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Lysimachia nummularia (Primulaceae): A non-native plant in Ozark springs

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ABSTRACT. – The presence, ecology, and probable physiological mechanisms of *Lysimachia nummularia* populations in Missouri Ozark spring systems is discussed, including the species' ability to function as a submerged aquatic.

INTRODUCTION

Moneywort (Creeping Jenny, *Lysimachia nummularia* L, Primulaceae. is commonly sold as a landscape plant in nurseries, gardening centers, and garden catalogs. This perennial evergreen species and native of Europe was naturalized in the United States by 1900, and it is thought to have originated from nursery stock (Mack 2003). Due to its widespread use in landscaping, it has frequently escaped cultivation and become feral in North America. The specific factors that facilitated the successful escape of Moneywort in North America are unknown, but are likely complex (Theoharides and Dukes 2007). Moneywort occurs throughout most of the eastern United States and Great Plains, as well as west of the Rocky Mountains (USDA, NRCS 2017). The National Park Service has reported Moneywort at 60 service properties in the United States, including the Buffalo National River, Arkansas, and Ozark National Scenic Riverways, Missouri (NPSpecies 2017). It is widely distributed in Missouri (Yatskievych 2013, USDA NRCS 2017).

Previous studies (Ramsey et al. 1993, Fleming and Kanal 1995, Aronson et al. 2004, Blood et al. 2010) found Moneywort to be among the most dominant invasive species in the plant communities they studied. The invasiveness of this species is at least partially related to its physical and environmental plasticity. It readily reproduces through fragmentation, roots at the nodes, and demonstrates an affinity for a wide range of environmental and habitat conditions (Godfrey and Wooten 1981). It predominantly inhabits wet areas along the banks of ponds, streams and springs, which also is the preferred habitat in its native range (Curry and Slater 1986) (Figure 1). Because of its preference for wetland habitats, Moneywort is occasionally sold as a plant for water gardens. Moneywort also can grow in a range of light conditions ranging from heavy shade to full sun (MIPAG 2005). Moneywort is not known to produce seeds in Missouri (Yatskievych 2013), and reproduction is apparently entirely vegetative. Nonetheless, the affinity of this species for wet areas and the abundance of its fragments in floodplain debris likely serves as an effective dispersal mechanism that facilitates its invasiveness (Gleason 1897, Ott 1969, Bell 1974, Carpenter and

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Chester 1987, Ramsey et al. 1993, Fleming and Kanal 1995, Basinger et al. 1997, Hughes and Cass 1997, Kearsley 1999, Taft 2003, Leck and Leck 2005, Van Vechten and Buell 1959, Yatskievych 2013).

Figure 1. *Lysimachia nummularia*, Round Spring, Shannon Co., Missouri. **A**: terrestrial population on bank; **B**: leaf shape and elongated stem of submerged plant; **C**: submerged plants (circled). All photos by the author.

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OCCURRENCE IN MISSOURI SPRINGS

Although widely known as a floodplain-inhabiting species, Moneywort is not generally considered to be a submersed aquatic plant, yet it is becoming an increasingly problematic invasive in and around Missouri spring systems. During surveys of aquatic vegetation occurring in Ozark springs, I commonly find Moneywort growing among the vegetation communities on the banks of these aquatic systems, and in many cases I find it growing entirely submersed (Fig. 1) at depths up to 0.5 m. I have found completely submersed and rooted populations of Moneywort at Big Spring (Carter Co.), Patterson Spring (Christian Co.), Maramec Spring (Phelps Co.), Boze Mill Spring (Oregon Co.), Hodgson Mill and Rainbow springs (Double Spring) (Ozark Co.), Cave and Round springs (Shannon Co.), Turner's Mill Spring (Oregon Co.), and Boiling Spring (Texas Co.). I found an additional submersed population growing in the Jacks Fork River approximately 1 km upstream of Bay Creek (Shannon Co.).

TOLERANCE TO SUBMERSION

Thermal and physical consistency associated with springs may be a contributing factor that makes such aquatic habitats favorable for establishment and spread of Moneywort, as has been shown for other invasive plants (Bowles and Bowles 2013, Bowles et al. 2011, Bowles and Dodd 2015). For example, in a survey of large springs at Ozark National Scenic Riverways, Bowles and Dodd (2015) reported submersed populations of Moneywort in addition to several other wetland and terrestrial species that were found growing submersed (i.e., native species—*Glyceria striata*, *Lobelia cardinalis*, *Physostegia virginiana*; introduced species—*Mentha aquatica, Poa annua*, *Rumex obtusifolius*). The physiological mechanism(s) used by these plants to inhabit aquatic environments and photosynthesize while submersed are not entirely understood, but several mechanisms have been identified that are used by terrestrial plants to manage complete submergence during flooding (Mommer et al. 2005, Mommer and Visser 2005, Voesenek et al. 2006, Striker 2012). Some of these same mechanisms, as described below, may be used by Moneywort and other wetland species to inhabit springs.

A critical physiological requirement of submersed plants is assimilation of carbon dioxide (CO_2) for photosynthesis. Although CO_2 often has a higher concentration in water compared to the atmosphere, its availability in water usually is lower because molecular diffusion of dissolved gases is about 10^4 times slower in water than in air (Winkel and Borum, 2009). Because of this limitation, many aquatic plants instead use bicarbonate for photosynthesis, or more rarely crassulacean acid metabolism (CAM) and C4-like metabolism (Keeley 1998). However, Pedersen et al. (2013) found that amphibious aquatic plant species that are only occasionally submersed rely mostly on CO_2 for photosynthesis. In comparison, aquatic systems high in alkalinity typically have a high proportion of aquatic plants that use bicarbonate for photosynthesis (see Pedersen et al. [2013] for review). Because of the carbonate substrates in the Ozarks, the pH of most springs ranges between 7 and 8 (Bowles et al. 2011), which is about the level where the relative distribution of carbon dioxide (CO_2) and bicarbonate (HCO_3^-) in water are at equilibrium (Pederson et al.

2013). Elevated levels of both CO_2 and HCO_3^- in karstic springs also may serve to reduce the respiration rate and requirement for dissolved oxygen in submersed plants (Gonzàles-Meler et al. 1996). Moreover, Mommer et al. (2005) showed that some plant species have higher underwater CO_2 assimilation rates after they become acclimated to submergence. Thus, it appears tolerance of plants to submergence occurs when they can maintain photosynthesis and high stomatal conductance as well as respiratory processes in their tissues (Onoda et al. 2009, Caudle and Maricle 2012). It remains unclear what method of carbon assimilation is being used by Moneywort and other species to tolerate submersion in Ozark springs.

In addition to requirements for dissolved gasses, submersed plants often facilitate increased photosynthesis through production of thinner cuticles and leaves, and increased stem lengths (Mommer et al. 2005, Mommer and Visser 2005, Voesenek et al. 2006, Striker 2012). High concentrations of CO_2 have been shown to result in stem elongation in some plants (Voesenek et al. 2006). Moreover, Bailey-Serres and Voesenek (2008) found that the gaseous plant hormone ethylene increases in tissues when plants becomes covered in water, which subsequently enhances shoot elongation. Although I lack empirical evidence to show that this is occurring in the aquatic populations of Moneywort, it is notable that the submersed forms of this species have longer stems and thinner leaves with a larger surface area compared to emergent plants (Fig. 1).

High CO_2 and HCO_3^- concentrations in karstic groundwater and springs (Knight and Notestein 2008), coupled with water clarity and thermal and physical consistency, likely facilitates the submersed growth of Moneywort and other wetland species in these systems as opposed to other surface waters.

MANAGEMENT CONSIDERATIONS

It remains unknown to what extent Moneywort may be impacting the springs or displacing native species, but Bowles and Bowles (2017) found that many introduced species do not cause discernible impacts to the ecosystems to which they are introduced, and minor impacts may be difficult to measure. Although Moneywort is invasive and readily spreads under favorable conditions, removal by hand pulling has been shown to be effective for controlling small patches of this species (Kennay and Fell 1992, Clark and Wilson 2001), but similar control for large patches has not been demonstrated. Prescribed burning for non-aquatic environments can be effective, but typically several burns are necessary for this treatment to be efficacious (Kennay and Fell 1992), and some areas may be too wet to burn. Such manual effort may not be practical for large populations, but smaller populations should be aggressively controlled when possible. Discouraging planting of Moneywort as an ornamental plant, and education on its invasive tendencies, would be helpful in slowing the spread of this invasive species.

Moneywort presently is not listed as an invasive species of concern for Missouri. Thus, many gardeners are unaware of this specie's tendency to escape. Indeed, one self-described 'native plant nursery' near Springfield Missouri listed this species as native and recommended it for native gardens. Education of vendors, government agencies, and the general public on the invasive tendencies of Moneywort will go far in helping to reduce the spread of this species.

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