

HIERACIUM CAESPITOSUM AND HIERACIUM PILOSELLOIDES (ASTERACEAE)
IN THE BLACK HILLS NATIONAL FOREST: NEW STATE RECORDS
FOR SOUTH DAKOTA, U.S.A.

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ABSTRACT

Hieracium spp. (Asteraceae) are noted for their taxonomic complexity, frequent incidence of apomixis and polyploidy, and invasive tendencies. Here we report the Eurasian taxa, *Hieracium caespitosum* Dumort. and *Hieracium piloselloides* Vill., as recent additions to the flora of South Dakota. Plants were collected at three locations in the Black Hills during 2014 and 2015 and compared to specimens of *H. caespitosum* and *H. piloselloides* at major herbaria (RM, MO, SDC) for five morphometric traits. We found significant differences ($P < 0.05$) between previously identified specimens of these species for involucre and pappus lengths and stellate leaf hair number; the latter was especially discriminatory in univariate and multivariate analyses and probably the most useful trait for field identification. *Hieracium* specimens from the Black Hills exhibited morphological characteristics of *H. caespitosum* and *H. piloselloides*, suggesting that both species were introduced in the region. These data will assist South Dakota land managers in identification of nascent weedy *Hieracium* populations and may also be of interest to biologists studying demographic and genetic factors related to weed establishment.

RESUMEN

Hieracium spp. (Asteraceae) se destacan por su complejidad taxonómica, la frecuente incidencia de apomixis y de poliploidia y tendencias invasoras. Aquí presentamos los taxones euroasiáticos, *Hieracium caespitosum* Dumort. e *Hieracium piloselloides* Vill., como nuevas especies para la flora de Dakota del Sur. Los ejemplares fueron recogidos en tres lugares dentro de las Black Hills en 2014 y 2015 y comparados en cinco rasgos morfométricos con las especies de *H. caespitosum* y *H. piloselloides* que se encuentran en herbarios principales (RM, MO, SDC). Cuando los comparamos con los ejemplares previamente identificados de estas especies, descubrimos diferencias significativas ($P < 0.05$) en involucre y longitud del vilano y número de pelos estrellados de la hoja, con este último siendo especialmente discriminatorio en los análisis univariado y multivariado, y probablemente el rasgo más útil para identificación en el campo. Los ejemplares de *Hieracium* de los Black Hills exhibieron características morfológicas de *H. caespitosum* y de *H. piloselloides*, lo que sugiere que ambas especies fueron introducidas en la región. Estos datos ayudarán a los gestores de espacios en Dakota del Sur a la identificación de las incipientes poblaciones invasoras de *Hieracium* y también pueden ser de interés para los biólogos que estudian factores genéticos y demográficos relacionados con el establecimiento de malezas.

INTRODUCTION

Hieracium is a large genus with 250 to 1000+ accepted species and over 9000 published species names (Strother 2006). Thirty-six *Hieracium* species occur in North America (Strother 2006), and 13 of these are introduced and often invasive (Gaskin & Wilson 2007). The invasive *Hieracium* species belong to subgenera *Pilosella* and *Hieracium* and are fibrous-rooted creeping perennials often with rhizomes (Jacobs & Wiese 2007). Seed production in the introduced hawkweeds is predominantly through agamospermy (seed formation without fertilization), but sexual reproduction, outcrossing, and hybridization may also occur. Agamospermy and other factors (including phenotypic plasticity, hybridization, and natural variation) often preserve subtle variations at population levels making species identification potentially difficult and confusing. This abundant variation of traits has resulted in the description of thousands of *Hieracium* species worldwide (Wilson 2007).

With the additions of *H. caespitosum* and *H. piloselloides*, there are six *Hieracium* species known to occur in South Dakota, three native and three introduced. Like other species of *Hieracium* subgen. *Pilosella*, *H. caespitosum* and *H. piloselloides* can be highly competitive due to abundant seed production, high germination rate, long-lived seed, vegetative spread, and broad environmental range. These species can form dense mats that have the potential to quickly choke out native vegetation (Jacobs & Wiese 2007).

Hieracium caespitosum is a fibrous-rooted perennial with short to long stolons and/or rhizomes. Plants are 20–75 cm in height. Abaxial leaf surfaces have moderately dense stellate hairs and long simple hairs (Wilson 2007). Florets have yellow corollas and are borne in terminal clusters of 5–25+ heads, each head with 25–50+ florets. Involucres are campanulate and 7.5–9 mm long and pappi are of white bristles 4–5 mm long (Strother 2006).

Hieracium piloselloides is a fibrous-rooted perennial without stolons. Plants are 15–70+ cm in height. Abaxial leaf surfaces are hairless except for a few simple or stellate hairs near the midvein (Wilson 2007). Florets have yellow corollas and are borne in terminal clusters of 10–30+ heads, each head with 60–80+ florets. Involucres are campanulate and 5–7 mm long, and pappi are of white bristles 3–4 mm long (Strother 2006).

It is the purpose of this study to report two new species, *Hieracium caespitosum* and *H. piloselloides* in the state of South Dakota. We also wish to inform workers about diagnostic characteristics and provide a key to the species present in South Dakota.

MATERIALS AND METHODS

During the 2014 field season, we documented three new locations of yellow-flowered weedy *Hieracium* in the Black Hills of South Dakota; specimens from the three sites were collected, pressed, and dried. Since *Hieracium* species can be difficult to differentiate due to high variation in characters, additional collections from two of the new sites were made in 2015. Herbarium abbreviations are from Thiers (continuously updated).

Hieracium caespitosum voucher specimens:

U.S.A. South Dakota. Pennington Co.: Black Hills National Forest, UTM 13 0629244E 4874730N, *Pinus ponderosa*/*Carex inops* ssp. *he-liophila* Woodland habitat type (NatureServe 2016), gentle to flat east facing slope, recent timber harvest at site (2008) and high recreation use area by motor vehicles, dominant spp. by frequency: *Danthonia spicata*, *Carex* spp., *Rubus idaeus*, *Taraxacum officinale*, and *Campanula rotundifolia*, rare and localized at site, 25 Jun 2014, Brian E. Dickerson 001 (BHSC, SDC).

U.S.A. South Dakota. Pennington Co.: Black Hills National Forest, Black Elk Wilderness, ca. 0.3 air miles SE of Harney Peak, along hiking trail, SW1/4 of SW1/4 of NE1/4 of S21 T2S R5E (Black Hills meridian), UTM 13 0618360E 4857610N, 6840 feet elevation, open canopy of *Pinus ponderosa* with many trees recently killed by mountain pine beetle, SE facing slope, associated species: *Populus tremuloides*, *Achillea millefolium*, *Taraxacum officinale*, *Ribes* sp., *Potentilla* sp., *Poa pratensis*, 02 Jul 2014, Cheryl Mayer 1485 (BHSC); 02 July 2015, Cheryl Mayer 1509 (BHSC, RM, SDC).

Hieracium piloselloides voucher specimens:

U.S.A. South Dakota. Lawrence Co.: Black Hills National Forest, north-central Black Hills, ca. 8.0 air miles NNE of Rochford, SD, along Custer Crossing Road (CTY-256), NE1/4 of SE1/4 of NE1/4 of S18 T3N R4E, (Black Hills meridian) UTM 13 0605816E 4897390N, 5660 feet elevation, relatively open, roadside area dominated by non-native vegetation and overstory of *Pinus ponderosa*, associated species: *Poa pratensis*, *Phleum pratense*, *Trifolium* sp., *Medicago lupulina*, *Antennaria* sp., *Achillea millefolium*, 27 Jun 2014, Cheryl Mayer 1483 (BHSC, RM, SDC); 10 Jul 2014, Cheryl Mayer 1491 (BHSC); 10 Jul 2015, Cheryl Mayer 1520 (BHSC); 24 Jul 2015, Mark Gabel et al. 7080 (BHSC).

Characters of Black Hills specimens were evaluated and compared to published descriptions of Eurasian *Hieracium* that have been introduced to North America. Initial species determinations pointed to *H. piloselloides* and *H. caespitosum* but identifications of some specimens were inconclusive; moreover, we were suspect of the likelihood for two new species being found within one month from one genus within a relatively small geographic area. We therefore decided to conduct a quantitative morphometric analysis of the newly introduced *Hieracium* with reference to previously-identified specimens of *H. piloselloides* and *H. caespitosum* archived in major U.S. herbaria (MO, RM, SDC).

Previously identified specimens used in this study are represented here by collector's last name, collector number (both in italics), herbarium acronym, and herbarium accession number.

Ahles 78828 (MO) 3685627; Anderson 20097 (MO) 1149884; Beetle 635 (RM) 152047; Bicknell s.n. (MO) 2460634; Bohlke 161 (MO) 5651835; Boivin 104 (MO) 1305155; Boufford 6373 (MO) 2463682; Brooks 19863 (RM) 561240; Burch Taylor 6692 (RM) 210810; Churchill s.n. (MO) 1053682; Churchill s.n. (MO) 1053681; Clarkson 1150 (RM/USFS) 479827; Clarkson 3094 (RM/USFS) 479829; Collins s.n. (MO) 1291221; Davids 3317 (MO) 3664658; Dorn 9242 (RM) 718372; Drushel 6019 (MO) 959861; Drushel 11162 (MO) 1184443; Drushel 11328 (MO) 1184442; Dutton s.n. (MO) 850214; Dutton s.n. (MO) 859093; Emmert s.n. (RM) 212449; Evert 23975 (RM) 780122; Fletcher s.n. (MO); Fletcher 1084 ½ (MO); Fosberg 23660 (MO) 5675337; Gereau 982 (MO) 2934112; Gereau 494 (MO) 3392253; Heinault 4859 (RM) 306030; Hermann 7723 (RM) 151804; Hess 7248 (MO) 5589389; Hess s.n. (MO) 5665941; House 26449 (MO) 1214086; House 26540 (MO) 1256739; House 16636 (MO) 979883; MacDonald 1432 (RM) 306026; Marie-Victorin 49-318 (RM) 174373; Markow 12501 (RM) 727269; Morey M-23 (RM/USFS) 479753; Morey M-118 (RM/USFS) 479825; Muenscher 1442 (MO) 1043327; Nee 50870 (MO) 5665928; Palmer 40180 (MO) 1036787; Park 73325 (RM/USFS) 479831; Progulské s.n. (SDC); Ripper 440 (RM/USFS) 479826; Rolland-Germain 29415 (RM) 134287; Rydberg 7886 (RM) 105435; Sargent s.n. (RM) 233710; Schmidt 1077 (MO) 4624936; Seymour 23989 (MO) 2453161; Seymour 19743 (MO) 2460636; Seymour 711(?) (MO) 970113; Seymour 19446 (MO) 2460641; Seymour 21535 (MO) 2460640; Seymour 19824 (MO) 2460637; Shchepanek 5290 (RM) 543034; Solomon 1595 (MO) 2977689; Steyermark 86178 (MO) 2882714; Taylor s.n. (SDC); Taylor 2434 (SDC); Taylor 1490 (SDC); Taylor s.n. (SDC); Unknown s.n. (MO) 3177882; Unknown s.n. (MO) 3177883; Utech 80-116 (MO) 2823951; Witte s.n. (RM) 182702; Witte s.n. (RM) 135937.

Five traits were selected for study based on their purported utility in distinguishing *Hieracium* taxa and practical use in rapid field identification (i.e., characters that could differentiate species without extensive dissection or extraordinary efforts); these traits included stem height, stem diameter at mid stem, involucre length, pappus length, and density of stellate leaf hairs. Traits were then measured on 32 pressed *Hieracium* plants from the Black Hills as well as identified specimens of *H. piloselloides* (N=42) and *H. caespitosum* (N=26) at MO, RM, and SDC. Measurements on these 100 total specimens were made in person (digitized specimen images lacked required resolution for evaluation of leaf pubescence and reproductive structures), mostly using ocular micrometers on dissecting microscopes. Because of the large number of stellate hairs on some specimens, a 5 mm × 10 mm “window” was cut in cardstock and the window placed over the abaxial side at the midpoint of the largest available leaf; hair densities were subsequently standardized to counts per cm² for data analysis and interpretation.

To evaluate the role of the five measured traits in distinguishing *Hieracium* species and gain insights into prior identification efforts by U.S. botanists, we compared characteristics of identified herbarium specimens of *H. piloselloides* and *H. caespitosum* with univariate analysis of variance models (ANOVA), multivariate analysis of variance (MANOVA), and discriminant function analysis (DFA) using the JMP software package (v.9; SAS Institute Inc., Cary, NC, U.S.A.). For the complete data set—including recently-sampled plants from the Black Hills—we performed Principal Components Analysis (PCA) and evaluated univariate trait distributions using JMP. All statistical analyses were performed on raw data (non-transformed) based on inspection of ANOVA residuals, which were normally distributed for most traits and taxon comparisons.

RESULTS

Univariate ANOVA indicated significant differences ($P < 0.05$) between previously-identified *H. piloselloides* and *H. caespitosum* herbarium specimens for leaf hair number, involucre length, and pappus length; stem diameter exhibited a marginally significant difference ($P = 0.068$) while stem height was not different (Table 1). Leaf hair number and pappus length appeared particularly discriminatory, with high R^2 values in ANOVA models (0.767 and 0.426 for these two traits, respectively) (Table 1). MANOVA confirmed that *H. piloselloides* and *H. caespitosum* were distinguished statistically by the measured traits (Wilks lambda=0.168, $P < 0.001$) and 100% of specimens were correctly assigned to species by the DFA. The first canonical of the DFA model was correlated primarily with leaf hair density and pappus length (standardized scoring coefficients, 0.948 and 0.600, respectively), suggesting that these traits are the basis on which species assignments of invasive *Hieracium* have in the past been made in the U.S. and Canada.

For the combined data set that included as-yet unidentified plants from the Black Hills, the first three eigenvalues of the PCA model explained 41.0, 27.8, and 16.7% of overall trait variation. PCA 1 was associated primarily with stem diameter, involucre length, and height (eigenvalues of 0.588, 0.490, and 0.464, respectively, for these traits) while PCA 2 was associated primarily with leaf hair number and pappus length (eigenvalues of 0.681 and 0.559, respectively, for these traits). Previously-identified herbarium specimens of *H. piloselloides* and *H. caespitosum* had overlapping values for PCA 1 but were strongly distinguished by PCA 2 and by

TABLE 1. Univariate comparisons (ANOVA) of previously-identified *H. piloselloides* (N=42 specimens) and *H. caespitosum* (N=26 specimens) from major herbaria (MO, RM, SDC).

Character	mean \pm SE <i>H. piloselloides</i>	mean \pm SE <i>H. caespitosum</i>	R ²	P
stem height	50.16 \pm 2.29	47.67 \pm 2.91	0.007	0.503
stem diameter	2.26 \pm 0.14	2.69 \pm 0.18	0.049	0.068
stellate hairs	10.74 \pm 8.32	208.96 \pm 10.58	0.767	<0.001
involucre length	6.06 \pm 0.14	6.55 \pm 0.17	0.072	0.027
pappus length	3.68 \pm 0.08	4.55 \pm 0.01	0.426	<0.001

univariate comparisons of the traits correlated with PCA 2 (Fig. 1). *Hieracium* specimens collected in the Black Hills appeared in some cases morphologically associated with *H. piloselloides* (N=22 plants) and in others with *H. caespitosum* (N=10 plants) (Fig. 1), suggesting that both species are present now in South Dakota. The following key may be used to separate the species of *Hieracium* present in South Dakota.

1. Basal and lowest leaves ephemeral and smaller than leaves at mid-stem _____ **H. umbellatum**
1. Basal and lowest leaves larger than leaves at mid-stem.
 2. Corollas white to ochroleucous; florets 12–25+ _____ **H. albiflorum**
 2. Corollas mostly yellow to orange; florets 25–120+.
 3. Corollas orange (may dry to dark red) _____ **H. aurantiacum**
 3. Corollas yellow.
 4. Fruits 5–7 mm long; pappus 5–8 mm long _____ **H. fendleri**
 4. Fruits 1–2 mm long; pappus 3–5 mm long.
 5. Stem and leaves glabrous to pilose with no or very few stellate hairs _____ **H. piloselloides**
 5. Stem and leaves with pilose, glandular, and numerous small (hand lens needed) stellate hairs _____ **H. caespitosum**

DISCUSSION

A native to Europe, *Hieracium caespitosum* was probably introduced in the eastern United States in 1828 but was not recorded until 1969 in the Pacific Northwest (Wilson & Callihan 1999). It is now found from Quebec to Manitoba and southward to Georgia and South Carolina (USDA NRCS 2016). Both *H. caespitosum* and *H. piloselloides* are listed as noxious weeds in the Pacific Northwest (USDA NRCS 2016), where sites most vulnerable to establishment include disturbed areas and mountain meadows at elevations of 2100 to 5400 feet (Stone 2011). In their native range of Eurasia these species are generally weak competitors and occur in isolated patches in disturbed areas such as pastures and roadsides (Wilson et al. 2006).

The occurrences of *H. caespitosum* and *H. piloselloides* in the Black Hills range in elevation from 4260 to 6840 feet and are associated with human disturbance (i.e., recent timber harvest and travel corridors including roads and trails). Due to the weedy nature of these two species, it is probable that sites in addition to those reported here currently exist in the Black Hills, and more will likely become established. As stated in FICNMEW (Federal Interagency Committee for the Management of Noxious and Exotic Weeds 2003) "... early detection and rapid response (EDRR) is a critical component of any effective invasive species program." This may be an opportunity to use the EDRR model to initiate a rapid assessment and test control methods to prevent these species from spreading in the Black Hills and surrounding areas. The most serious potential impact is loss of native plant diversity that can degrade pasture land and disrupt overall ecosystem function (Wilson & Callihan 1999). The occurrence of newly-invasive hawkweed populations also provides opportunity for biologists to study roles of apomixis, hybridization, and polyploidy—all common in the genus *Hieracium*—in demographic establishment.

Species of *Hieracium* subgen. *Pilosella* are known for readily hybridizing, a process that may increase phenotypic variability of populations and augment invasive potential (Krahulec & Krahulcová 2011). We find no evidence of interspecific hybridization, however, between *H. piloselloides* and *H. caespitosum* in specimens from major herbaria or samples collected in the Black Hills; all plants appeared cleanly distinguished in DFA/MANOVA as well as univariate inspections of leaf hair number and pappus length. Although there is trait

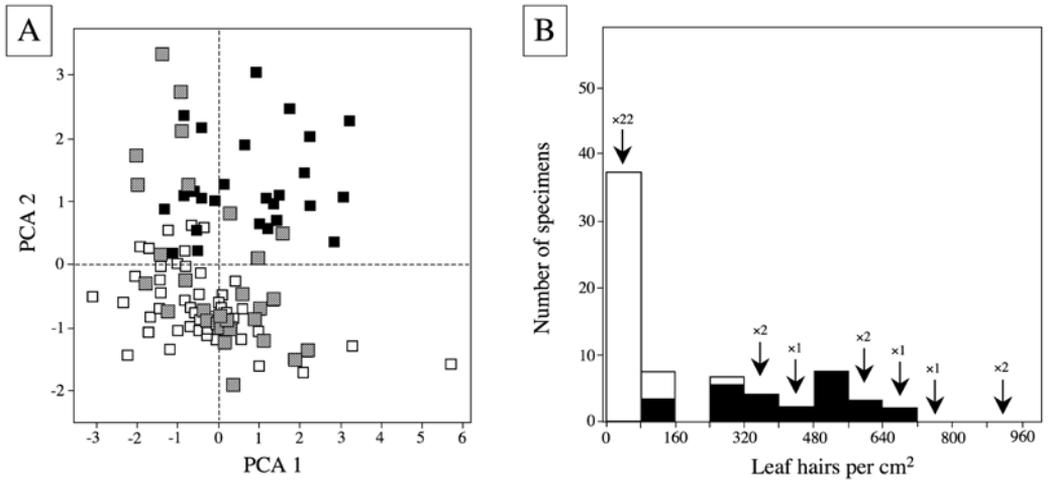


FIG. 1. Phenotypic characteristics of previously-identified herbarium specimens of *H. piloselloides* (in white; N=42) and *H. caespitosum* (in black; N= 26) as well as plants collected 2014–2015 in the Black Hills (in gray; N=32). **A.** Results of Principal Components Analysis based on five morphometric traits. **B.** Distribution of trait values for stellate leaf hairs, a character of apparent importance for distinguishing *H. piloselloides* vs. *H. caespitosum*; arrows indicated values measured in specimens from the Black Hills.

overlap between the species for stem traits and involucre length—and correspondingly, in PCA 1 that is closely associated with these characters—these sorts of traits are probably affected by environmental factors and specimen age as well as intrinsic genetic differences between species. As means for field identification, leaf hair observations appear to be the most reliable character for identifying plants in nascent populations of South Dakota. The ability to reliably differentiate among closely related, newly establishing invasive species will be important for monitoring the species' occurrences and predicting spatial spread and ecological impacts (Moffat et al. 2015).

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