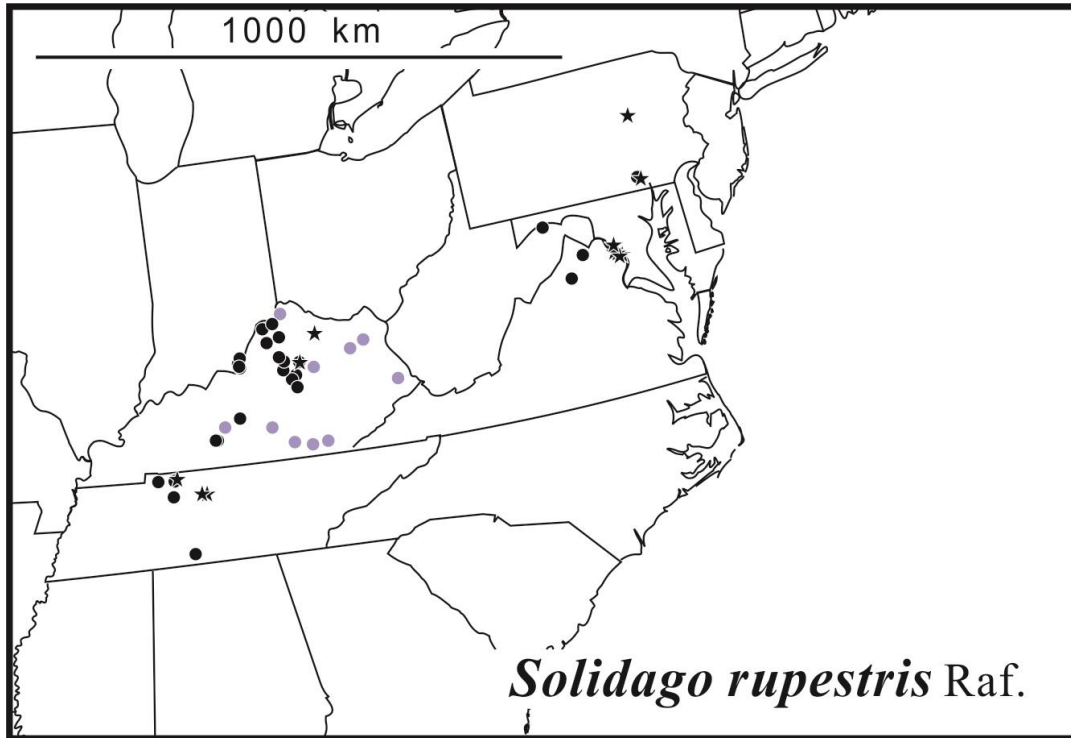


Figure 4. Distribution of *Solidago rupestris* in the eastern USA; stars indicate specimens included in multivariate analyses, black dots indicate vouchers seen, lavender dots indicate records with vouchers not seen.

#### MATERIALS AND METHODS

Multivariate comparisons were made using data on some 99 specimens of two species of subject. *Triplinerviae* and one species of subject. *Serotinae* selected from multiple hundreds of collections seen. Multivariate analyses of 30 specimens of *Solidago canadensis* var. *canadensis*, 21 specimens of *S. canadensis* var. *hageri*, 36 specimens of *S. gigantea*, and 12 specimens of *S. rupestris* were undertaken following the methods described in Semple et al. (2016). Two analyses were run. First, a STEPWISE discriminant analysis (SYSTAT 10. SPSS Inc. 2000) of *S. canadensis*, *S. gigantea*, and *S. rupestris* was run. Second, a STEPWISE discriminant analysis of *S. canadensis* var. *canadensis*, *S. canadensis* var. *hageri*, and *S. rupestris* was run. All traits scored are listed in Table 1.

Table 1. Traits scored for the multivariate analyses of 99 specimens of *Solidago canadensis*, *S. gigantea*, and *S. rupestris*.

Abbreviation	Description of trait scored
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)
CAPLBRLN	Length of longest lower inflorescence branches (cm)
INVOLHT	Involucre height at anthesis (mm)
OPHYLL	Outer phyllary length (mm)
IPHYLL	Inner phyllary length (mm)
RAYNUM	Number of ray florets per head
RSTRAPLN	Ray strap length top of the corolla tube to the tip of the strap (mm)
RSTRAPWD	Ray strap width measured at the widest point (mm)
RACHLN	Ray floret ovary/fruit 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 ovary/fruit body length at anthesis (mm)
DPAPLN	Disc floret pappus length at anthesis (mm)

**RESULTS**

The Pearson correlation matrix yielded  $r > |0.7|$  for most upper leaf traits and only mid stem leaf length, width and number of serrations were included in the STEPWISE analysis. Ray and disc floret ovary/fruit body lengths at anthesis correlated highly and only the latter trait was included in the analysis. Involucre height, number of ray florets, ray floret lamina length, number of disc florets, disc floret corolla, lobe length, and pappus length at anthesis were included in the STEPWISE analyses.

**Analysis 1**

In a STEPWISE discriminant analysis of 98 specimens of three species level a priori groups (*Solidago canadensis*, *S. gigantea*, and *S. rupestris*) the following 3 traits were selected and are listed in order of decreasing F-to-remove values: number of disc florets (21.66), disc floret pappus length at anthesis (19.40), and disc floret ovary/cypsela body length at anthesis (6.51). 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 2. F-values based on Mahalanobis distances of the between group centroids indicated the largest separations were between *S. canadensis* and *S. gigantea* (105.13); the smallest separation was between *S. canadensis* and *S. rupestris* (1.863).

Table 2. Between groups F-matrix for the three a priori groups in a STEPWISE analysis (df = 3 93).

Group	<i>canadensis</i>	<i>gigantea</i>
<i>gigantea</i>	105.128	
<i>rupestris</i>	1.863	27.973

Wilks' lambda = 0.2215 df = 3 2 95; Approx. F= 24.8656 df = 6 186 prob = 0.0000



In the Classificatory Discriminant Analysis of 110 specimens of the three species level a priori groups (*Solidago canadensis*, *S. gigantea*, and *S. rupestris*), percents of correct a posteriori assignment to the same a priori group ranged from 64-92%. The Classification matrix and Jackknife classification matrix are presented in Table 3. Thirty-three of the specimens of the *S. gigantea* a priori group plus 5 specimens only included a posteriori were assigned a posteriori to the *S. gigantea* group: 30 specimens with 94-100% probability, 4 specimens with 84-89% probability, 3 specimens with 71-77% probability, and 1 specimen with 45% probability (44% to *S. rupestris* and 11% to *S. canadensis*; Turner 3205 WAT from Fort Saskatchewan, Alberta). Three specimens of the *S. gigantea* a priori group was assigned a posteriori to *S. rupestris* with 53% probability (24% to *S. rupestris* and 23% to *S. canadensis*; Semple & Keir 4693 WAT from Northumberland Co., New Brunswick), 52% probability (48% to *S. canadensis*; Semple et al. 3422 WAT from Rougemont, Québec; 2n=18), and 46% probability (45% to *S. rupestris* and 9% to *S. canadensis*; Semple & Brouillet 6948 WAT from Douglas Co., Minnesota). Thirty-three of the 51 specimens of the *S. canadensis* a priori group (69%) were assigned a posteriori to the *S. canadensis* group: 2 specimens with 88% and 86% probabilities, 12 specimens with 70-78% probability, 9 specimens with 60-65% probability, and 12 specimens with 59% probability (41% to *S. rupestris*; Poindexter 05-2014 WAT from Ashe Co., North Carolina; hairy lower stem), 59% probability (41% to *S. rupestris*; Semple & Keir 4966 WAT from Saratoga Co., New York; lower stem not hairy), 59% probability (41% to *S. rupestris*; Semple & Chmielewski 5876 WAT from Clarke Co., Virginia; mid stem hairy), 59% probability (41% to *S. rupestris*; Semple & Keir 4911 WAT from Penobscot Co., Maine), 56% probability (44% to *S. rupestris*; Morton & Venn NA16152 TRT from Roanoke Co., Virginia; lower stem hairy, 2n=18), 55% probability (45% to *S. rupestris*; Semple 10728 WAT from Bath Co., Virginia; lower stem hairy), 54% probability (46% to *S. rupestris*; Semple & Keir 4780 WAT from Guysborough Co., Nova Scotia; lower stem not hairy), 53% probability (46% to *S. rupestris*; Schlaepfer CH135SC036 WAT from Zurich-Friesenberg, Switzerland), 52% probability (47% to *S. rupestris*; Semple & Keir 4889 WAT from Kings Co., Nova Scotia; lower stem not hairy), 51% probability (49% to *S. rupestris*; Melville 1490 WAT from Lambton Co., Ontario; lower stem hairy, 2n=18), 51% probability (59% to *S. rupestris*; Semple & B. Semple 11462 WAT from Gloucester Co., New Brunswick), and 50% probability (*J.K. Morton s.n.* TRT from Berlin, Germany; lower stem hairy, 2n=18). Sixteen specimens of the *S. canadensis* a priori group were assigned a posteriori to *S. rupestris* with 67% probability (32% to *S. canadensis*; Semple & Keir 4615 WAT from Woburn, Québec), 64% probability (35% to *S. canadensis*; Semple 6903 WAT from Addison Co., Vermont), 63% probability (32% to *S. canadensis*; Morton & Venn NA8219 WAT from Bruce Co., Ontario), 63% probability (35% to *S. canadensis*; Melville 401 WAT from Timiskiming Dist., Ontario; 2n=18), 61% probability (39% to *S. canadensis*; Semple & B. Semple 11423 WAT from Gaspésie, Québec), 61% probability (39% to *S. canadensis*; Semple & Brouillet 3519 WAT from Orange Co., Vermont), 58% probability (42% to *S. canadensis*; Melville 1882 WAT from Elgin Co., Ontario), 58% probability (39% to *S. canadensis*; Semple & Keir 4730 WAT from Pictou Co., Nova Scotia), 56% probability (39% to *S. canadensis*; Semple & Keir 4676 WAT from Victoria Co., New Brunswick), 55% probability (44% to *S. canadensis*; Morton & Venn 10762 WAT from Manitoulin Dist., Ontario), 54% probability (45% to *S. canadensis*; Semple & Brammall 2790 WAT from Bruce Co., Ontario), 52% probability (47% to *S. canadensis*; Morton & Venn s.n. TRT from Oneida Co., New York), 52% probability (48% to *S. canadensis*; Morton & Venn NA 10785 WAT from Bruce Co., Ontario), 50% probability (50% to *S. canadensis*; Semple & Brouillet 3442 WAT from Lamoille Co., Vermont), and 44% probability (42% to *S. gigantea* and 13% to *S. canadensis*; Morton & Venn NA17617 from Washington Co., Maine). Seven of the 12 specimens of the *S. rupestris* a priori group (64%) plus 1 specimen only included a posteriori were assigned a posteriori to the *S. rupestris* group: 1 specimen with 77 probability, 5 specimens with 62-68% probability, and 2 specimens with 57% probability (42% to *S. canadensis*; Knapp et al. 5299 WAT from Montgomery Co., Maryland) and 53% (46% to *S. canadensis*; Chickering s.n. NY from near Washington, District of Columbia). Four specimens of the *S. rupestris* a priori group was assigned a posteriori to *S. canadensis* with 60%

probability (40% to *S. rupestris*; Chester 87-775 NY from Montgomery Co., Tennessee), 57% probability (42% to *S. rupestris*; Nash s.n. NY from York Co., Pennsylvania), 56% probability (44% to *S. rupestris*; Semple & Surlito 9594 WAT from Robertson Co./Nicholas county line, Kentucky; 2n=36), and 51% probability (49% to *S. rupestris*; Leonard 791 NY from Fairfax Co., Virginia).

Table 3. Linear and jackknife classification matrices from the Classificatory Discriminant Analysis of four a priori groups; a posteriori placements to groups in rows.

Group	<i>canadensis</i>	<i>gigantea</i>	<i>rupestris</i>	% correct
<i>canadensis</i>	35	0	16	69
<i>gigantea</i>	0	33	3	92
<i>rupestris</i>	4	0	7	64
<b>Totals</b>	39	33	26	77

Jackknifed classification matrix

Group	<i>canadensis</i>	<i>gigantea</i>	<i>rupestris</i>	% correct
<i>canadensis</i>	32	0	19	63
<i>gigantea</i>	0	32	4	89
<i>rupestris</i>	4	0	7	64
<b>Totals</b>	36	32	30	72

A two dimensional plot of CAN1 versus CAN2 canonical scores for 98 specimens of *Solidago canadensis*, *S. gigantea*, and *S. rupestris* are presented in Fig. 5. Eigenvalues on the first two axes were 3.472 and 0.009.

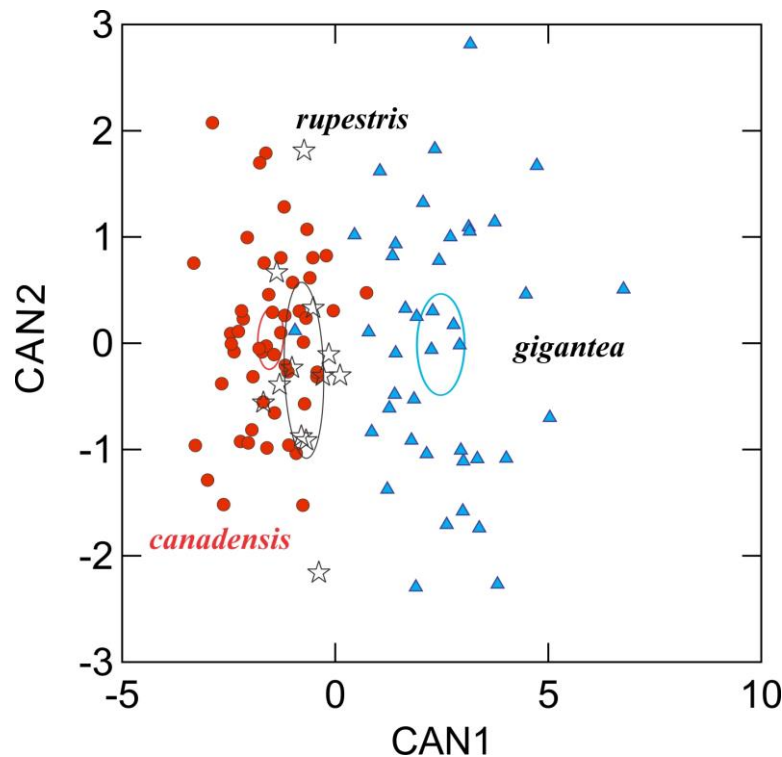


Figure 5. Plot of canonical scores (CAN1 vs CAN2) for 98 specimens of *Solidago* subsect. *Triplinerviae*: *S. canadensis* (red dots), *S. gigantea* (blue triangles), and *S. rupestris* (black-outlined open stars).



## Analysis 2

In a STEPWISE discriminant analysis of 62 specimens of three species/variety level a priori groups (*Solidago canadensis* var. *canadensis*, *S. canadensis* var. *hargerii*, and *S. rupestris*) the following 4 traits were selected and are listed in order of decreasing F-to-remove values: number of ray florets (18.62), mid stem leaf width (16.99), disc floret corolla lobe length (16.12), and outer phyllary length (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 4. F-values based on Mahalanobis distances of the between group centroids indicated the largest separation was between *S. canadensis* var. *canadensis* and *S. canadensis* var. *hargerii* (20.496); the smallest separation was between *S. canadensis* var. *hargerii* and *S. rupestris* (6.259).

Table 4. Between groups F-matrix for the three a priori groups in a STEPWISE analysis (df = 4 56).

Group	var. <i>canadensis</i>	var. <i>hargerii</i>
var. <i>hargerii</i>	20.496	
<i>rupestris</i>	11.244	6.259

Wilks' lambda = 0.3043 df = 4 2 59; Approx. F= 11.3810 df = 8 112 prob = 0.0000

In the Classificatory Discriminant Analysis of 62 specimens of the three species level a priori groups (*Solidago canadensis* var. *canadensis*, *S. canadensis* var. *hargerii*, and *S. rupestris*), percents of correct a posteriori assignment to the same a priori group ranged from 71-97%. The Classification matrix and Jackknife classification matrix are presented in Table 5. Twenty-nine of the 30 specimens of the *S. canadensis* var. *canadensis* a priori group (97%) were assigned a posteriori to the *S. canadensis* var. *canadensis* group: 13 specimens with 90-100% probability, 8 specimens with 80-89% probability, 4 specimens with 74-78% probability, 2 specimens with 55% probability (36% to *S. rupestris* and 9% to *S. canadensis* var. *hargerii*; Semple & Keir 4966 WAT from Saratoga Co., New York; lower stem not hairy) and 53% probability (28% to *S. canadensis* var. *hargerii* and 20% to *S. rupestris*; Semple & Keir 4709 WAT from Westmoreland Co., New Brunswick), and 2 specimens with 42% probability (34% to *S. canadensis* var. *hargerii* and 24% to *S. rupestris*; Semple & Keir 4919 WAT from Waldo Co., Maine) and 36% probability (32% each to *S. canadensis* var. *hargerii* and *S. rupestris*; Semple & Keir 4959 WAT from Windham Co., Vermont). One specimen of the *S. canadensis* var. *canadensis* a priori group was assigned a posteriori to *S. rupestris* with 54% probability (37% to *S. canadensis* var. *canadensis* and 9% to var. *hargerii*; Semple & Keir 4654 WAT from Penobscot Co., Maine). Nine of the 11 specimens of the *S. rupestris* a priori group (82%) were assigned a posteriori to the *S. rupestris* group: 4 specimens with 92-97% probability, 2 specimens with 84% and 80% probabilities, 1 specimen with 61% probability, 1 specimen with 56% probability (37% to *S. canadensis* var. *hargerii* and 6% to var. *canadensis*; Chester 87-775 NY from Montgomery Co., Tennessee) and 1 specimen with 47% probability (32% to *S. canadensis* var. *canadensis* and 19% to var. *hargerii*; Leonard 791 NY from Fairfax Co., Virginia). Two specimen of the *S. rupestris* a priori group was assigned a posteriori to *S. canadensis* var. *hargerii* with 59% probability (41% to *S. rupestris*; Knapp et al. 5299 WAT from Montgomery Co., Maryland) and 51% probability (36% to *S. rupestris* and 13% to var. *canadensis*; Chickering s.n. NY from near Washington, District of Columbia). Fifteen of the 21 specimens of the *S. canadensis* var. *hargerii* a priori group (71%) were assigned a posteriori to the *S. canadensis* var. *hargerii* group: 6 specimens with 90-100% probability, 2 specimens with 89% and 86% probabilities, 2 specimens with 69% and 65% probabilities, 2 specimens with 58% probability (39% to var. *canadensis*; Morton & Venn NA15207 TRT from Oconto Co., Wisconsin) and 54% probability (42% to *S. rupestris*; Semple & Chmielewski 5876

WAT from Clarke Co., Virginia; mid stem hairy), and 3 specimens with 46% probability (45% to *S. rupestris*; Semple & Brammall 2859 WAT from Algoma Dist., Ontario; lower stem sparsely hairy), 45% probability (36% to var. *canadensis* and 19% to *S. rupestris*; Morton & Venn s.n. TRT from Oneida Co., New York; lower stem hairy), and 45% probability (45% to var. *canadensis* and 11% to *S. rupestris*; Schlaepfer CH135SC036 WAT from Zurich-Friesenberg, Switzerland). Six specimens of the *S. canadensis* var. *hargerii* a priori group was assigned a posteriori to other taxa: 3 specimens to *S. rupestris* with 99% probability (Semple & Brammall 2786 WAT from Bruce Co., Ontario), 71% probability (21% to var. *hargerii* and 8% to var. *canadensis*; Semple & Shea 2916 WAT from Leeds Co., Ontario), and 54% probability (45% to var. *hargerii*; Morton & Venn NA18716 TRT from Montgomery Co., Ohio); and 3 specimens to *S. canadensis* var. *canadensis* with 87% probability (11% to var. *hargerii*; Melville 1490 WAT from Lambton Co., Ontario; lower stem hairy), 56% probability (29% to var. *hargerii* and 15% to *S. rupestris*; Semple 10728 WAT from Bath Co., West Virginia), and 53% probability (45% to var. *hargerii*; Melville 1623 WAT from Niagara Reg., Ontario; hairy lower stem).

A two dimensional plot of CAN1 versus CAN2 canonical scores for 64 specimens of *Solidago canadensis* var. *canadensis*, *S. canadensis* var. *hargerii*, and *S. rupestris* are presented in Fig. 6. Eigenvalues on the first two axes were 1.280 and 0.442.

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

Group	var. <i>canadensis</i>	var. <i>hargerii</i>	<i>rupestris</i>	% correct
var. <i>canadensis</i>	29	0	1	97
var. <i>hargerii</i>	3	15	3	71
<i>rupestris</i>	0	2	9	82
<b>Totals</b>	32	17	13	85

Jackknifed classification matrix

Group	var. <i>canadensis</i>	var. <i>hargerii</i>	<i>rupestris</i>	% correct
var. <i>canadensis</i>	26	1	1	87
var. <i>hargerii</i>	5	12	3	57
<i>rupestris</i>	0	2	9	82
<b>Totals</b>	31	15	13	76

### DISCUSSION

The results of the multivariate analyses indicate that *Solidago rupestris* is much more similar to *S. canadensis* than to *S. gigantea*, based on mostly floral characters selected as discriminating. Including both varieties in *S. canadensis* resulted in lower levels of separation between *S. canadensis* and *S. rupestris* (20 specimens assigned a posteriori to the other species) than when *S. rupestris* was compared to *S. canadensis* var. *canadensis* and *S. canadensis* var. *hargerii* separately (7 specimens assigned a posteriori to other taxa). Based on 1 leaf and 3 floral traits, 2 specimens of *S. rupestris* were assigned a posteriori into var. *hargerii* and none were assigned to var. *canadensis* although the former two taxa are absolutely separable by the lack of lower and mid stem hairs on specimens of *S. rupestris* and the presence of hairs on lower and mid stems on specimens of *S. canadensis* var. *hargerii*. Specimens of *S. rupestris* from the eastern portion of its range were more often assigned to *S. canadensis* (both varieties included) or only weakly assigned to *S. rupestris* than collections from the western portion of the range and none were assigned a posteriori to *S. gigantea* (percent of

assignment to *S. gigantea* ranged from 0-7%). Likewise in the second analysis comparing *S. rupestris* to *S. canadensis* var. *canadensis* and *S. canadensis* var. *hargerii*, 3 of the 4 specimens of *S. rupestris* assigned a posteriori to *S. rupestris* with low probability or to var. *canadensis* with low probability were from the eastern portion of the range. The results indicate that there are some subtle differences between the eastern and western populations of *S. rupestris*, but specimens with the highest a posteriori assignment probabilities to *S. rupestris* (80-94%) came from both eastern and western parts of the range. Data on ploidy level is too limited to be informative with the single diploid and tetraploid counts coming from western individuals. The one known tetraploid individual from Kentucky was assigned to *S. canadensis* (including both varieties) with 56% probability in the first analysis and to *S. rupestris* with 61% in the second analysis with the two varieties of *S. canadensis*. The individuals of *S. canadensis* assigned a posteriori to *S. rupestris* in either analysis came nearly entirely from Canada and Maine, locations well outside the range of *S. rupestris*.

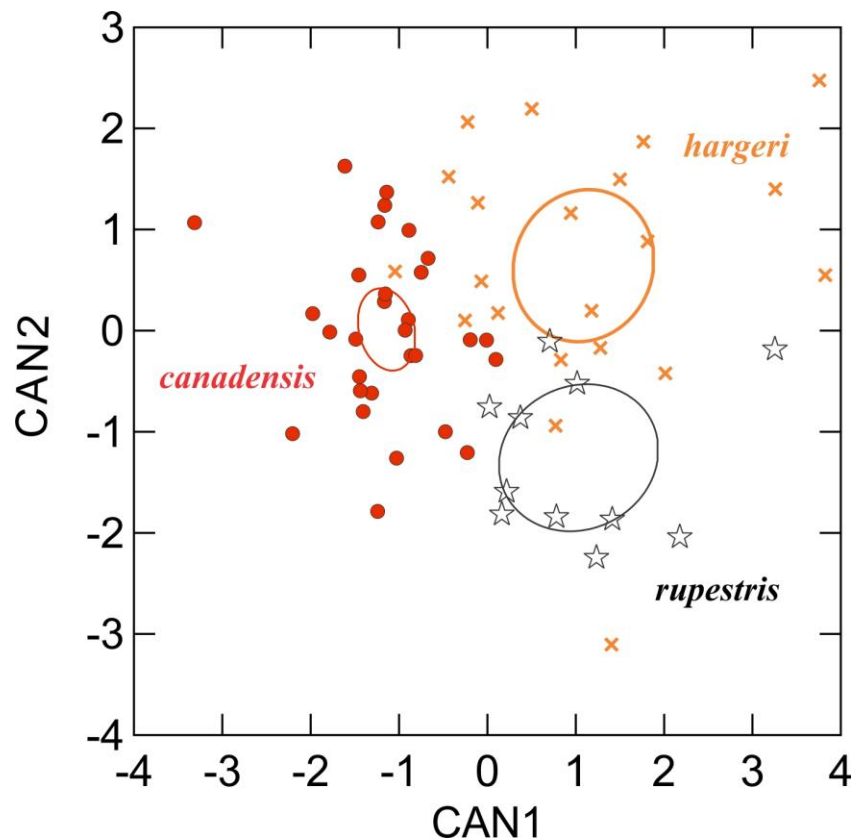


Figure 6. Plot of canonical scores (CAN1 vs CAN2) for 62 specimens of *Solidago* subject. *Triplinerviae*: *S. canadensis* var. *canadensis* (red dots), *S. canadensis* var. *hargerii* (orange x's), and *S. rupestris* (black-outlined open stars).

*Solidago rupestris* was not included in the polygenomic DNA analysis of *Solidago* by Semple et al. (2023), which was used by Semple and Beck (2021) in their revised classification of *Solidago*. On the basis of morphology, *Solidago rupestris* was placed in ser. *Canadenses* Semple & Beck, which includes *S. altissima*, *S. bartramiana* (syn: *S. brendae* Semple), *S. canadensis*, *S. elongata*, *S. fallax*, *S. lepida*, and the very rare *S. shortii*. Only the ranges of the distributions of *S. canadensis* and *S. altissima* overlap with the range of distribution of *S. rupestris*. All of the ser. *Canadenses* species include some individuals with short-haired mid to lower stems, although some species include individuals with few to no hairs like *S. rupestris* on the upper stem below the inflorescence. *Solidago*



*canadensis* is the species that includes individuals most similar to *S. rupestris* in leaf shape but the former always have hairy upper stems and usually more hairy veined leaves than *S. rupestris*. It is assumed here that *S. rupestris* is most closely related to *S. canadensis*, but DNA analysis is needed to confirm this assumption.

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### LITERATURE CITED

- Beaudry, J.-R. 1963. Studies on *Solidago* L. VI. Additional chromosome numbers of taxa of the genus. *Canad. J. Genet. Cytol.* 5: 150–174.
- Cronquist, A. 1968. *Solidago* L. Pp. 413–438, in H.A. Gleason (ed.). *The New Britton and Brown Illustrated Flora of the Northeastern United States and Adjacent Canada*. Hafner Pub. Co., New York.
- Gleason, H.A. and A. Cronquist. 1991. *Manual of Vascular Plants of Northeastern United States and Adjacent Canada*. 2nd edition. New York Botanical Garden, Bronx.
- Fernald, M.L. 1950. *Gray's Manual of Botany*, 8th ed. Van Nostrand, New York.
- Nesom, G.L. 1993. Taxonomic infrastructure of *Solidago* and *Oligoneuron* (Asteraceae: Astereae) and observations on the phylogenetic position. *Phytologia* 75: 1–44.
- Semple, J.C. and J.B. Beck. 2021. A revised infrageneric classification of *Solidago* (Asteraceae: Astereae). *Phytoneuron* 2021-10: 1–6.
- Semple, J.C., Jie Zhang, and ChunSheng Xiang. 1993. Chromosome numbers in Fam. Compositae, Tribe Astereae. V. Eastern North American taxa. *Rhodora* 95: 234–253.
- Semple, J.C., T. Shea, H. Rahman, Y. Ma, and K. Kornobis. 2016. A multivariate study of the *Solidago sempervirens* complex of *S.* subsect. *Maritimae* (Asteraceae: Astereae). *Phytoneuron* 2016-73: 1–31.
- Semple, J.C., McMinn-Sauder, H., Stover, M., Lemmon, A., Lemmon E., and J.B. Beck. 2023. Goldenrod herbariomics: Hybrid-sequence capture reveals the phylogeny of diploid *Solidago*. *Amer. J. Bot.* 110(7): e16164. <https://doi.org/10.1002/ajb2.16164>
- SPSS Inc. 2000. SYSTAT version 10 for Windows. SPSS Inc., Chicago, Illinois.
- Thiers, B. [continuously updated]. *Index Herbariorum: A Global Directory of Public Herbaria and Associated Staff*. New York Botanical Garden's Virtual Herbarium.