

## A New Prairie Moonwort (*Botrychium* Subgenus *Botrychium*) from Northwestern Minnesota

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Within the last decade, repeated discoveries of new species of moonworts have shown that the North American diversity of *Botrychium* subgenus *Botrychium* has been underappreciated (Wagner & Wagner, 1981, 1983, 1986, 1990a, 1990b). In large measure this is due to the morphological simplicity of these plants and consequent subtlety of morphological differences among species. A further hindrance has been the difficulty of finding these small plants in numbers sufficient for analysis. Recent advances have been achieved through recognition that morphological species differences, though subtle, are detectable and constant, and through heightened awareness of favored moonwort habitats.

In western North America the occurrence of moonworts in open grassy mountain meadows and roadsides is well established. It has only recently been discovered that eastern moonworts may also occur abundantly in treeless habitats such as dunes and railroad rights-of-way. It is not surprising, then, that moonworts also occur in native grassland prairies. *Botrychium campestre* Wagner and Farrar, described from western Iowa prairies (Wagner & Wagner, 1986), in fact has not been recorded from mature woodland habitats. In its reproduction by underground gemmae (Farrar & Johnson-Groh, 1990) and in its early spring phenology, *B. campestre* appears to be particularly adapted to dry prairie habitats (Farrar, 1985; Farrar & Johnson-Groh, 1986).

As part of an ongoing study of the ecology and occurrence of *B. campestre* in Iowa and Minnesota, we have encountered two other moonworts in native prairie habitats. One of these is the circumboreal *Botrychium simplex*. Though apparently confined to moist sandy swales in Iowa prairies, *B. simplex* occurs sporadically throughout many of the prairies we have examined in northwestern Minnesota. The second prairie moonwort encountered in our field research was previously undescribed; here we describe it as a new species.

***Botrychium gallicomontanum*** Farrar & Johnson-Groh, sp. nov. (Figs. 1,2,4)

*B. campestris* simile, sed distancia inter primum par pinnarum et secundum longior, pinnae latiores et minus aequilaterae incisaeque, stipites trophophori sporophorique longiores, et sporae majores. Cum *B. campestri* et *B. simplici* crescens, et inter has intermedium.

Underground stems erect, fleshy, 1-3 cm tall, bearing 3-8 fleshy roots and numerous (6-66, avg. 22) spherical gemmae 0.5-1.0 mm in diameter attached directly to the stem; above ground leaf herbaceous, yellow-green, 7.2 (5-12) cm tall, undivided petiole 4.6 (3-7) cm tall; trophophore (blade-bearing portion)



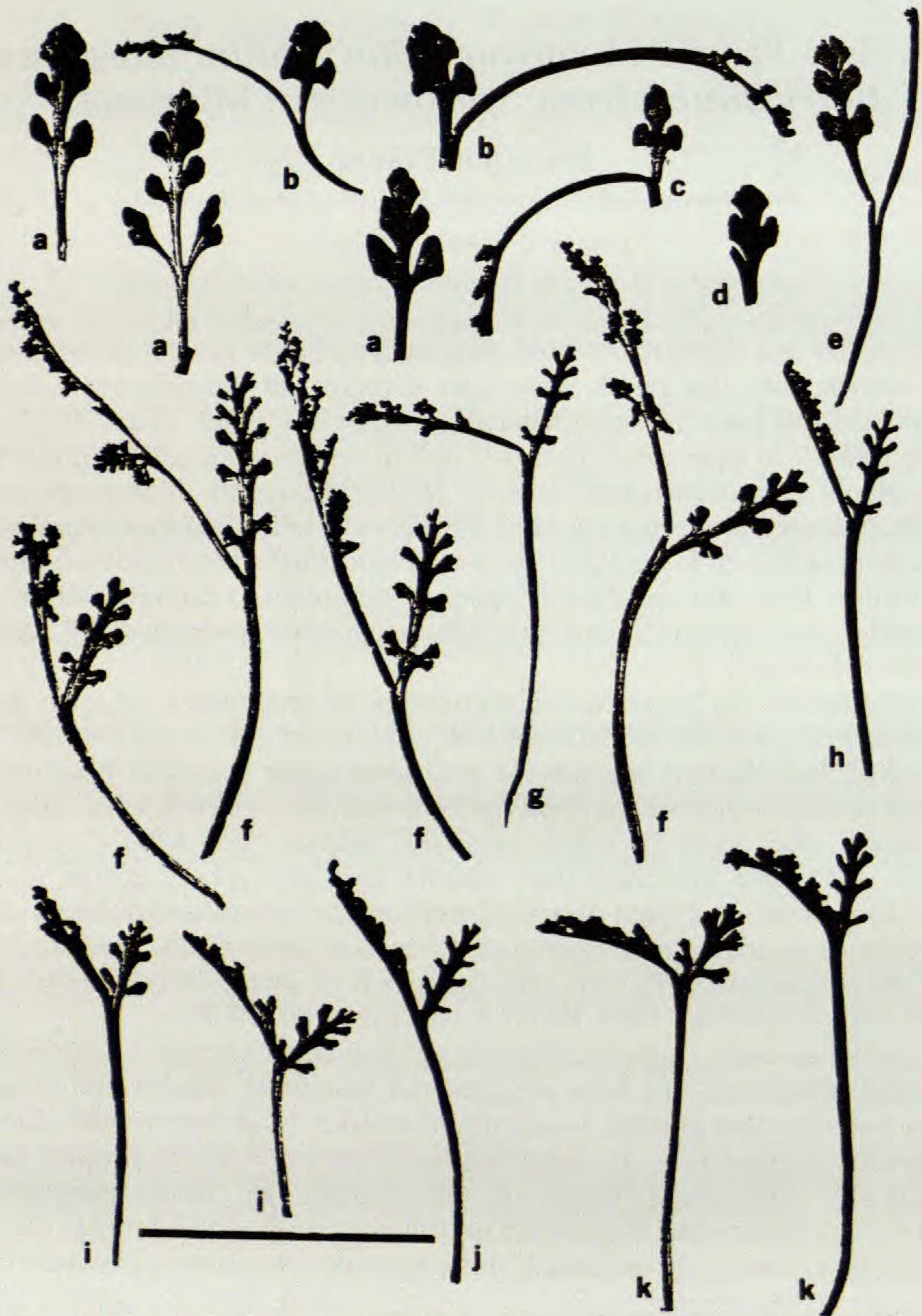


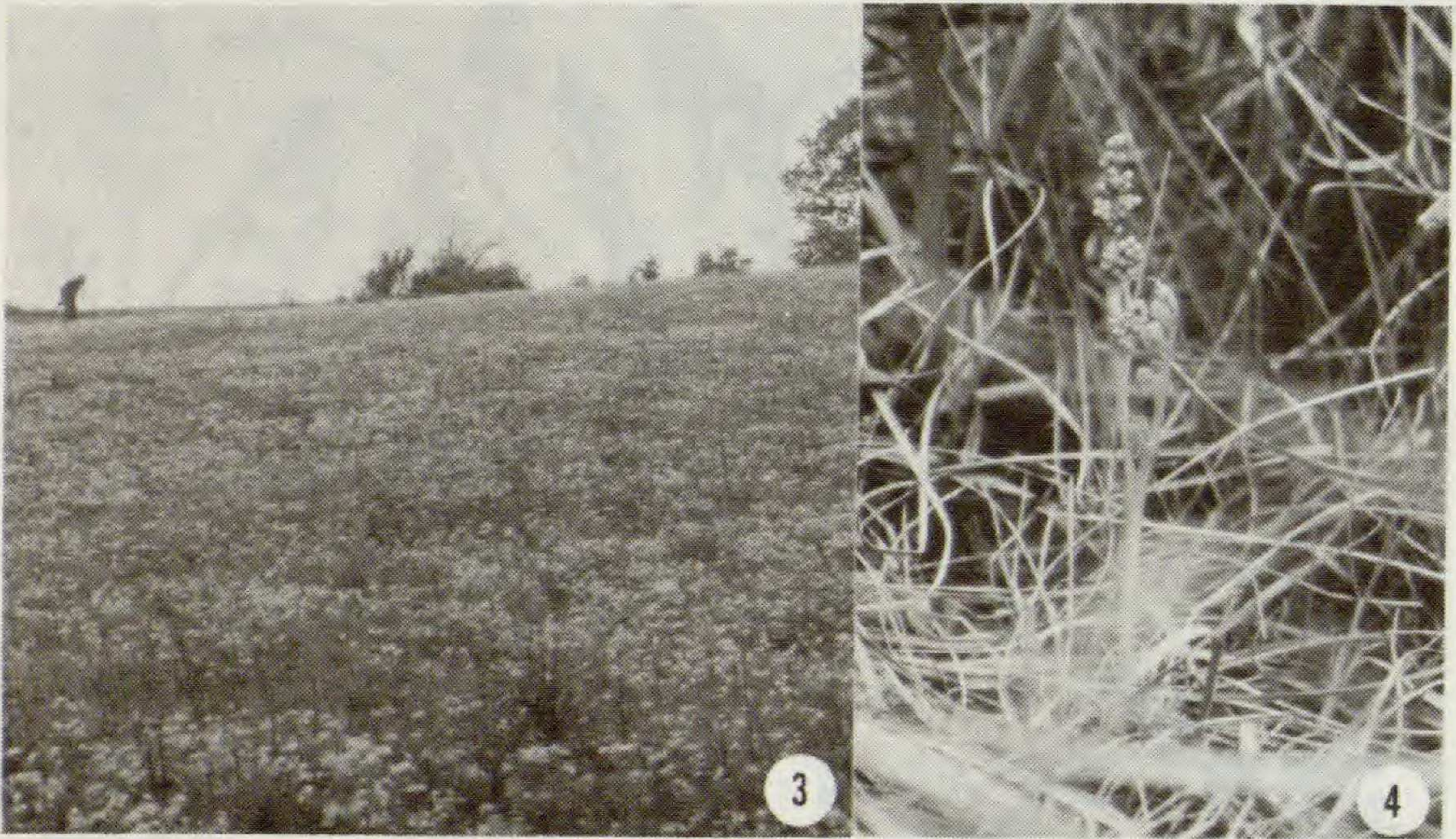
FIG. 1. *Botrychium gallicomontanum* (middle row) and probable parental taxa *Botrychium simplex* (top row) and *Botrychium campestre* (bottom row). a. Farrar 87-6-27-6, from Grand Sable Dunes, Alger Co., MI. b, c. Pittillo *sn* (May 1990, June 1989), from Richland Balsam, Jackson Co., NC. d. Farrar 87-5-24-6, from Frenchman's Bluff, Norman Co., MN. e. Farrar 86-6-12-1, from Norway Dunes, Kitson Co., MN. f, g, h. Farrar 86-6-10-4, 90-6-6-1, 86-6-10-2, from Frenchman's Bluff, Norman Co., MN. i. Farrar 86-5-31-1, from 5-Ridge Prairie, Plymouth Co., IA. j. Farrar 86-6-2-1, from Niobrara River, Brown Co., NE. k. Farrar 87-5-22-1, from Big Stone State Park, Big Stone Co., MN. Fertile segments and petioles below the segment junction have been removed from some of the *B. simplex* specimens. Bar = 5 cm.





FIG. 2. *Botrychium gallicomontanum* (top row), *Botrychium spathulatum* (middle) and *B. minganense* (bottom). a, b, c. Farrar 90-6-6-1, 86-6-10-4, 86-6-10-2, from Franchman's Bluff in Norman Co., MN. d, e. Farrar 87-6-27-3, 87-6-28-2, from Grand Sable Dunes, Alger Co., MI. f. Farrar 87-6-28-2a, from Grand Sable Dunes, Alger Co., MI. g. Farrar 87-6-26-2, from Tower Road, Emmet Co., MI. Bar = 5 cm.





FIGS. 3-4. Frenchman's Bluff and *Botrychium gallicomontanum*. 3. Native prairie habitat of *B. gallicomontanum* on Frenchman's Bluff, Norman Co., MN. 4. Living plant of *B. gallicomontanum*.

stalk 3.7 (1–8) mm long, trophophore blade ovate to linear, 2.2 (1.4–3.5) cm long, 1.0 (0.6–1.5) cm wide; pinnae pairs 4.5 (3–6), strongly ascending, the basal pair commonly separated from the remainder by a space conspicuously greater than that separating the remaining pairs; pinnae flabellate to narrowly spatulate, often asymmetrical with the upper (anterior) portion exaggerated and arching over the basal portion, entire or irregularly cleft (usually in basal pinnae only), with entire or crenate margins; largest pinnae 4 (2–7) mm long and 4 (4–8) mm wide, with 4 (3–6) major veins terminating at the outer margin in 13 (6–20) veinlets; sporophore (sporangia-bearing portion) 4.1 (1.8–7.5) cm long with a short stalk 1.4 (0.5–2.8) cm long; sporangia numerous and crowded; spores large, 39 (34–46)  $\mu\text{m}$  in longest diameter. Co-exists with *B. campestre* and *B. simplex* between which it is more or less intermediate.

TYPE: U.S.A., Minnesota, Norman Co., Frenchman's Bluff Prairie Preserve, Farrar 86-6-10-4 (holotype ISC; isotypes MIN, MICH, NY, MO, US).

Additional Collection: U.S.A., Minnesota, Norman Co., one mile west of Frenchman's Bluff Prairie Preserve, Farrar 87-5-24-7, 87-5-24-8 (ISC).

The epithet refers to the only known location of the species, in Norman Co. on the topographic landmark known as Frenchman's Bluff. Frenchman's Bluff is a glacial moraine which tops beach deposits associated with the southwestern shore of glacial Lake Agassiz (Fig. 3). The highest point of the bluff, approximately 60 meters above the glacial lake bottom, is gently rolling terrain supporting mesic to dry native prairie vegetation. *Botrychium gallicomontanum* occurs on a 42 acre tract owned by the Minnesota Chapter of The Nature Conservancy, along with *B. campestre* and *B. simplex*, though in lesser abundance than *B. gallicomontanum*.



Despite several thorough searches, *Botrychium gallicomontanum* has not been found in an adjacent heavily grazed prairie pasture or in nearby bur oak and aspen woodlands. Searches in similar prairie habitats throughout western Minnesota have also been unproductive. The only other known location of *B. gallicomontanum* is in prairie vegetation on the basal slope of Frenchman's Bluff about 1 mile west of the Nature Conservancy preserve. Here it is much less abundant than either *B. simplex* or *B. campestre*.

Since its discovery in 1986, we have located approximately 500 plants of *B. gallicomontanum*. They are present on all slope aspects and can be found among both sparse and dense prairie vegetation. Like *B. campestre*, *B. gallicomontanum* has an early spring phenology, with spore release occurring about June 10 and the plants senescing in late June or early July. We are currently monitoring the species' population dynamics and its response to fire and climate fluctuations.

*Botrychium gallicomontanum* can be distinguished from *B. campestre* by its peculiar spacing of the basal pinna pair and overarching of the anterior portion of the pinnae (Fig. 1). Pinnae of *B. campestre* are less flabellate and more symmetrical and, in large pinnae, more frequently incised. The trophophore of *B. campestre* is sessile or short-stalked, and the sporophore and its stalk are likewise shorter than those of *B. gallicomontanum*. The spores of *B. gallicomontanum* are distinctly larger than those of *B. campestre* [39 (34–46) vs 35 (33–37)  $\mu\text{m}$ ] although their ranges overlap.

Next to *B. campestre*, *B. gallicomontanum* most closely resembles *B. minganense* Vict. (Fig. 2). Plants traditionally treated as the latter are now thought to warrant division into two species, the true *B. minganense* and a new species, *B. spathulatum* Wagner and Wagner (Wagner & Wagner, 1990a, 1990b). However both of these entities differ from *B. gallicomontanum* in having trophophores with more evenly graded separations between pinnae pairs, and lower pinnae that are less strongly ascending and more symmetrical, i.e., without exaggerated and arching anterior portions. *B. gallicomontanum* also differs in having smaller trophophores and, in plants of comparable size, shorter sporophores with much shorter stalks comprising about 30% (20–50) of the total sporophore length. In *B. spathulatum* the sporophore stalk comprises about 50% (35–70) of the total length of the sporophore, and in *B. minganense* the sporophore stalk is longer still. Finally, *B. spathulatum*, which most closely resembles *B. gallicomontanum* in pinna outline, differs in having a stalkless sterile segment in contrast to the distinctly stalked sterile segment of *B. gallicomontanum*.

We have not yet obtained a chromosome count for *B. gallicomontanum*, but strongly suspect it to be tetraploid, based on evidence from starch-gel enzyme electrophoresis. Of 17 loci scored in 10 enzyme systems, 3 display fixed heterozygosity and the remainder are homozygous. Absence of segregation at the heterozygous loci and absence of any allelic variation within the species suggest a possible origin of *B. gallicomontanum* through interspecific hybridization followed by chromosome doubling. Supporting this conclusion is the production of normal (non-abortive) spores.



We suspect that *B. gallicomontanum* originated through interspecific hybridization between *B. campestre* and *B. simplex* (Fig. 1). This origin would explain the distinctive morphological features of *B. gallicomontanum*, namely the presence of gemmae and partially incised pinnae, inherited from *B. campestre*, and the peculiar spacing of the basal pinnae and the anterior arching of the asymmetrical pinnae, derived from *B. simplex*. Other morphological features, including the sporophore length and spore size (*B. simplex* has long sporophores and large spores measuring 46 (40–50)  $\mu\text{m}$  in longest diameter), are reasonably intermediate between these diploids. Furthermore, these two putative parents are intermixed with *B. gallicomontanum* at Frenchman's Bluff, and no other diploid moonworts occur in the vicinity. It may be significant that in other known co-occurrences, these two species tend to be segregated topographically with *B. simplex* occurring in swales and *B. campestre* occurring on better drained slopes and crests.

Enzyme electrophoresis also supports a *B. campestre*  $\times$  *simplex* origin of *B. gallicomontanum*. Of 20 alleles detected at 17 loci in samples from 50 plants of *B. gallicomontanum*, each is present in either *B. campestre* or *B. simplex* or both. This will be documented in a report of isozyme evidence of evolutionary relationships within the *Botrychium campestre* complex currently in preparation.

*Botrychium gallicomontanum*, as presently understood, constitutes one of the rarest ferns in North America. This may be due in part to loss of its habitat, undisturbed upland prairie, in the upper Midwest. Were it not for the preservation of the Frenchman's Bluff natural area, this moonwort would likely have remained undiscovered and possibly become extinct.

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