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Reproductive strategy, management, and medicinal uses of field horsetail (*Equisetum arvense*)

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Intriguing World of Weeds

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Abstract

Field horsetail (*Equisetum arvense* L.) is a perennial weed native to many areas of the northern hemisphere. Like other horsetail species, field horsetail is a spore-bearing plant from an ancient clade. Unlike some other horsetails, field horsetail is a problematic agricultural weed. It is especially difficult to control in low-tillage cropping systems. Neither chemical nor mechanical tactics are likely to achieve full control in a single operation. However, these tactics may be successfully combined in an integrated weed management program. This review summarizes available information about the biology, ecology, and management of field horsetail. We also note its potential value as a source of pharmaceutical compounds.

Introduction

Field horsetail (*Equisetum arvense* L.), also known as common horsetail, is a herbaceous perennial weed reproducing via rhizomes and spores (James and Rahman 2010; Marshall 1986). The average height of these plants is 30 to 40 cm, and rhizomatous structures can reach up to 2 m depth (Bell and Popay 1988; Carneiro et al. 2019; James and Rahman 2010). Field horsetail's ability to occupy various habitats, including sandy soils and flood plains of agricultural fields or riverbeds, contributes to its distribution across Europe, North America, and Asia (GBIF 2024; James and Rahman 2010; Schaffner 1930). It is an issue in agricultural fields and in pastures, where it can be toxic to grazing ruminants and cause unpleasant odors and flavors in milk (Bell and Popay 1988). Dispersal of field horsetail via floods and tolerance of wet conditions may favor establishment within frequently flooded riparian zones (Garssen et al. 2017; James and Rahman 2010; Paynter and Barton 2008). Field horsetail is often difficult to control, but chemical and mechanical strategies can be effective. Despite being viewed as a problematic weed, field horsetail is valued for its medicinal properties.

Etymology

The common names "field horsetail" and "common horsetail" both refer to the distinctive morphology of *Equisetum* species, which have jointed stems, whorls of needle-like branches, and highly reduced leaves. The name horsetail comes from the Latin *Equisetum*: *equus* or *equip* (horse) and *seta* or *setum* (tail, hair, bristle); in addition to a horse's tail, this plant shares visual similarities with asparagus and bamboo (Carneiro et al. 2019; Filipov and Chiorescu, 2021; Makia et al. 2022; Şahinler 2022; Villani 2015). Another common name, "scouring rush" (also applied to *E. hyemale* L.), is associated with the presence of silicates, which give *Equisetum* species an abrasive texture that enables their use for cleaning kitchen implements and polishing wood (Burrill and Parker 1994; Filipov and Chiorescu, 2021; Parrish et al. 2022; Sapei 2007). Field horsetail belongs to the class Polypodiopsida, including pteridophytes such as ferns, quillworts, and club mosses, and the subclass Equisetidae, of which *Equisetum* species (sometimes controversially referred to as "living fossils") are the only surviving members (Hrabovský and Zahradníková 2022; Merryweather 2020; Parrish et al. 2022; Szypuła and Pietrosiuk 2021).

Distribution and Habitat

Field horsetail is native to many arctic and temperate areas of the northern hemisphere, including parts of Europe, North America, and Asia (Carneiro et al. 2013; Parrish et al. 2022; Paynter and Barton 2008; Sandhu et al. 2010). The subclass Equisetidae is one of the oldest on earth, and continental movement is identified by Carneiro et al. (2019) as a reason for the

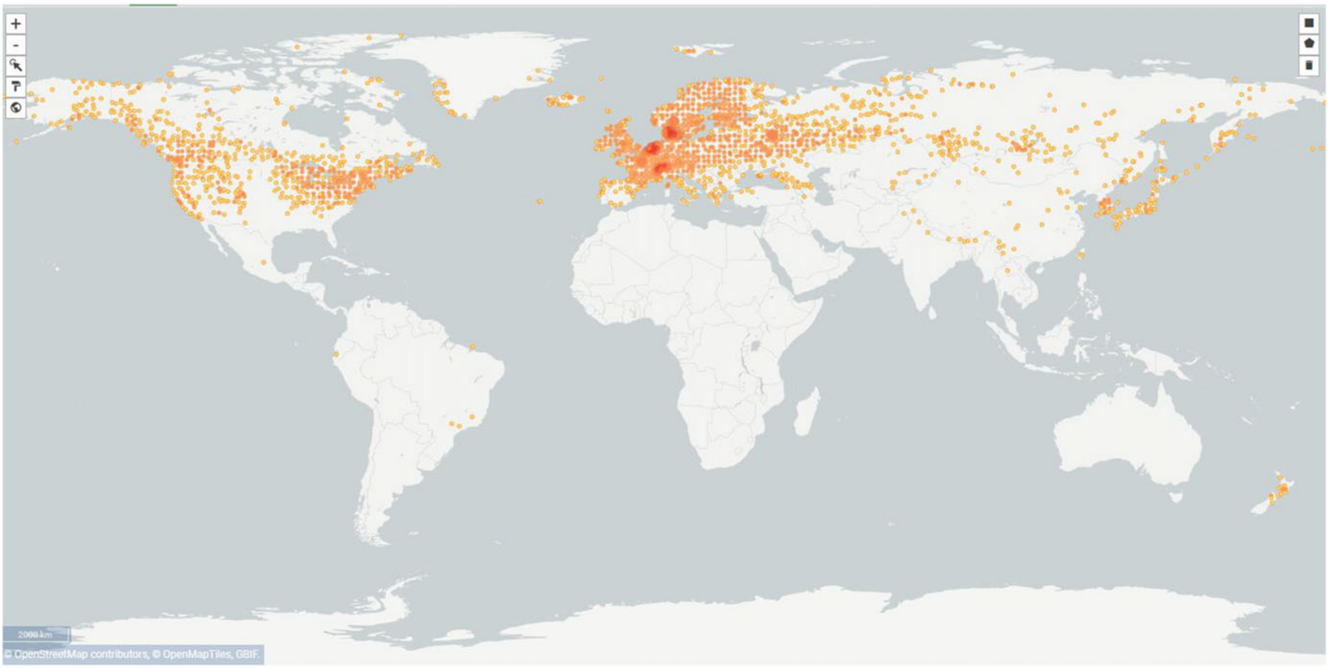

Figure 1. Global distribution of field horsetail, as reported between 2021 and 2024 (figure generated by GBIF 2024).

expansive native distribution of species within this group, including field horsetail, across the globe. In addition to its native distribution, field horsetail now occupies additional areas, including parts of the southern hemisphere (Figure 1; GBIF 2024). It was anthropogenically introduced to Mexico, South America, South Africa, and New Zealand (Hultén and Fries 1986 as cited by Svanberg 1997). In Brazil, introduction was motivated by the potential medicinal properties of this plant, which is commonly referred to as "cavalinha", from Portuguese *cavalo* (horse) and -*inha* (a suffix denoting smallness or shortness) (Almeida et al. 2015; Carneiro et al. 2019). Field horsetail is extremely problematic in New Zealand, where some populations cover areas up to 200 ha, and the National Pest Plant Accord lists the plant, along with all other *Equisetum* species, as invasive (Newfield and Champion 2010; Paynter and Barton 2008).

Field horsetail is prevalent in areas with moderate to high moisture levels, especially on well-drained soils, and can be found growing at elevations up to 1,100 to 1,500 m during summer months (Filipov and Chiorescu, 2021; James and Rahman 2010; Makia et al. 2022). Field horsetail is commonly found on coarse sandy soils but may also be found on dense clay soils (Labun et al. 2012). Rhizomes and tubers contribute to abiotic stress tolerance as well as vegetative reproduction (Nakatani et al. 1993; Sakamaki and Ino 2006). This species tolerates a range of pH levels; however, it may be considered a bioindicator in acidic soils, as increased pH may be correlated with increased biomass (Bastiene et al. 2006; Filipov and Chiorescu, 2021; Labun et al. 2012). Once a stand is established, it may grow well in gravel roadways, riverbeds, and drier areas, with successful emergence even recorded in asphalt (Burrill and Parker 1994; Filipov and Chiorescu, 2021; Heron et al. 2021; James and Rahman 2010; Merryweather 2020). Field horsetail is often prevalent in disturbed soils, such as fire-prone or agricultural areas (Holingswoth et al. 2013; Marshall 1986; Merryweather 2020). Transport on farm machinery contributes to the spread of field horsetail within and between farms (Altland 2005).

Figure 2. Fertile stems of field horsetail showing strobuli (sporangia-bearing cones). Photo credit: Joseph Neal.

Biology and Ecology

Field horsetail is a vascular plant that produces and releases spores into the wind, which then germinate in damp soil (Burrill and Parker 1994; Bussmann et al. 2020; Campbell 1883; Merryweather 2020; Zhao et al. 2015). Fertile stems of field horsetail rapidly emerge between April and May and can be identified by their unbranched morphology and a tinge of red pigment (Burrill and Parker 1994; Campbell 1883; Carneiro et al. 2019; Parrish et al. 2022; Yatskievych and Windham 2008). Fertile stems range from 10 to 25 cm in length, and the apex of each stalk produces a strobilus (sporangia-bearing cone) containing millions of viable spores, resembling green orbs, which are released prior to shoot demise (Figure 2; Bussmann et al. 2020; Carneiro et al. 2019; Martinson et al. 2007; Merryweather 2020; Yatskievych and

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Figure 3. Vegetative stems of field horsetail. Photo credit: Randy Prostak.

Windham 2008). Under high humidity, the spores of *Equisetum* species can germinate within 2 d, which is advantageous because spores lose viability relatively quickly (Hoekstra 2002; Zhao et al. 2015). Spores are enclosed in a tough case and can survive desiccation, with effective spring dispersal via floodwaters, mud, or birds (Edwards et al. 2019; Hoekstra 2002; Parker 2009; Yatskievych and Windham 2008). Fertile stems of field horsetail are less common than and precede emergence of sterile vegetative stems, which may reach 50 cm in length (Burrill and Parker 1994; Merryweather 2020). The vegetative stems are green and photosynthetic, although leaves remain highly reduced with a singular unbranched vein (microphylls) (Figure 3; Carneiro et al. 2019; Makia et al. 2022).

Plants tend to develop aboveground photosynthetic structures and then transport photosynthate to rhizomes and tubers, which account for 85% of the plants' annual dry-mass production (Sakamaki and Ino 2006; Sandstedt 2011). These underground structures form thick mats that can grow up to several meters deep in soil, act as storage organs, and enable vegetative reproduction (James and Rahman 2010; Sakamaki and Ino 2006). Rhizome fragments contain lower starch content than tubers but offer greater rates of regrowth (Sakamaki and Ino 2006).

Field horsetail exhibits sensitivity to light, water, and crop competition (Andersson and Lundegårdh 1999a; Cloutier and Watson 1985). Shaded conditions require plants to rely on starch reserves in rhizomes and tubers (Andersson and Lundegårdh 1999b; Sakamaki and Ino 2006). Response to nitrogen application is minimal in field horsetail, so more nitrogen-responsive plants may have a competitive advantage under fertilized field conditions (Andersson and Lundegårdh 1999a; Harbur and Owen 2004). Field horsetail has high demands for potassium, which increases tolerance of environmental stresses such as drought, high temperature, cold weather, and disease (Andersson and Lundegårdh 1999b; Hasanuzzaman et al. 2018; Kafkafi 1990; Labun et al. 2012). Field horsetail is sensitive to water stress, and competition for water can contribute to mortality (Cloutier and Watson 1985).

Weediness

Field horsetail is recognized as a challenging agricultural weed worldwide (Figure 4; Bastiene et al. 2006; Liew et al. 2013). Perennial weed species, including field horsetail, are most problematic in reduced tillage and no-tillage cropping systems (Légère and Samson 2004; Nakatani et al. 1993; Sims et al. 2018). Conservation tillage in spring improved field horsetail control and crop yield, relative to no-till crop production (Arshad et al. 1994). Although field horsetail is most prevalent in no-till areas, it can even be problematic in tilled agricultural fields. In fields with root-restricting hard or plow pans, reduced access to water and nutrients impedes cash crop growth; however, field horsetail rhizomes can extend into cracks in plow pans to enable continued survival and spread (Elkins et al. 1983; Filipov and Chiorescu 2021; Suleymanov et al. 2020; Witt and Haefele 2005).

A field horsetail shoot density of 280 shoots m^{-2} reduced corn yield by over 40%, but yield loss was not observed when the weed occurred at a lower density of 180 shoots m^{-2} or was removed within 5 to 8 wk after corn emergence (Cloutier 1982). Specialty crops such as strawberries or ornamentals may be so highly infested with field horsetail that the crop is lost (Peabody and Roche 1963). In addition to competing for moisture and nutrients, field horsetail can penetrate tile drainage systems and obstruct irrigation for crops (Bastiene et al. 2006; Kladivko and Brown 2016). In Lithuania, obstruction of drainage systems in agricultural fields by dense root systems of field horsetail accounts for one third of all drainage failures (Bastiene et al. 2006).

Field horsetail is problematic in grazing systems and can be toxic to livestock, especially horses (Burrill and Parker 1994). Poisoning of livestock by field horsetail is known as "equisetosis" (Dayton 1960; Pammel 1911; Peabody and Roche 1963; Steyn 1933). In horses, this plant's thiaminase enzyme induces vitamin B_1 deficiency, leading to symptoms including wobbly gait, weakness, slow pulse, fever, depression, nervousness, and sometimes even mortality (Bates 2023; Burrill and Parker 1994; Martinson et al. 2007; Pammel 1911; Pohl 1955; Rapp 1954). Field horsetail is most likely to be dangerous if it is

Figure 4. Field horsetail infesting summer squash. Photo credit: Joseph DiTomaso.

consumed dry in hay rather than fresh as forage and comprises at least 5% of total hay volume (Ingebrigtsen 2010; Peabody and Roche 1963; Rapp 1954).

Other ruminant animals affected by consumption of field horsetail include cows and sheep, though symptoms are seen at decreased rates in both animals compared with horses (Burrill and Parker 1994; Pammel 1911; Paynter and Barton 2008; Rapp 1954; Svanberg 1997). The high levels of silica in field horsetail reduce its desirability as forage for cows, which may exhibit diarrhea, weight loss, and spoiled milk with decreased production after ingesting field horsetail (Bell and Popay 1988; El Mahdy et al. 2017; Rapp 1954). Especially in calves, severe symptoms may include cardiac or respiratory issues and even convulsions (El Mahdy et al. 2017 and references therein). Sheep who are pregnant and consume field horsetail may be susceptible to premature delivery (Svanberg 1997 and references therein). For these reasons, it is advisable to control field horsetail in pastures (Riet-Correa et al. 2017).

Field horsetail can also be problematic in non-agricultural contexts. It has been a major issue along railway tracks in Sweden, because glyphosate, commonly used for weed control along tracks, does not provide complete control of this species (Torstensson 2001; Torstensson and Börjesson 2004).

Chemical Control

Chemical control of field horsetail can be difficult, and reported outcomes from previous experiments have been mixed (Table 1). Challenges in controlling this species with herbicides largely reflect poor retention or translocation (Marshall 1984). In British Columbia, Canada, application of amitrole at 9 kg ha^{-1} between July 16 and July 30 reduced field horsetail stand population by 96% after 1 yr (Hoyt and Carder 1962). In the same study, MCPA applied at 0.3 to 0.6 kg ha^{-1} reduced stand population the next year by 50% to 65% (Hoyt and Carder 1962). Bell and Popay (1988) found that amitrole (4.4 kg ai ha^{-1}), glyphosate (1.0 or 2.0 kg ai ha^{-1}), dichlobenil (11 kg ai ha^{-1}), picloram (0.25 or 0.5 kg ai ha^{-1}), and 2,4-D + picloram (0.5 + 0.125 or 1.0 + 0.25 kg ai ha^{-1}) did not achieve sustained control. Undiluted glyphosate (360 g ai L^{-1}) (sponge application) reduced stem density the year after application (Ainsworth et al. 2006). MCPA (500 g ai L^{-1}) at 4.5 ml L^{-1} (spray application) prevented growth the year after application (Ainsworth et al. 2006).

In greenhouse trials, imazapyr (0.125% ai), amitrole (1.8% or 3.6% ai), metsulfuron (0.03% ai), and picloram (0.02 or 0.04 g pot^{-1}) achieved good aboveground control (James and Rahman 2010). In field trials of the same study, field horsetail exhibited regrowth following treatments of amitrole (3.6% ai), metsulfuron (0.03% ai), and MCPA (0.16% ai) within 2 mo after treatment (James and Rahman 2010). Triazine has also been reported to be ineffective at controlling field horsetail (Rola and Pejka 1970; Šarić et al. 2011). In British Columbia, Canada, Bae et al. (2022) tested herbicide application times aligned with cranberry phenology. Applications of dichlobenil (4,400 g ai ha^{-1}) post-harvest, clopyralid (102 g ai ha^{-1}) or mesotrione (100.8 g ai ha^{-1}) at bud break, and mesotrione (100.8 g ai ha^{-1}) + sethoxydim (495 g ai ha^{-1}) at the hook stage allowed for >90% control of field horsetail 56 d after the final treatment (Bae et al. 2022).

In trials conducted within corn fields of Ontario, Canada, postemergence applications of flumetsulam + MCPA amine (50 + 630 g ai ha^{-1}) reduced field horsetail biomass by 82% and density by 75% (Soltani et al. 2015). Biomass and density were reduced by 87% and 78%, respectively, by postemergence application of nicosulfuron/rimsulfuron + flumetsulam + MCPA amine (25 + 50 + 630 g ai ha^{-1}). This treatment provided 70% to 83% visual weed control (Soltani et al. 2015).

Dichlobenil is an example of an herbicide that reduces stand populations but, when applied alone, cannot fully destroy underground rhizome and tuber structures (Bell and Popay 1988; Marshall 1984; Ryan 1976). Miller et al. (2012) found that practices such as flame application (causing defoliation), hand hoeing, and especially dormant-season application of dichlobenil helped control field horsetail. These findings are consistent with general guidance suggesting that nonchemical and chemical control methods may be combined for effective weed control (Bastiene et al. 2006; Koning et al. 2019).

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Table 1. Examples of herbicide treatments that have been tested on field horsetail

Treatment (adjuvant, surfactant)	Rate (unit)	Control achieved (trial type)	Reference
Amitrole	9 (kg ha^{-1})	Reduced stand by 96% after 1 yr	Hoyt and Carder 1962
Amitrole	4.4 (kg ai ha^{-1})	Limited control	Bell and Popay 1988
Amitrole (Li700 adjuvant)	3.6% ai	Unsuccessful (field trial)	James and Rahman 2010
Dichlobenil	4.5 or 9 (kg ha^{-1})	Control maintained in season after application	Ryan 1976
Dichlobenil	11 (kg ai ha^{-1})	Tubers and rhizomes feasible after treatment	Bell and Popay 1988
Glyphosate	1.0 or 2.0 (kg ai ha^{-1})	Unsuccessful	Bell and Popay 1988
Imazapyr (Pulse adjuvant)	0.125% ai	Complete top growth control (greenhouse trial)	James and Rahman 2010
MCPA	0.3 or 0.6 (kg ha^{-1})	Reduced stand by 50% to 65% the next year	Hoyt and Carder 1962
Metsulfuron (Pulse adjuvant)	0.03% ai	Unsuccessful (field trial)	James and Rahman 2010
Picloram	0.25 or 0.5 (kg ai ha^{-1})	Tip burn, reduced shoot numbers	Bell and Popay 1988
Picloram	0.02 or 0.04 g pot^{-1}	>95% top growth control, 26 wk after treatment (greenhouse trial)	James and Rahman 2010
2,4-D + picloram	0.5 + 0.125 (kg ai ha^{-1})	New shoot growth 10 mo after application	Bell and Popay 1988
2,4-D + picloram	1.0 + 0.25 (kg ai ha^{-1})	New shoot growth 10 mo after application	Bell and Popay 1988
Flumetsulam + MCPA amine or nicosulfuron/ rimsulfuron + flumetsulam + MCPA amine	50 + 630 (g ai ha^{-1}) or 25 + 50 + 630 (g ai ha^{-1})	Biomass and density reduced 75% to 87%	Soltani et al. 2015
Undiluted glyphosate or MCPA	360 (g ai L^{-1}), undiluted or 500 (g ai L^{-1}), 4.5 ml L^{-1}	Browning occurred. New growth in following year in glyphosate treatment	Ainsworth et al. 2006
Dichlobenil + clopyralid or mesotrione (Agral 90 surfactant) + mesotrione (Agral 90 surfactant) + sethoxydim (Merge surfactant)	4,400 (g ai ha^{-1}) 102 (g ai ha^{-1}) 100.8 (g ai ha^{-1}) 100.8 (g ai ha^{-1}) 495 (g ai ha^{-1})	>90% control, 56 d after mesotrione + sethoxydim application	Bae et al. 2022

Mechanical Control

Early-season defoliation can be an effective tactic in conservation tillage systems, because this approach hampers the plant's ability to restore its belowground reserves (Bostrom et al. 2013; Liew et al. 2013). Mowing provides some control but does not necessarily result in mortality because of the belowground reserves (Ainsworth et al. 2006; Conn and Delapp 1983). Deep excavation is possible at small scales, but the expense of equipment makes this approach cost-prohibitive at larger scales (Ainsworth et al. 2006). It is also important to note that fragmentation of rhizomes can facilitate the spread of field horsetail (Sakamaki and Ino 2006). Mechanical control was found to be 32% more effective for perennial weeds including field horsetail, relative to thermal weed control (Virbickaite et al. 2006). In a study conducted by Archut et al. (2023), field horsetail showed low regrowth rates along makeshift railway tracks after 41 d of hot-water application (95 to 98 C) at 10 L m^{-2} and 20 L m^{-2} from a height of 20 cm.

Koning et al. (2019) compared effects of glyphosate application and tillage on weeds including field horsetail. Treatments included (i) glyphosate at 100% of the recommended rate (1,080 g ai ha^{-1}), (ii) glyphosate at 50% of the recommended rate (540 g ai ha^{-1}), (iii) chisel plowing, and (iv) moldboard plowing (Koning et al. 2019). Each treatment was applied two or three times within the season. This experiment demonstrated decreased abundance of field horsetail and other creeping perennials in glyphosate treatments compared with tilled treatments (Koning et al. 2019). Forget-me-not [*Myosotis arvensis* (L.) Hill] and common poppy (*Papaver rhoeas* L.), were among the species more abundant in glyphosate treatments, with tolerance attributed to reduced foliar uptake of the herbicide (Koning et al. 2019).

Current and Potential Uses

Field horsetail is pharmacologically active and can be used in numerous ways. It has been incorporated into traditional medicines and consumed as food throughout history (Luanda et al. 2023; Svanberg 1997), typically as tea or other oral preparations (Kultur et al. 2021). Galatian peoples historically used the plant to dye fabrics, and Romans consumed it as a vitamin C supplement (Svanberg 1997; Villani 2015). Extensive research on this plant has suggested anticancer, antitumor, anti-inflammatory, antibacterial, antifungal, and antidiabetic benefits (Al Mohammed et al. 2017; Luanda et al. 2023; Taylor et al. 2022). It may also help treat respiratory, urinary, digestive, and inflammatory disorders (Kultur et al. 2021; Luanda et al. 2023). Ointment containing field horsetail was found to encourage wound healing after episiotomies in a randomized placebo trial (Asgharikhatooni et al. 2015). Horsetail extracts may contribute to bone regeneration in individuals with osteoporosis and arthritis (da Costa e Silva et al. 2022; Labun et al. 2013). A diet including 60 mg kg^{-1} of field horsetail extract increased trabecular bone thickness in rats by 11% to 46% (da Costa e Silva et al. 2022). In addition, *in vitro* studies suggested that field horsetail, used in combination with palmitoylethanolamide, can help alleviate neuropathic pain by acting on the peripheral nervous system (Ruga et al. 2023).

A literature review found that, although data are available on the efficacy of field horsetail–based products, these products do not meet safety criteria for medicinal applications (Carneiro et al. 2013). The review acknowledged the ancient and traditional uses of field horsetail in medicine and encouraged continued research efforts on their potential future applications (Carneiro et al. 2013, 2019).

Conclusion

Horsetails (*Equisetum* species) are representatives of an ancient, spore-bearing vascular plant clade in which key morphological and life history traits have remained largely unchanged since the Jurassic or earlier (Husby 2013). The long-term survival of this clade can be partially attributed to its members' ability to thrive in a wide range of habitats and tolerate abiotic stress (Husby 2013). In modern times, these same characteristics contribute to the widespread distribution and weediness of field horsetail.

Field horsetail is a hard-to-control weed that colonizes numerous soil types and habitats, including agricultural crop fields and railroad tracks (Bastiene et al. 2006; Bell and Popay 1988; Sakamaki and Ino 2006; Torstensson 2001). Field horsetail is tolerant of many herbicides and other toxins (Andrejić et al. 2023; Bastiene et al. 2006). We note that much of the existing literature on chemical control was conducted decades ago, so may not reflect current product availability or efficacy. Nonchemical control can also be challenging, given that this perennial species forms tubers and rhizomes for belowground storage and reproduction. Additional research on control options is warranted.

Although field horsetail is a problematic weed worldwide, it is also a valuable source of pharmaceutical compounds. Although there is some controversy about safety and limited data regarding medicinal applications of field horsetail, its contributions to traditional medicine and available information on its efficacy encourage continued exploration (da Costa e Silva et al. 2022; Luanda et al. 2023).

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