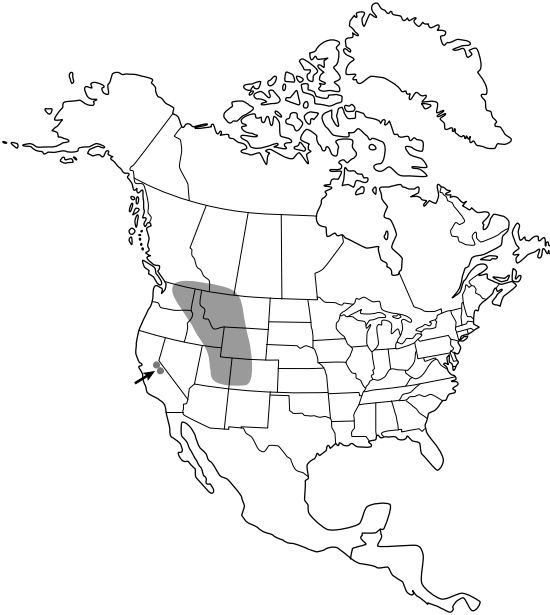


## *Botrychium paradoxum*

**Family:** Ophioglossaceae  
**Genus:** *Botrychium*  
**Species:** *Botrychium paradoxum* W. H. Wagner  
**Common Name:** Paradox Moonwort  
**Ploidy:** Tetraploid



**Published description:** Leaf 9 (7—15) cm tall, the stalk 0.5—2.0 mm. in diameter; texture varying from delicately herbaceous to robust and fleshy, color glaucous; sterile segment absent, replaced by a second fertile segment; the two fertile segments 2.5 (0.5—4.0) cm tall, unequal, the shorter one  $\frac{2}{3}$  the length of the longer one, to equal in length, erect and approximate to on another, nearly sessile to stalked, the stalks up to  $\frac{1}{2}$  the total fertile segment length; fertile portion mainly linear in outline because the lateral branches are sessile or nearly so and short, usually only 1—3 mm long; sporangia mostly 2 or 3 (1—12) per lateral branch. Spores 40 (36—43  $\mu\text{m}$  in diameter. Chromosome number unknown. (Wagner and Wagner 1981) Apparently tetraploid (Farrar)

## Taxonomy

The name “paradoxum” proposed by Wagner and Wagner (1981) for this species is fitting because of the several puzzles presented by its morphology. First, it has no expanded, blade-like trophophore, only a second sporophore. It seemingly has sacrificed photosynthetic capability for production of additional spores. Second, it is an allotetraploid, but what parentage could have produced it. If it is intermediate between its parents, as most allotetraploids are, what diploid morphology could have contributed the absence of a trophophore. No diploids with this morphology are known. Third, is it possible that more than one species is represented by this morphology. These questions are addressed in the following discussions.

## Identification

*Botrychium paradoxum* is unique among moonwort species in having no trophophore. Rather it has two nearly identical sporophores. All moonwort species occasionally, and some regularly, produce sporangia on the margins of the trophophore pinnae, especially the basal pair. Many species also occasionally produce one or a few plants in a population that have two sporophores and no trophophore, but in these cases the sporophores are not identical. *B. paradoxum* differs from the first situation in producing no trophophore blade tissue at all, and from the second situation in producing populations in which all plants have two sporophores and no trophophore. Two somewhat similar moonwort are *B. xwatertonense*, a hybrid between *B. paradoxum* and *B. hesperium*, in which sporangia are produced around the margin of all the trophophore pinnae, and *B. furculatum* sp. nov. ined. The latter is an undescribed allotetraploid having *B. pallidum* as one of its parents. Two-sporophore plants are often present in populations of this taxon that are very similar to *B. paradoxum* and can be separated only on the basis of genetic composition.

Further complicating the issues of *B. paradoxum* taxonomy and identification are results of genetic testing showing two distinct genotypes in populations that meet the morphological criteria for the species. This could be the result of two independent origins of the species. However, given the rarity of the species, it seems unlikely that descendants of two separate origins would so often be found in the same population. A more likely explanation is possible hybridizations between *B. paradoxum* and another species in which genes controlling the production of a second trophophore are dominant, i.e., the hybrid looks identical to *B. paradoxum*. The problem of two genotypes in some populations is under study. Meanwhile, the name “paradoxum” grows evermore appropriate.

## Distribution

*Botrychium paradoxum* occurs from south central Utah and Colorado northward to Montana and Washington and into southern British Columbia, Alberta and Saskatchewan. It is disjunct into the Sierra Mountains of east-central California.

## Habitat

*Botrychium paradoxum* is a plant of mesic subalpine mountain meadows dominated by grasses, sedges and in some cases, dense herbaceous (fireweed) and shrubby (*Salix* and *Potentilla*) cover.

In California *B. paradoxum* has been found in three populations in Yosemite National Park, all of these in soils influenced by metasedimentary bedrock.

## Population Genetics

The problem of two distinct genotypes of *B. paradoxum* has been discussed above. A given population may express both or only one, but within each genotype, very little variation is present.

In California, of the two populations tested, these about 25 miles apart, one expressed only a single genotype, the other was also dominated by this genotype, but expressed the second genotype in a few plants.

## Phylogenetic Relationships

As with many allotetraploids, one of the genome sets appears to have been contributed by a taxon containing the most common alleles of the genus. Among currently known diploids, this genome is most closely, but not entirely, matched by *B. pallidum*, but also as in other allotetraploids in which *B. pallidum* is the best match for one parent, there are alleles present in *B. paradoxum* that are not present in any known diploid. Thus, as in expressing the parentage of these other allotetraploids (e.g., *B. minganense*) we hypothesize that one of the parents was pallidum-like, and perhaps an extinct ancestor of *B. pallidum*. This is expressed in Table 2 in the Historical Review section as *B.* "X". The other parent of *B. paradoxum*, the diploid contributing the dominant gene controlling expression of the second sporophore, remains a mystery.

*B. paradoxum* has combined with *B. hesperium* to produce the named hybrid *B. xwatertonense*. In *B. xwatertonense*, blade tissue is clearly present in the modified trophophore, but it is surrounded by marginal sporangia. Though apparently sterile, *B. xwatertonense* is surprisingly common where present (Wagner et al. 1983). Possibly it reproduces by underground gemmae, a character inherited from its pallidum-like parent.

Additional images of *Botrychium paradoxum*:

