State of Michigan's
Species Profile for Stiltgrass
(*Microstegium vimineum*) Management

Created December, 2023

Introduction and Scope

Microstegium vimineum (stiltgrass) is a delicate terrestrial grass native to Asia. Its native range stretches from Japan west to Nepal and South to Malaysia (Rauschert & Nord, 2010). It was first discovered in the United States in 1919 in Knoxville, Tennessee. By 1998 it had spread as far north as Massachusetts (Leicht et al., 2005). It was first reported in Michigan in 2017 but has been on the State's watchlist since 2006 (Clawson, 2017). Stiltgrass has the ability to overtake forest floors by out-competing native species and altering soil pH (Zhao & Brenner, 2021).

Synonyms

Common Name: Japanese stiltgrass, packing grass, Nalalese browntop, Nepal grass, Chinese packing grass, flexible sea grass, annual jewelgrass, Asian stilt grass, bamboograss, flexible sea grass, Japanese grass, Mary's grass, Nepal microstegium, and Vietnamese stilt grass
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- Consolidating current science-based knowledge relative to the biology and ecology of stiltgrass
- Summarizing scientific literature and research efforts that inform management options for stiltgrass in Michigan.
- Identifying future directions for research relative to successful stiltgrass management in Michigan.

This document was written by Halee Dunlap under the direction of Dr. Megan Butler and was reviewed by the Michigan Departments of Natural Resources and Agriculture and Rural Development. This document references peer-reviewed journals and publications. Any chemical, company, or organization that is mentioned was included for its involvement in peer-reviewed, published, publicly shared information, not to imply endorsement of the chemical, company, or organization.

Biology and Ecology

I. Identification

Microstegium vimineum (stiltgrass) is an annual terrestrial grass that forms dense monocultures greater than one m thick (Kleczewski et al., 2011). Its loose-branched leaves interconnect between the plants forming a monoculture and allowing no growth of native species below the dense mats (Kleczewski et al., 2011). These thick mats are a key factor used to identify stiltgrass populations.

Figure 1. Stiltgrass photo (Merhoff, 2022)

This delicate terrestrial grass is easily identified by its pale green leaves with a distinct silvery white or lighter green colored off-center mid-rib (Kleczewski et al., 2011; OEPP, 2016). Leaves usually have reflective hair fibers that make them shine on summer afternoons (Nitzsche, 2017). The base of the leaf appears as an oval shape and slowly thins to a sharp-tipped point (Figure 1; OEPP, 2016). Leaves are typically ½ in wide at their widest point, and appear alternate (Kleczewski et al., 2011). Leaves are connected to the stem via a membranous leaf sheath about 2mm long with hair covering it (OEPP, 2016).

Figure 2. Stiltgrass as a seedling (Evans et al. 2012)

Stiltgrass stems look different depending upon their stage of development, with four stages: seedling, maturity, brown up, and winter thatch (Evans et al., 2012). In the initial stages of development, the thin stem is green and appears fleshy, storing large amounts of water (Evans et al., 2012). While the stem appears smooth, it will have hair closer to the sheath of the leaf (Evans et al., 2012). Stiltgrass sprouts (Figure 2) have dark green leaves that are 2-4 in long and about 1-2 in wide. Each stem has small stilt-like prop roots that allow it to stand upright (Templeton et al., 2020). When stiltgrass reaches maturity (Figure 3), the grass no longer stands up straight but rather begins to “flop” and cover the ground. Stiltgrass stems are thin and easily intertwined which allows them to form tangled mats and dense monocultures, wrapping around each other and allowing no other viable growth underneath (Kleczewski et al., 2011). Once plants are woven together, they also make human and wildlife passage difficult

(Evans et al., 2012). Once the plant starts to die off in fall, the stem turns purplish or brown (Figure 4). Finally, during the brown-up stage the stem turns completely brown and lays flat on the ground forming a thick winter thatch the covers area (Nitzsche, 2017; Evans et al., 2012) and blocks other vegetation from germinating and growing in spring. This final phase usually starts after the first frost in the mid to late fall (Landschoot et al., 2020; Neal & Judge, 2022).

Figure 3: Mature stiltgrass (Evans et al. 2012)

The fruit of stiltgrass is a three mm long grain that stands straight up and appears yellowish and red. The flower (Figure 5) is a spikelet (Neal & Judge, 2022). Although stiltgrass most commonly flowers from August to October, this timeline fluctuates based on climate, location, and other environmental conditions. Stiltgrass typically produces seeds in late summer (Ziska et al., 2015).

Figure 4: Stiltgrass brown up (Evans et al. 2012)

Stiltgrass has a very shallow root system (Nitzsche, 2017). As a result, stiltgrass can be hand-pulled easily. Roots may emerge from any node of the plant when the node touches the ground, which makes spreading easier (Nitzsche, 2017). There are multiple roots sprawling from the larger stem (Evans et al., 2012). Nodes increase both asexual and sexual reproduction because they promote stem, leaf, and flower growth which leads to more seeds being reproduced and dispersed (Nitzsche, 2017).

Common Look-Alikes

Common native plants which can be mistaken for invasive stiltgrass include Virginia cutgrass or white grass (*Leerisia viginica*), crabgrass (*Digitaria spp*) and Pennsylvania smartweed (*Polygonum persicaria*) (Coffey, 2021, Swearingen et al., 2014; Nitzsche, 2017).

Figure 5. Fruit of stiltgrass (Neal, 2023)

One way to distinguish stiltgrass from native species is to look for its distinct, bright white midrib. For example, white grass, the species most commonly mistaken for stiltgrass does not have the distinctive stripe down the center (Figure 6), nor is it covered in fine hairs like *Microstegium vimineum* (Kenny & Lingenfelter, 2022). White grass also doesn't brown out in fall but rather will stay green year-round (Kenny & Lingenfelter, 2022).

Figure 6. Leaves and stem of white grass (White Grass, 2019)

Large crabgrass (Figure 7) is a native grass that is also very similar to stiltgrass but can be distinguished by its bulky stem that retains its size throughout the height of the plant and appears flat (Nitzsche, 2017). In addition, large crabgrass leaves are a darker forest green and lacks the distinctive

Figure 7. Large crabgrass (Marbse, 2023)

Figure 8. Pennsylvania smartweed (Division of Plant Sciences, 2020)

off-center white stripe. The stem is tougher and harder to pull than the fragile stiltgrass root (Evans et al., 2012)

The last look-alike to stiltgrass is Pennsylvania smartweed (Figure 8). It is most commonly mistaken for stiltgrass during the seedling phase because the leaves are the same shape and size. However, the stem of this plant is usually pinkish at the nodes and the plant is a very light yellow-green color (Nitzsche, 2017).

II. Detection

Historically, invasive stiltgrass populations have been identified in new locations once they are already established and have formed characteristic dense mats (Figure 9). Stiltgrass is typically found in forested areas that have recently been disturbed by natural or anthropogenic forces (Culpepper & Ness, 2018). It is also commonly found on roadsides, highly trafficked trail systems, and other areas that have experienced disturbance (Apsley & Smith, 2011). Early detection is most effective with constant surveillance in these areas (Culpepper et al., 2018). At the same time, existing populations should be monitored and managed to prevent them from spreading (Apsley & Smith, 2011; Culpepper et al., 2018). Locations with a lot of traffic and existing populations of stiltgrass need to be observed regularly to track the ecological effects that stiltgrass put on an ecosystem (Culpepper et al., 2018).

Figure 9. Forest infested with stiltgrass (Evans et al., 2012)

The use of techniques such as eDNA and remote sensing could be very valuable for managers hoping to identify new stiltgrass infestations before they become established. While remote sensing technology has not yet been used to detect stiltgrass, research conducted on the East coast of the United States with wayleaf basketgrass (*Oplismenus hirtellus ssp. undulatifolius*) has shown promising results (Moore, 2010). This study used remote sensing, environmental predictors, and observational data to create landscape suitability maps and predict future infestations (Moore, 2010). More research is needed to understand how remote sensing and other technologies can help promote early detection of this species and predict its spread.

III. Life History and Spread Dispersal

Reproduction

Stiltgrass is known for its fast growth and massive seed production. A single plant can produce over 1000 viable seeds during a single growing season, and seeds remain viable in the soil seed bank for up to five years (Willis et al., 2022). This means that in an area where the plant has become established, there may be as many as 1 to 4 million seeds per m^2 (Judge et al, 2005). Once established in an area, this grass will be able to continuously resprout from the soil seed bank (Hilty, 2019).

The flowers on these plants allow them to reproduce through both chasmogomous (open petals) and cleistogomous (non-opening, self-pollinating petals) means (Flory, 2017). This ability to cross and self-pollinate makes the spread of stiltgrass faster and easier (Judge et al., 2005; Ward et al., 2012; Weaver et al., 2020).

Seeds are easily dispersed. Animals walking through tall grass hitting the seeds can make them fall (Willis et al., 2022), or those seeds can collect in fur and be transported to new locations (Pointer, 2018; Frey and Schmit, 2015; Weaver et al., 2020). In addition, because this plant is very fragile, shallow-rooted, and buoyant, floods and rainfall can also disperse seeds (Willis et al., 2022). Human disturbance such as logging or walking can also transport the seeds via shoe tread (Frey & Schmit, 2015; Weaver et al., 2020) or unsanitary equipment to new undisturbed sites (Willis et al., 2022). In areas with little disturbance, spread is slow and steady. Roadsides are one of the main habitats for this invasive because it is where disturbances are most likely to occur with high access from the public. In particular, gravel roads with high traffic, and regular road maintenance are more accessible to invasion (Mortensen et al., 2009).

Another way that the stiltgrass can spread is by vegetative means. When the stem nodes touch the ground, they can develop roots and allow the plant to spread to increase more (Nitzsche, 2017). With weak stems likely to fall over and rooting ability at the nodes, the plant is able to spread more effectively. When stiltgrass has cleistogomous flowers, it does not reproduce vegetatively (Flory, 2017). More research is necessary to understand whether and how stiltgrass reproduction varies between its invasive and native ranges.

Stiltgrass germinates and sprouts in the spring usually when the soil temperature is 50 degrees Fahrenheit (Nichols, 2021). Seedlings are able to sprout through thick vegetation and leaf litter (Evans et al., 2012; Zhao & Brenner, 2021). The plant reaches full maturity in early summer. By late summer, it will begin seeding out (Zhao & Brenner, 2021).

IV. Habitat

Native Range

Stiltgrass is native to Southern and Southeast Asia including Korea, China, Japan, Nepal, Pakistan, and India (Zhao & Brenner, 2021). Even within its native range, this species is highly adaptable and can fit into a variety of ecological niches compared to many other species in the region (Swearingen et al., 2014, Swearingen & Adams, 2008). For example, it thrives in woodland openings, wetlands, floodplains, and disturbed areas such as roadsides and ditches

(Swearingen & Adams, 2008, Hilty, 2019). This grass can establish itself in a full-sun environment or a very shaded forest leaving a wide range of locations possible (Swearingen et al., 2014, Swearingen & Adams, 2008). Stiltgrass can still perform photosynthesis in low light conditions, allowing it to cover forest floors that would usually be covered with leaf litter (Swearingen & Adams, 2008). Higher soil moisture levels facilitates the growth of the grass (Payne et al., 2019). Additional research is necessary to understand how this species fits into ecosystems within its native range.

Invasive Range

Figure 10: Known global distribution of Microstegium vimineum USFS, 2020)

This hardy and adaptable species has been able to spread well beyond its native range (Figure 10). Stiltgrass was first discovered in the United States in 1919 in Knoxville, Tennessee (Zhao & Brenner, 2021). By 1960, the grass had spread to Ohio and all eastern states around as far as New Jersey (OEPP, 2016). Today, it can be found throughout much of the eastern United States and Midwest (Figure 11). Its current invasive range is as far North as New England, as far west as Texas, and as far south as the Gulf Coast of the United States (EDDMapS, 2023). The spread of stiltgrass is facilitated by its ability to thrive in a variety of habitats (Zhao & Brenner, 2021).

Preferring disturbed areas, it invades roadsides, shallow wetlands, riverbanks, and forests (Hunt and Zaremba, 1992; Redman, 1995). This grass is able to grow in both low and high-light environments very successfully (Nord et al., 2010). It's easily adaptable to forests or roadsides in a variety of locations and climates, provided moderate soil moisture (Judge et al., 2005). Disturbance is also key to successful invasion. Roadsides are especially well-suited due to the traffic along those roads kicking up seeds and dispersing them and an elevated pH from gravel (Nord et al., 2010).

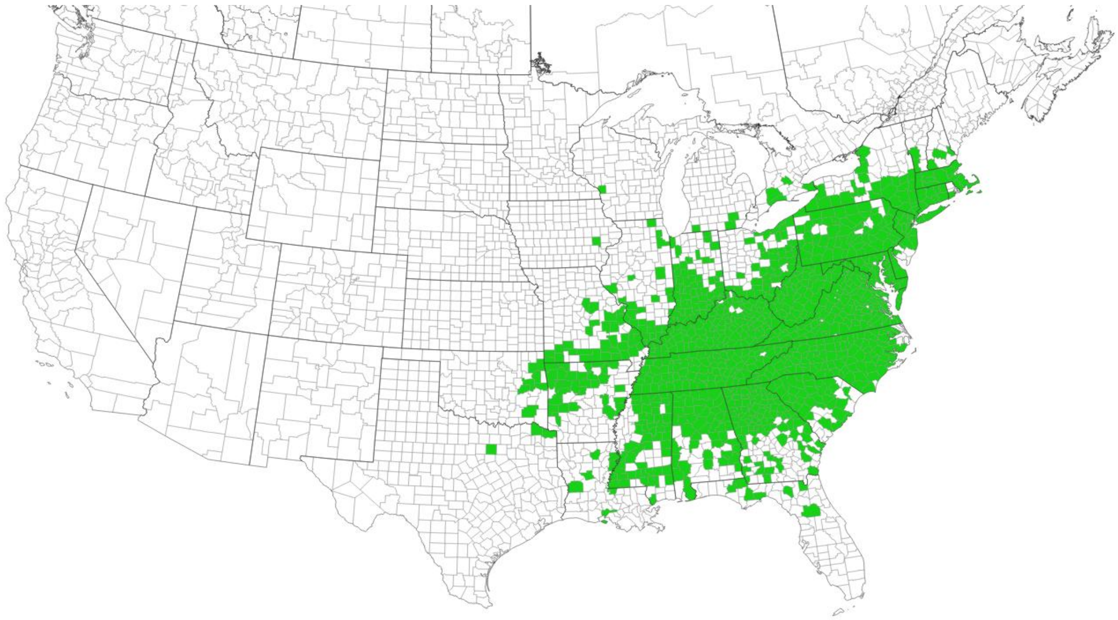

Figure 11: Current distribution of stiltgrass in the United States (EDDMapS, 2023)

In Southeast Asia, there was a time when stiltgrass was commonly used as a packaging material to protect porcelain during shipping. It is hypothesized that the seeds could have been dispersed when the porcelain was taken out of the box in the United States (Nord et al., 2010). It was found in Britain from being mixed with birdseed (Ryves et al., 1996, OEPP, 2016). The problem with it being in birdseed is when ingested and released from the bird, the seeds in the feces can germinate and spread (OEPP, 2016). Transporting soil for activities like gardening has also been shown to spread the species. Hikers going off trail or through dense monocultures next to trails can disperse seeds if they are picked up in the treads of boots and brought to non-infected areas (OEPP, 2016). Roadsides and parking areas are particularly susceptible to stiltgrass infestation due to the species' ability to hitch rides on humans and vehicles.

V. Effects of Stiltgrass

Negative Effects

Stiltgrass is very detrimental to native ecosystems. Once established, *Microstegium vimineum* alters the ecosystem by forming a dense monoculture on the forest floor, which can reduce the growth of native flowering plants and degrade native plant and insect communities (Apsley & Smith, 2011). Established patches of stiltgrass inhibit native seedling regeneration due to competition for resources and by physically restricting seeds from contacting soil (Goldsmith et al., 2023; Barden, 1987; Oswalt and Oswalt, 2007). In winter, the leaves decompose quickly but the stems form a dense thatch that covers the area. This further prevents other species from germinating the following year (Swearingen & Adams, 2008). The invasive plant's shallow root system may also prevent the uptake of nutrients by native species (Field, 2021).

In addition to physically inhibiting growth, over the long-term stiltgrass also alters the chemical and biological structure of the soil itself in several ways. First, stiltgrass is known to alter nitrogen cycling and raises soil pH (DeMeester and Richter, 2010; Culpepper et al., 2018; Emery et al., 2013; Zhao & Brenner, 2021), causing an increase in nitrogen and phosphorus levels in the soil, reducing nutrient absorption and limiting the growth of neighboring plants (Zhao & Brenner, 2021). In addition, the presence of stiltgrass alters microbial and mycorrhizal communities in the soil (North and Torzilli, 2017) further disadvantaging native species that rely on these communities. Finally, *Microstegium vimineum* secretes allopathic chemicals into the soil that inhibit the growth of other species (Tekiela et al. 2012, Corbett and Morrison, 2012; Pisula and Meiners, 2010).

Stiltgrass also impacts native wildlife. For example, changes in soil nitrogen and pH reduce the diversity of arthropods in the soil (Zhao & Brenner, 2021). There is also a relationship between white-tailed deer and stiltgrass, as deer and many other grazers avoid eating it, permitting stiltgrass to flourish and produce more seeds, which can then be dispersed to where there is less competition. This allows stiltgrass to form more dense monocultures and outgrow native species (Swearingen & Adams, 2008, Nitzsche, 2017). It also impacts ground-nesting birds such as bobwhite quail; dense monocultures do not provide nesting habitat and prevent these birds from fleeing from predators because of the thin, interconnecting stems (TISI, 2014).

Stiltgrass can economically impact livestock production. When the grass becomes established in pastures, it leaves less surface area for grazing and out-competes alfalfa and other pasture fodder species, which could alter the diets of cattle affecting their growth (Kenny & Lingenfelter, 2022).

Positive Effects

While stiltgrass has many negative impacts on local ecosystems, it may provide some advantages for certain species. For example, with a thick, dense monoculture, some predators can be more camouflaged when attacking prey; snakes in particular prefer the tall dense stiltgrass as cover (TISI, 2014). A recent study (Lorenzen, 2020) has also shown that some species of Satyr butterfly use stiltgrass as a host plant. In addition, because the stems are so flexible, they can be used for basket weaving (OEPP, 2016).

Current Status and Distribution in Michigan

There have been several reports of stiltgrass in Michigan (S. Singh, personal communication, 2023). The first report in Michigan was in Washtenaw County (Figure 12); this site has been treated with herbicide and hand pulling (EDD Maps, 2023). The second report was in Jackson County where a dense established monoculture was identified on a roadside (EDD Maps, 2023). There has been a recent reporting of a dense monoculture on an off-road vehicle road in Cass Michigan (EDD Maps, 2023). So far, these areas have been contained and there have been no other reports. However, the risk of spread is still high due to Michigan's abundance of young forests and low elevations (Culpepper et al., 2018; Korienek, 2017) and ease of spread. Climate change could also facilitate the spread of stiltgrass into new areas as winters in Michigan become milder. Land-use patterns that result in more disturbance and habitat fragmentation may also facilitate the spread of this species (Culpepper et al., 2018).

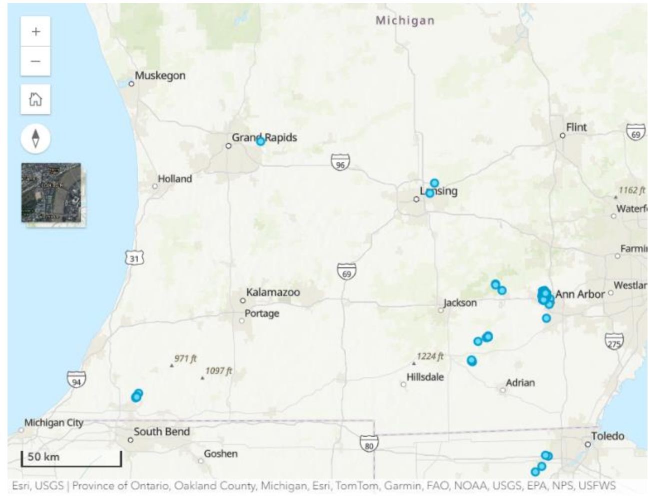

Figure 12. Reported sightings of stiltgrass in Michigan (MISIN, 2023)

Management

I. Prevention

Prevention of further spread is key for managing this species as stiltgrass could permanently alter Michigan's native forest communities (Batten et al, 2006., Howes, 2017). Human-caused disturbances are one of the main ways stiltgrass spreads (Marshall & Buckley, 2009). As such, community involvement and public awareness are key to preventing the spread of stiltgrass. The general public must be educated about the negative impacts of stiltgrass and steps that can be taken to prevent its spread. It is also important to monitor and take preventative action in areas stiltgrass is prone to invade such as walking trails, horse trails, ATV trails, and roads (Apsley & Smith, 2011). Removing seeds from shoes, hooves, and vehicle treads can limit the chance of spread (Apsley & Smith, 2011). It is important to provide information and boot brushes at the end of each hiking trail because seeds can stick on to walkers' clothing as much as boot treads (Pointer, 2018; Apsley & Smith, 2011). Horseback riders can use a hoof pick after trail rides to prevent carrying seeds to new locations in the sole of their horse's hoof. Landscaping and logging equipment should be sanitized before moving between areas to prevent seed spread (Apsley & Smith, 2011). Leaving the leaf litter on the ground or using mulch in landscaping also helps prevent invasive grasses from sprouting from seed (Field, 2021; Willis et al., 2022).

II. Management/Control

Key Considerations

As mentioned in the previous section, prevention is key in managing this species (Nord et al., 2010). Public education and outreach are important components of any prevention campaign. In addition, when taking management action, it is important to decontaminate equipment and gear to prevent stiltgrass from being inadvertently spread.

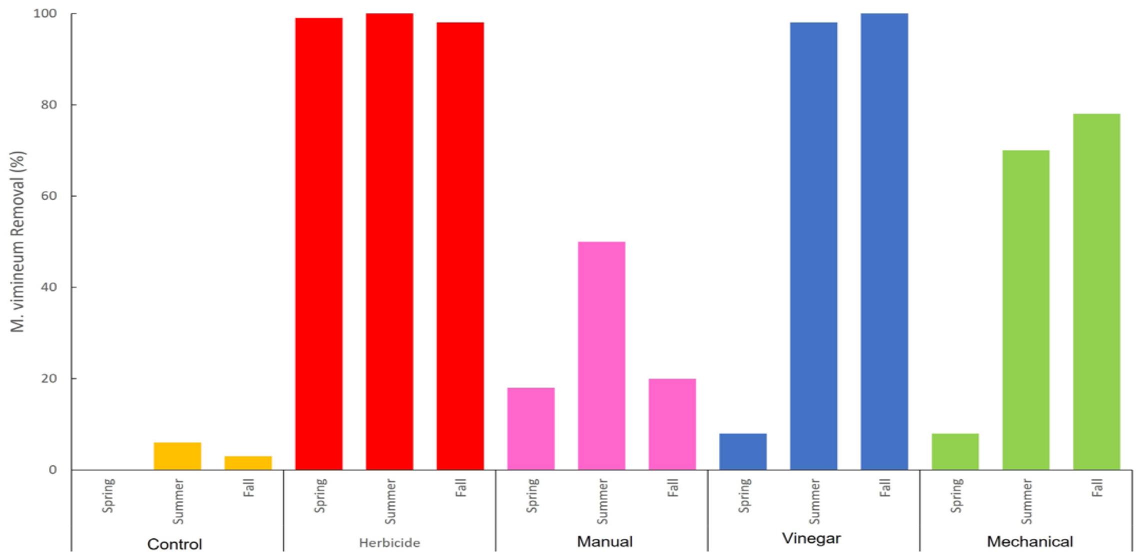

Figure 13. Type of management strategy, timing, and percentage of M. vimineum removed from various sites by specific management options (Willis et al., 2022). Herbicide treatment was effective throughout the year whereas mechanical control was only valuable in the summer and fall before the plant went to seed.

Several methods have been used to manage this species with various rates of success (Figure 13). The most effective treatment across seasons was herbicide treatment with glyphosate with a 98% average removal (Figure 13; Willis et al., 2022). When determining the type of management technique to use, consider the time of year, the ecosystem, and the prospective damage caused by each management activity relative to its efficacy. No matter the treatment, follow-up treatments will likely be required for several years on the site to prevent re-establishment from the soil seed bank (Osborne & Edgin, 2017). Erosion must also be taken into consideration when managing this species; when the dense patches of the invasive are killed, it leaves a bare spot exposed to wind and rain that is highly susceptible to erosion (Kenny & Lingenfelter, 2022).

Physical or Manual Control

Two physical management methods have commonly been used for stiltgrass: hand pulling and mowing. Factors to consider when choosing between manual control methods are the density of the spread and size of the site.

Hand pulling is the most labor-intensive form of manual control (EPPO 2016, Willis et al., 2022). This type of control requires every stem and root to be removed from the ground (Willis et al.,

2022) with the goal of controlling the plant before it goes to seed. Hand-pulling is less effective compared to chemical treatment with recent studies showing only a 15% decrease in density after manual removal. It may also take up to three years to observe a decrease in density due to hand pulling (Flory & Lewis, 2009; Judge et al., 2008). However, when native species are present, consistent hand-pulling can help protect native biodiversity and facilitate the re-establishment of native plants. Consistent hand-pulling may allow native plants to outcompete the invasive stiltgrass (Judge et al. 2008, Flory & Lewis, 2009). On the other hand, inconsistent hand-pulling may simply increase disturbance and therefore increase habitat for stiltgrass (Judge et al. 2008, Flory & Lewis, 2009). Every root and stem must be removed from the ground for the process to be effective (Flory, 2010).

If there is a dense patch, another manual control is mowing and trimming. Ward and Mervosh (2012) mowed stiltgrass in July and August before seed-set with a weed whip over a two-year period and found that this method reduced the density of stiltgrass by 82%. However, if mowing is not repeated regularly, the invasive grass can grow back denser (Ward et al., 2012, Willis et al., 2022). The effectiveness of mowing also depends on how long stiltgrass has been established on the site (Flory & Lewis, 2009) as the longer stiltgrass has been present the greater the seed bank. Additionally, equipment would need careful decontamination between uses, particularly before use on non-infested sites.

Additional considerations for manual and mechanical control include increased soil compaction from higher foot traffic and impact to non-target species.

Chemical Control

There are two types of herbicides that could be applied to invasive stiltgrass: a pre-emergent chemical or a post-emergent chemical. Pre-emergent herbicide is applied early in the year to prevent seedling growth and stop seed production (Willis et al., 2022), including a foliar treatment that will harm any plants that it comes into contact with (Figure 14) and a non-foliar treatment that only harms specific plants (Figure 15). Pre-emergent herbicide applied to *M. vimineum* can decrease growth by up to 87 for at least eight weeks (Judge, 2015; Willis et al., 2022).

Post-emergent, systemic herbicides are most effective when applied before the plant goes to seed. Post-emergent herbicide must be applied every year to prevent regrowth (Willis et al., 2022). Glyphosate is nonselective and will affect all vegetation but at low doses can be controlled. Glufosinate is non-selective but doesn't move through the plants' vascular system so it will be limited to where it came into contact with the plant (Templeton et al., 2020). Post-emergent herbicides can be very effective with studies showing they reduce *M. vimineum* growth to very low levels (Flory, 2010; Willis et al., 2022).

Figures 14 and 15 show post-emergent foliar treatment selective grass-specific herbicides (Figure 14) and pre-emergent non-selective residual herbicides (Figure 15) herbicides which may limit germination (Apsley & Smith, 2011). Post-emergent herbicides should be applied when plants are 10-15 cm tall (Flory, 2017). While herbicides can be effective during the spring, summer and fall, applying herbicides too early in the year can result in plants being missed and more reproduction taking place, creating more dense mats (Flory, 2017).

Herbicide	Example Brand Names	Comments
glyphosate	Roundup herbicides; Accord herbicides	Non-selective; 1–2% solution in water (vol/vol); when leaves are green; add surfactant if not in herbicide
fluazifop-P-butyl	Fusilade DX	Selective grass herbicide; 16–24 oz per acre or 0.5% solution in water (vol/vol); add non-ionic surfactant; retreatment may be necessary
sethoxydim	Poast	Selective grass herbicide; 1.0–1.5% in water (vol/vol)

Figure 14. Post-emergent foliar treatment methods for M. vimineum (Apsley & Smith, 2011)

Herbicide	Example Brand Names	Comments
pendimethalin	Pendulum AquaCap	4.2 qts/acre; apply 2–3 weeks prior to germination; will not affect plants that have germinated
imazapic	Plateau	4–6 oz/acre; treat when plants are less than 4 inches tall; both pre- and post-emergence control
sulfometuron	Oust XP	1 1/3–3 oz/acre; pre-and post-emergence activity

Figure 15. Pre- emergent herbicide methods for M. vimineum (Apsley & Smith, 2011)

Herbicides carry the possibility of accidentally harming off-target and native species. Even at low doses, herbicides can prevent native species from recovering (Ward et al., 2012). Herbicides can also decrease native seed production and reproduction timelines (Judge et al. 2005, Ward et al., 2012). As such, it is important to use caution when using this method of invasive species control.

Cultural Control

In addition, fire has been explored as a control method for stiltgrass. Studies have shown that fire can reduce overall cover by 79% and biomass by 90% (Flory and Lewis, 2009). However, while spring fires have been shown to reduce the overall cover of stiltgrass, they were not shown to impact the overall density of the species on the landscape (Flory & Lewis, 2009).

Biological Control

Biological control is not available for stiltgrass at the time of writing. However, some pathogens have been seen infecting the grass's population naturally (Swearingen et al., 2014). More research is needed on potential biological control agents for this species (Culpepper et al., 2018).

Indirect Management

In conjunction with direct management, a method of treatment for pastures using a natural barrier such as a wooded tree line to establish a border around the infestation to prevent spread. The stiltgrass is then treated chemically or manually for several years (Kenny & Lingenfelter, 2022). After each treatment, the pasture should be reseeded with cool-season perennial forages such as small grain cereal grasses like rye or oats (Kenny & Lingenfelter, 2022;

Sleep, 2017). Once established, the perennial forages will out-compete the Sstiltgrass (Kenny & Lingenfelter, 2022). Maintaining natural disturbances like natural flood cycles can also help control this species (Templeton et al., 2020)

Research Needs

I. Biology and Ecology

Stiltgrass is a difficult plant to manage, as it is very adaptable in its living conditions. There have been many studies on stiltgrass and its impact on reducing biomass in varying locations, but more long-term studies are necessary to understand the legacy effects on ecosystems and growing conditions (Nord et al., 2010; Goldsmith et al., 2023). Additionally, continued research about factors that affect the growth of stiltgrass can help inform prevention and management (Culpepper et al,2018). For example, more research is needed on stiltgrass adaptability to light availability and soil moisture over extended periods of time (Nord Andrea et al., 2010).

Stiltgrass interactions with native species in its invasive range is also understudied. Research on native species that can tolerate the presence of stiltgrass in the ecosystem would be helpful. Native species regeneration after stiltgrass is treated and removed from an area also requires more research. Native species reintroduction is a slow process in forested ecosystems and long-term research on native species restoration techniques is needed (Culpepper et al., 2018). In addition, little is known about stiltgrass interactions with invertebrates. Some studies have noted a dramatic decrease in butterfly populations surrounding stiltgrass (Swearingen & Adams, 2008) but further study is necessary to understand the drivers of these population shifts. Arthropod communities are known to establish in stiltgrass communities (Logan, 2017), but the quality of these communities needs further study.

Finally, very little research is available on stiltgrass in its native range. For example, more research is necessary to understand how this species fits into its native ecosystems. Research that explores whether stiltgrass spreads aggressively and what factors keep the species in check in its native range will help inform management decisions. In addition, no research exists comparing stiltgrass reproduction in the species' invasive and native ranges. More research is necessary to understand whether and how stiltgrass reproduction varies between its invasive and native ranges.

II. Detection

Currently, stiltgrass populations are most commonly detected once they have become established and formed dense mats. More research is necessary to improve early detection for this species. Research focusing on the use of eDNA, remote sensing technologies, and additional habitat markers will be particularly helpful in improving early detection of this species. Research using remote sensing technology called the Invasive Species Forecasting

System to detect invasive grasses on the east coast of the United States (Moore, 2010) has shown promising results but requires further development as well as testing to identify whether this technique could work for stiltgrass.

III. Management

There are several research gaps related to the management of this species. More research needs to focus on the treatment efficacy compared to infestation size and how long a treatment suppresses stiltgrass or improves its growth (Flory & Lewis, 2009). In addition, research that identifies native species that are susceptible and resilient to stiltgrass infestations will be valuable for management.

Current methods of stiltgrass management may harm native invertebrate and plant communities. More research into alternative management and detection techniques is necessary. Little is known about whether prescribed burns could be an effective management technique (Flory & Lewis, 2009). Similarly, climate change impacts, including effects on fire regimes in the eastern states may also be important for understanding management of this species (Flory & Lewis, 2009). In addition, more research is needed on potential biological control agents for this species (Culpepper et al., 2018).

In addition, more research is needed to understand stiltgrass growth and spread patterns. It is currently difficult to predict the spread of stiltgrass as it can thrive in a variety of habitats including heavily forested areas and open fields. A better understanding of how existing populations may spread will help managers design effective methods of prevention.

Future Directions for Michigan and Management

There are currently many opportunities for managing the spread of stiltgrass in Michigan. Preventing the spread of the species is the state’s first line of defense when it comes to protecting the state’s valuable ecosystems. In order to accomplish this feat, consistent monitoring and management of existing populations are necessary. Management actions often require repeat applications over several years to be successful. It is important that financial support for management be consistent to successfully prevent the spread of this species.

Along with management it is necessary to educate the public about the ecological impacts of the species and why it is being managed. Human disturbance is the main vector by which the species spreads. As such, community involvement and awareness are key to preventing its spread. Public education campaigns are valuable resources for managers trying to control the spread of species like stiltgrass, including steps that they can personally take to prevent its spread. Managers should provide educational materials close to areas where stiltgrass commonly spreads such as walking trails, ATV trails and horse trails. Education combined with resources that allow community members to identify and remove seeds from shoes, hooves, and vehicles is particularly valuable.

Local cooperative invasive species management areas (CISMAs) are important resources that can help coordinate management and educate the public about stiltgrass and other invasive species that threaten Michigan's native ecosystems. Partnering with local CISMAs can help ensure prompt management and effective monitoring.

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