

Smut grass (*Sporobolus indicus*) chemical control: a systematic review

Review

Cite this article: Martins HL, Campalle AN, de Oliveira AB, Zanqueta JFD, Santos RTda S, de Souza Rodrigues J, Dutra FV, Baxter L, Grey TL, Alves PL da CA (2026). Smut grass (*Sporobolus indicus*) chemical control: a systematic review. *Weed Sci.* **74**(e11), 1–10. doi: [10.1017/wsc.2026.10087](https://doi.org/10.1017/wsc.2026.10087)

Received: 6 November 2025

Revised: 30 December 2025

Accepted: 8 January 2026

Associate Editor:

William Vencill, University of Georgia

Keywords:

Hexazinone; integrated management; pastures; selective chemical control

Corresponding author:

Heytor Lemos Martins;
Email: heytor.lemos18@gmail.com

Heytor Lemos Martins¹ , Arthur Nardi Campalle¹ , Andrey Batalhão de Oliveira¹, João Francisco Damião Zanqueta¹ , Renata Thaysa da Silva Santos² , Juliana de Souza Rodrigues³ , Fernanda Vitorete Dutra⁴ , Lisa Baxter⁵ , Timothy L. Grey⁵  and Pedro Luís da Costa Aguiar Alves¹ 

¹Biology, UNESP: Universidade Estadual Paulista Julio de Mesquita Filho, Brazil; ²UEPA: Universidade do Estado do Para, Brazil; ³Auburn University, USA; ⁴USP: Universidade de Sao Paulo, Brazil and ⁵University of Georgia, USA

Abstract

This systematic review evaluated studies published between 1980 and 2025 on the chemical control of smut grass [*Sporobolus indicus* (L.) R. Br.] in the Americas, with a focus on pastures. After 446 publications were screened, 13 peer-reviewed articles met the inclusion criteria. Most studies were conducted in the subtropical United States, particularly in Florida, on bahiagrass (*Paspalum notatum* Flueggé) pastures, with only one study carried out in Brazil. The most frequently reported herbicide was hexazinone, present in more than 80% of the studies, applied either alone or in combination with mechanical methods or fertilization. Consistent results indicated control efficacy above 85%, especially at doses ≥ 0.84 kg ha⁻¹ and when applied during summer. Selectivity for use in bahiagrass was considered satisfactory despite temporary phytotoxic symptoms. Integrated strategies, such as herbicide applications combined with nitrogen fertilization, showed potential to restore forage dominance and reduce reinfestation. Other herbicides, such as glyphosate, indaziflam, imazapic, mesotrione, and triazines, were less frequently investigated. Indaziflam, applied preemergence, caused a significant reduction in the seedbank, showing promise for preventive management, given the high dormancy and longevity of *S. indicus* seeds. The integration of chemical and mechanical control produced variable outcomes: in some cases, mowing before application reduced efficacy, whereas in others, when associated with strategies to remove growing points and subsequent herbicide application, it enhanced control. The scarcity of studies under Brazilian and other tropical or subtropical conditions limits the understanding of this species' adaptation and the efficiency of management methods across different edaphoclimatic contexts. Expanding research in these regions is crucial for developing effective and sustainable management strategies.

Introduction

The grass family, Poaceae, belongs to the order *Poales* and comprises 789 genera and 11,783 species distributed across 12 subfamilies (Soreng et al. 2022). Members of this family are characterized by lanceolate leaves with sheaths, inflorescences arranged in spikes or panicles, unisexual flowers, and small, dry pollen grains (Simpson 2010). Poaceae has a cosmopolitan distribution and is among the most economically important plant families, particularly in the food sector (APG 2016).

The genus *Sporobolus*, within Poaceae, includes approximately 150 to 200 species distributed throughout tropical and subtropical regions worldwide (Simon and Jacobs 1999). Despite its ecological relevance, the genus remains underexplored, with limited dedicated research to date. Species occur mainly in open environments, such as pastures, fields, and savannas (DiTomaso and Kyser 2013; Rana et al. 2012), and exhibit adaptations to adverse conditions, including the C₄ photosynthetic pathway, which enhances survival in hot and dry environments (Dias-Filho 2015; Quattrocchi 2006).

Taxonomically, *Sporobolus* belongs to the subfamily Pooideae, tribe Sporoboleae. Although its taxonomy is generally well established, identification can be challenging due to the high morphological similarity among species, which often requires detailed analysis (Dias-Filho 2011; Peterson et al. 2014). The generic name *Sporobolus* derives from the Greek words *sporos* (seed) and *bolos* (to throw), referring to the seed-dispersal mechanism in which mature seeds are expelled from the fruit (Clifford and Bostock 2007; Quattrocchi 2006). This feature also inspired the common English name “dropseed.”

The identification of *Sporobolus* species is particularly complex in the so-called “indicus complex” (Baaijens and Veldkamp 1991; Pilger 1956). For example, in Australia, five exotic invasive species—rat-tail grass [*Sporobolus africanus* (Poir.) Robyns & Tournay], smut grass

© The Author(s), 2026. Published by Cambridge University Press on behalf of Weed Science Society of America. This is an Open Access article, distributed under the terms of the Creative Commons Attribution licence (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted re-use, distribution and reproduction, provided the original article is properly cited.



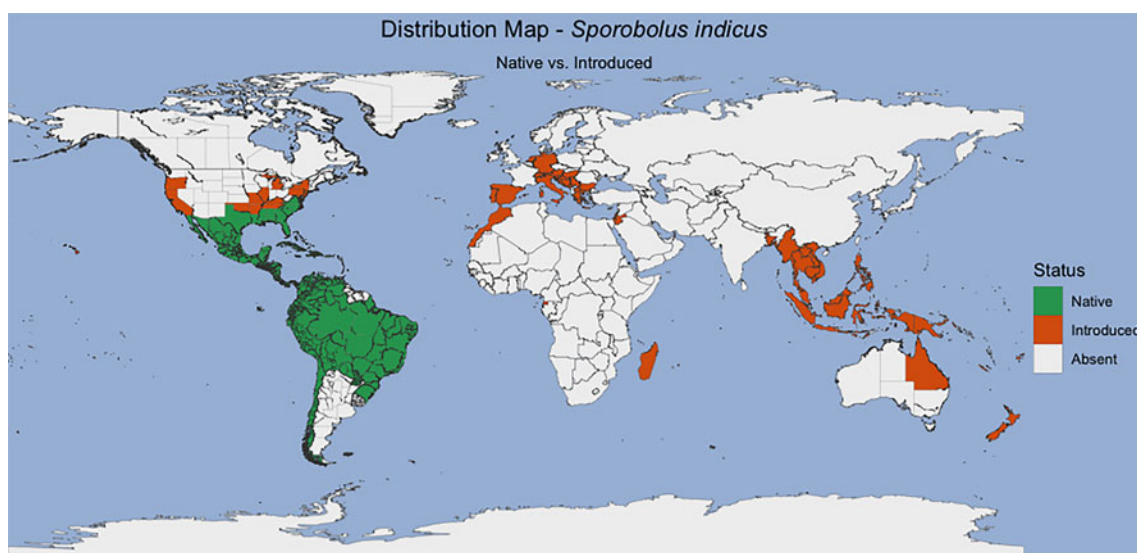


Figure 1. Geographic distribution of *Sporobolus indicus*.
Source: WFO (2025).

[*Sporobolus fertilis* (Steud.) Clayton], West Indian dropseed (*Sporobolus jacquemontii* Kunth) (a synonym of *S. pyramidalis* according to The Plant List [2013]), *Sporobolus natalensis* (Steud.) T. Durand & Schinz, and *Sporobolus pyramidalis* P. Beauv.—are collectively referred to as “weedy sporobolus grasses” (Bray and Officer 2007; Palmer 2012). Morphological difficulties in differentiating these taxa have led to the development of molecular tools to support accurate identification (Peterson et al. 2014; Shrestha et al. 2003, 2012).

Sporobolus indicus (L.) R. Br., commonly known as *capim-capeta* or *capim-mourão* in Brazil and “smut grass” in the United States, is a perennial species native to the New World, ranging from the southern United States through Mexico, Central America, the Caribbean, and South America (Vélez-Gavilán 2022). It is characterized by rapid and aggressive growth (Cáceres 2021). Its wide distribution has resulted in numerous regional names, including “wiregrass” or *espartillo* in Cuba, “mouse tail” in Mexico, and *serrillo* in Puerto Rico, reflecting its relevance in diverse production systems. Today, *S. indicus* occurs across the Americas as well as in parts of Europe, Asia, and Oceania (Figure 1), owing to its ability to adapt to a broad range of environments (Flora e Funga do Brasil 2025; Quattrocchi 2006). It is recognized as an invasive weed in pastures in Brazil, the United States, and elsewhere (Bauer and Verloove 2023; Kissmann 1991; Lorenzi 2000; Quattrocchi 2006) and is widely considered an indicator of pasture degradation (Dias-Filho 2011).

Several traits make *S. indicus* a particularly harmful pasture weed: it is of low palatability, has poor nutritional value, and has the potential to produce large quantities of seed; *S. indicus* can produce up to ~200,000 seeds per plant annually (Dias-Filho 2015; Padilla et al. 2013). Moreover, a high proportion of seeds are dormant, with the capacity to germinate 2 to 10 yr after dispersal, complicating eradication efforts (Bray and Officer 2007; Padilla et al. 2013). The mucilaginous seed coat is thought to confer ecological advantages in harsh environments (Yang et al. 2010, 2012; Young and Evans 1973).

In addition, several well-documented drivers of pasture degradation facilitate the establishment and spread of *S. indicus*. Exotic species such as *S. indicus* may also act as indicators of altered soil

dynamics, reflecting systems characterized by low structural stability, reduced carbon sequestration capacity, and consequently, diminished ecological value (Dias-Filho 2011, 2015; Padilla et al. 2013; Rai and Singh 2020). Drought reduces competitive pressure by suppressing the growth and recovery of desirable forage species, creating recruitment niches for stress-tolerant weeds. Fire, depending on intensity and frequency, can remove aboveground biomass and expose mineral soil, enhancing seedling emergence of pioneer and opportunistic grasses. Mowing at inadequate heights or frequencies weakens perennial forage stands and increases light penetration to the soil surface, promoting germination of small-seeded weeds. Improper pasture management combined with low soil fertility has intensified degradation processes, resulting in substantial ecological and economic constraints (Dias-Filho 2023).

High grazing pressure exacerbates these effects by reducing soil cover, increasing compaction, and selectively eliminating palatable forage species, thereby favoring the establishment and spread of grazing-tolerant and unpalatable species such as *S. indicus*. As degradation advances, pasture systems progressively lose their carrying capacity, directly limiting livestock productivity and regional economic performance (Dias-Filho 2023). Consequently, identifying the drivers of pasture degradation and implementing effective mitigation strategies is fundamental to ensuring the long-term sustainability of grazing systems (Bustamante et al. 2019).

As a means of mitigating these impacts, postemergence herbicides have been widely used for the management of *S. indicus*. Among the most frequently studied compounds are hexazinone, a triazine herbicide that inhibits photosystem II (PSII), leading to interveinal and marginal chlorosis (Ferrell and Mullahey 2006). Hexazinone exhibits predominantly apoplastic movement, with limited phloem translocation following foliar absorption (Shaner 2014). Glyphosate is also extensively investigated; it acts as a 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) inhibitor, disrupting the shikimic acid pathway and preventing the synthesis of essential aromatic amino acids (Mendes and Silva 2022). However, glyphosate efficacy is limited (Cáceres 2021), especially in large infestations. Because it is nonselective, glyphosate often causes phytotoxicity to surrounding forage species, necessitating targeted

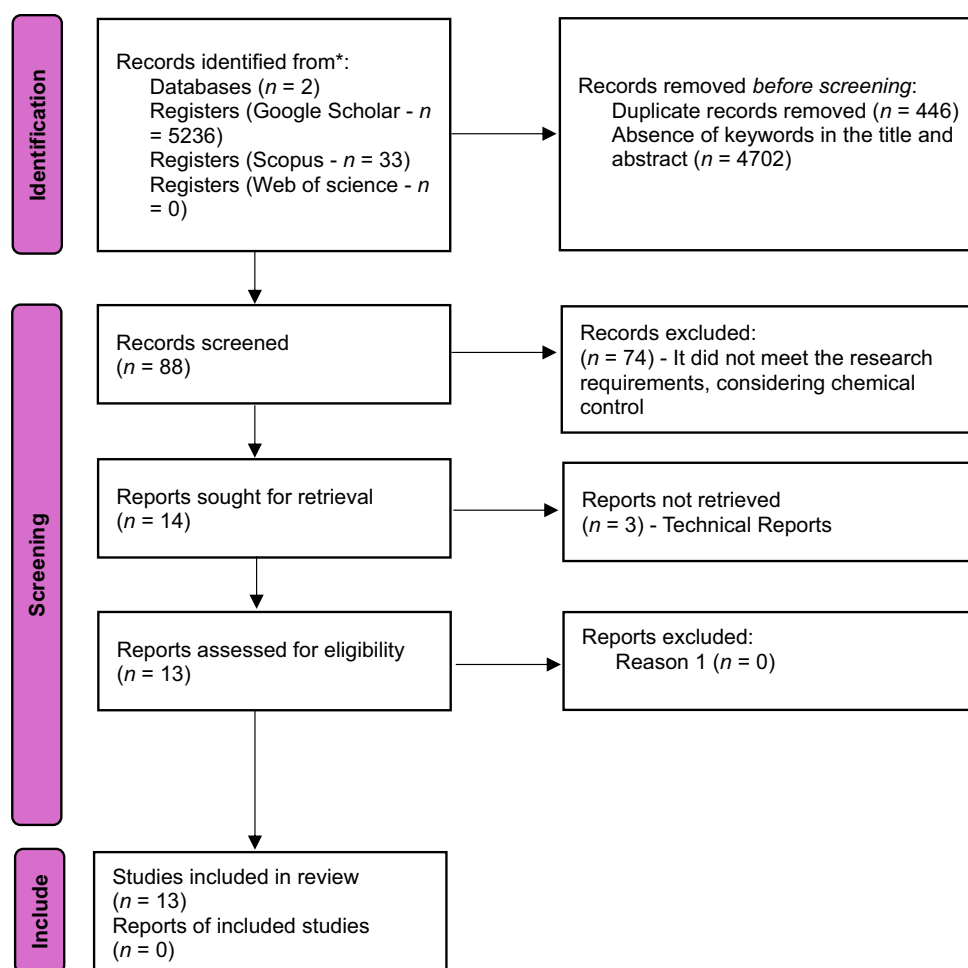


Figure 2. PRISMA flow diagram of article selection for chemical control *Sporobolus* spp. (Page et al. 2021).

applications only to *S. indicus* clumps (Andrade and Dias-Filho 2018; Dias-Filho 2015). Chemical control is further complicated by the morphological and physiological similarity of *S. indicus* to forage grasses, which increases the risk of herbicide injury.

Overall, the management of monocotyledonous weeds, particularly perennial Poaceae species, remains challenging, because herbicides selective in perennial forage grasses generally provide poor control of invasive grasses within the same family (Santos et al. 2008). Furthermore, mechanical and cultural practices such as burning or mowing often stimulate regrowth from basal buds, contributing to rapid reinfestation (Adjei et al. 2003). Therefore, the objective of this study is to conduct a systematic review of *Sporobolus* spp., synthesizing information on its occurrence and chemical management in the Americas between 1980 and 2025.

Materials and Methods

For this literature review, scientific articles on *S. indicus* were analyzed from digital platforms. A structured step-by-step process was established, beginning with the development of the key research question, objectives, and hypothesis. Subsequently, research methods and article selection criteria were defined. After information gathering, the available evidence regarding the chemical control of the species was critically analyzed.

A comprehensive literature search was conducted using ISI Web of Science (<https://mjl.clarivate.com/search-results>), Scopus (<https://www.scopus.com/standard/marketing.uri#basic>), and Google Scholar (<https://scholar.google.com>). The search was performed between October 2024 and June 2025 with the following keywords: “Pasture”, “Smutgrass”, and “*Sporobolus indicus*”. No language restrictions were applied, and the search covered the period from 1980 to 2025. The starting year was defined based on preliminary scoping searches indicating that the scientific use of the name *Sporobolus indicus* became consistent in indexed literature from this period onward, thereby ensuring taxonomic clarity and reproducibility of the search strategy.

The initial search retrieved 5,269 articles. After removal of duplicates, 446 unique documents remained, whose titles and abstracts were screened for relevance. Screening followed eligibility criteria requiring that: (1) the study was published in a peer-reviewed journal; (2) it employed a structured experimental design in field or greenhouse conditions; and (3) it reported at least one of the following response variables: weed density, weed control efficacy, or treatments applied.

Following this method, 88 full-text articles were selected for weed management in general. Of these, 13 articles from the Americas were chosen for detailed analysis of chemical control, as most publications on this species originated from this *geographic region*. The article selection process followed the PRISMA guidelines (Page et al. 2021; Figure 2).

Information was extracted from the selected articles, including common and scientific names, application timing, herbicides, application rates, study location, forage species, fertilizers, site characteristics, year of publication, and treatment efficacy. Data were obtained from both text and tables. Graphs were generated in R (R Core Team 2022) using the GGLOT2 package (Wickham 2016).

Results and Discussion

The systematic literature review on the control of *Sporobolus* spp. identified 13 peer-reviewed studies published between 1999 and 2025 (Table 1), conducted primarily in pasture systems in the United States and Brazil. Most were carried out in bahiagrass (*Paspalum notatum* Flueggé) pastures, with fewer studies in other forage species such as koronivia grass [*Urochloa humidicola* (Rendle) Morrone & Zuloaga] and bermudagrass [*Cynodon dactylon* (L.) Pers.].

The taxonomic identity of some *Sporobolus* populations in Florida remains uncertain, as they may correspond to *S. indicus*, *S. pyramidalis*, or *S. jacquemontii*. Although several records and descriptions exist in the literature, there is no consensus on the botanical classification of these populations, with varieties such as *indicus*, *africanus*, and *pyramidalis* frequently reported.

A temporal distribution of the reviewed studies was observed. Although the search period spanned from 1980 to 2025, no eligible studies on the chemical control of *S. indicus* were published between 1980 and 1998. The first study meeting the inclusion criteria appeared between 1999 and 2006 (four studies), followed by isolated publications in 2011 and 2015, and a marked increase in research output between 2022 and 2025 (six studies) (Table 1).

Among the chemical control strategies, hexazinone was the most frequently reported herbicide, appearing in more than 80% of the studies, either applied alone or in combination with mowing or other active ingredients. Glyphosate, although widely used in general weed management, was reported less often and typically combined with mechanical practices such as mowing. Its application employed different equipment, including rope-wick applicators (weed wipers) and backpack sprayers. Other active ingredients mentioned included mesotrione, indaziflam, metsulfuron-methyl, nicosulfuron, terbutylazine, and imazapic, although these were less frequently documented across the publications (Figure 3).

Regarding application timing, postemergence treatments were the most frequently reported approach in the reviewed literature, reflecting the emphasis of existing studies rather than application intensity within individual experiments (Figure 4). A smaller number of studies evaluated preemergence applications, primarily involving indaziflam, while others reported sequential strategies combining preemergence and postemergence treatments. In addition, some studies described integrated approaches in which herbicide applications were combined with mechanical practices, such as mowing followed by chemical control, illustrating how chemical management has been incorporated into broader integrated weed management frameworks.

Geographically, most studies were conducted in Florida (USA), particularly those addressing the control of West Indian dropseed, also known as giant smut grass [*Sporobolus indicus* (L.) R. Br. var. *pyramidalis* (P. Beauv.) Veldkamp], a highly problematic biotype in pastures of the southeastern United States. For South America, only one study was identified, carried out in Brazil, which evaluated combinations of mesotrione and triazine-class herbicides in *Brachiaria* spp. pastures, thereby expanding the available chemical control options.

The taxonomic uncertainty surrounding *Sporobolus* in Florida reflects an issue well recognized in the literature. While some authors distinguish *S. jacquemontii* from *S. pyramidalis* based on morphological traits (Clayton et al. 1974; Peterson et al. 2003; Simon and Jacobs 1999), others consider them morphologically indistinguishable and treat them as synonyms of *S. indicus* var. *pyramidalis* (Baaijens and Veldkamp 1991; Wunderlin et al. 2025). Molecular evidence indicates that all three belong to *Sporobolus* sect. *Sporobolus*, although *S. pyramidalis* from Africa and Australia is genetically distinct from *S. indicus* and *S. jacquemontii* of the Americas (Peterson et al. 2014). Historical introductions of African and Brazilian accessions into USDA germplasm programs further contribute to this uncertainty, emphasizing the need for genetic analyses to clarify the identity of Florida populations. This taxonomic complexity, combined with the invasive behavior of several *Sporobolus* species, highlights the importance of identifying effective management strategies, particularly chemical control of *S. indicus*.

This integrated review of studies published between 1980 and 2025 demonstrates significant advances in understanding herbicide efficacy, integrated management approaches, and the limitations of conventional methods in tropical and subtropical pastures. Hexazinone emerged as the most studied and effective herbicide, particularly in Florida and Georgia (Mislevy et al. 1999; Rana et al. 2015; Shay et al. 2022, 2024). Control levels above 85% were consistently achieved, particularly when hexazinone was applied at rates $\geq 0.84 \text{ kg ha}^{-1}$ during the rainy season. Although hexazinone generally shows satisfactory selectivity for bahiagrass, temporary phytotoxicity may occur; however, plants typically recover within 40 d after treatment (Mislevy et al. 1999). Recent field-based evidence has further demonstrated that hexazinone performance is strongly influenced by the interaction between application rate, rainfall following application, and application timing, with adequate precipitation being essential for consistent control (Dias et al. 2025).

The use of fertilizers following herbicide application has been shown to mitigate phytotoxic effects and stimulate forage growth, accelerating canopy recovery and reducing weed competition. It has been associated with the mitigation of phytotoxic effects and the stimulation of forage growth, promoting faster canopy recovery and reducing weed interference. In this context, studies have shown that timely fertilization after hexazinone application accelerates the recovery of forage grasses such as bahiagrass, thereby increasing their competitiveness against weeds (Regmi et al. 2023; Sellers et al. 2023; Shay et al. 2022). Although fertilizers represent a high-cost input for low-technology production systems, evidence indicates that the combined use of hexazinone and fertilization is more effective in controlling *S. indicus* than hexazinone applied alone (Rana et al. 2013).

Application timing also strongly influenced outcomes. Summer applications achieved greater weed control with hexazinone herbicide than spring treatments (Howard et al. 2023), likely reflecting higher metabolic activity and more effective translocation of systemic herbicides during this period. The perennial growth habit of *S. indicus*, combined with the intensified allocation of carbon reserves to the root system during the pre-dormancy period, may contribute to increased efficacy of systemic herbicides. Although hexazinone exhibits predominantly xylem-mediated mobility, the greater physiological demand of roots during this phase may favor its accumulation in belowground tissues, thereby enhancing the effectiveness of chemical control (Howard 2020). By contrast, pendimethalin, traditionally classified as a soil-applied,

Table 1. Summary of published studies on herbicide-based control of *Sporobolus* species in the United States and Brazil, including the main author and year, study location, pasture type, herbicide treatment and application timing, evaluated doses (kg ai ha⁻¹), fertilizer rates (kg ha⁻¹), and the scientific and common names reported.

Authors	Location	Pasture	Treatment	Timing of application ^a	Doses	Fertilizer	Scientific name	Common name
Braz et al. (2025)	Santo Antônio da Barra, Goiás, BR	<i>Urochloa humidicola</i>	Mesotrione	POST	kg ai ha ⁻¹ 125	kg ha ⁻¹ 0	<i>Sporobolus indicus</i>	Smut grass
			Mesotrione		150			
			Mesotrione + atrazine		125 + 1,250			
			Mesotrione + atrazine		150 + 1,500			
			Mesotrione + atrazine		125 + 1,250			
			Mesotrione + atrazine		150 + 1,500			
			Mesotrione + terbuthylazine		125 + 750			
			Mesotrione + terbuthylazine		150 + 900			
Dias et al. (2024)	Bowling Green, FL, USA	Bahia grass (<i>Paspalum notatum</i>)	Glyphosate	Handheld weed wiper POST	0, 22.25, 44.5, 89, 178, and 356	0	<i>Sporobolus indicus</i> var. <i>pyramidalis</i>	Giant smut grass
			Hexazinone		0, 15, 30, 60, 120 and 240			
			Mowing + glyphosate	ATV-mounted weed wiper POST	0, 62.3, 124.6, and 249.2			
			Mowing + hexazinone		0, 36, 72, and 144			
Dias et al. (2025)	Ona, FL, USA	–	Hexazinone	POST	0.56 and 1.12	0	<i>Sporobolus indicus</i> var. <i>pyramidalis</i>	Giant smut grass
Ferrell and Mullahey (2006)	Immokalee, FL, USA	Pensacola bahiagrass (<i>Paspalum notatum</i>)	Mowing + hexazinone	POST	0, 0.56, 1.1, and 1.7	56 kg N	<i>Sporobolus indicus</i> var. <i>pyramidalis</i>	Giant smut grass
Ferrell et al. (2006)	Immokalee, FL, USA	Pensacola bahiagrass (<i>Paspalum notatum</i>)	Mowing + hexazinone	POST	0 and 1.12	56 kg N	<i>Sporobolus indicus</i> var. <i>pyramidalis</i>	Giant smut grass
Howard et al. (2023)	Richards and Bellville, TX, USA	Bermudagrass (<i>Cynodon dactylon</i>) and bahiagrass (<i>Paspalum notatum</i>)	Hexazinone, nicosulfuron + metsulfuron methyl, nicosulfuron + metsulfuron methyl followed by nicosulfuron + metsulfuron methyl, imazapic + glyphosate, and quinclorac	Spring, summer, and follow-up treatment	0.84, 56.1 + 15.8, 56.1 + 15.8, 0.21 + 0.52 and 0.42	0	<i>Sporobolus indicus</i>	Smut grass
Howard et al. (2023)	Richards and Bellville, TX, USA	Bermudagrass (<i>Cynodon dactylon</i>) and bahiagrass (<i>Paspalum notatum</i>)	Hexazinone, nicosulfuron + metsulfuron methyl, glyphosate, and imazapic	Spring, summer, and fall	1.26, 56.1 + 15.8, 0.52, 0.21	0	<i>Sporobolus indicus</i>	Smut grass
			Hexazinone, pendimethalin, and indaziflam	PRE/greenhouse	0.21, 0.42, and 0.63; 0.53, 1.07, and 1.6; 18.25, 36.5, and 54.75, plus a non-treated control			
Mislevy et al. (1999)	Ona, FL, USA	Bahiagrass (<i>Paspalum notatum</i>)	Hexazinone	Late spring, midsummer and fall applications	0, 0.56, 0.84, and 1.12	0	<i>Sporobolus indicus</i>	Small smut grass

(Continued)

Table 1. (Continued)

Authors	Location	Pasture	Treatment	Timing of application ^a	Doses	Fertilizer	Scientific name	Common name
Mislevy et al. (2002)	Okeechobee, FL, USA	Bahiagrass (<i>Paspalum notatum</i>)	Mowing + hexazinone	POST	0.00, 0.56, 0.84, 1.12, 1.40, and 1.68	N (56) + P (15) + K (56) + S (6.7)	<i>Sporobolus indicus</i> var. <i>pyramidalis</i>	Giant smut grass West Indian dropseed
Rana et al. (2015)	Zolfo Springs and Lorida, FL, USA	Bahiagrass (<i>Paspalum notatum</i>)	Hexazinone Renovation + hexazinone	Sequential	1.12 followed by 0.56 Renovation + 0.56	0 0	<i>Sporobolus indicus</i> var. <i>pyramidalis</i>	Giant smut grass
			Fall roller chopping + hexazinone		Fall roller chopping + 0.56	0		
	Zolfo Springs and Lorida, FL, USA		Hexazinone		1.12/0 1.12/0.56	0/56 kg N		
	Zolfo Springs and Ona, FL, USA		Hexazinone		0.56/0.28 0.84/0.56 1.12/0.84	0		
Shay et al. (2022)	Alapaha, GA, USA	Pensacola bahiagrass (<i>Paspalum notatum</i>) and 'Tifton-9'	None Indaziflam Hexazinone Indaziflam + hexazinone	Control PRE POST PRE + POST	0 0.058 0.98 0.058 + 0.98	56 kg N + 56 kg K ₂ O	<i>Sporobolus indicus</i>	Small smut grass
Shay et al. (2024)	Alapaha, GA, USA	Pensacola bahiagrass (<i>Paspalum notatum</i>) and 'Tifton-9'	Indaziflam	PRE	0.058	56 kg N + 56 kg K ₂ O	<i>Sporobolus indicus</i>	Smut grass
Wilder et al. (2011)	Ona and Alachua, FL, USA	Bahiagrass (<i>Paspalum notatum</i>)	Hexazinone	POST	0, 0.28, 0.56, 0.84, 1.12, 1.4, and 1.68	0	<i>Sporobolus indicus</i> <i>Sporobolus indicus</i> var. <i>pyramidalis</i>	Smut grass Giant smut grass

^aATV, all-terrain vehicle; POST, postemergence herbicide; PRE, preemergence herbicide.

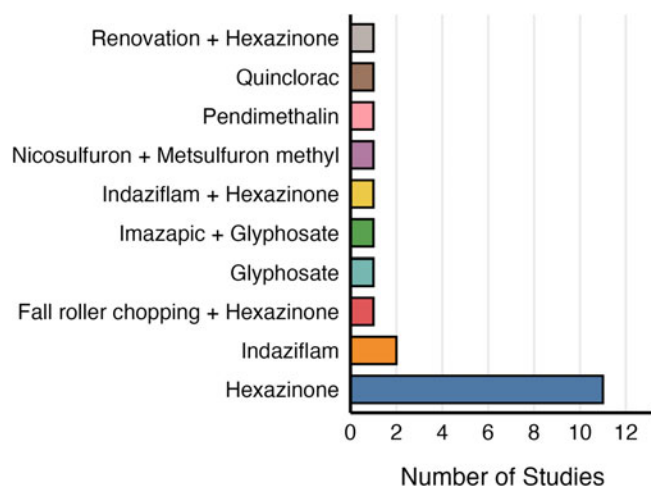


Figure 3. Number of studies conducted in the United States and Brazil evaluating different herbicides, herbicide combinations, and management practices for *Sporobolus indicus* control. “Renovation + hexazinone” refers to pasture renovation practices combined with hexazinone application, not to a commercial herbicide product.

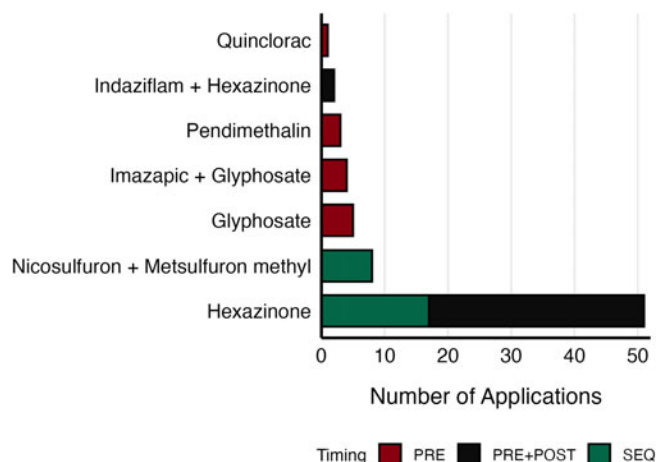


Figure 4. Frequency of herbicide application events reported across studies conducted in the United States and Brazil, grouped by active ingredient and application timing. Bars represent the total number of application events described in the reviewed literature, not the number of applications within individual experiments.

preemergence herbicide rather than a contact herbicide, showed low efficacy, which is consistent with Howard et al. (2023), who reported preemergence applications provided limited control of *S. indicus* compared with indaziflam and hexazinone. This pattern is consistent with recent findings showing that rainfall shortly after application is a critical determinant of hexazinone activation and efficacy under field conditions (Dias et al. 2025).

Integrated approaches combining postemergence herbicide applications with nitrogen fertilization have shown that reductions in *S. indicus* cover can be accompanied by improved recovery and dominance of bahiagrass (Shay et al. 2022, 2024). These findings indicate that effective chemical control of *S. indicus* should be aligned with fertilization practices that stimulate forage growth, thereby supporting pasture recovery and limiting reinfestation. Evidence for mowing, however, is mixed: while Sellers et al. (2024) reported reduced efficacy when mowing preceded herbicide application, Ferrell and Mislevy (2001) observed no significant

differences in control across mowing frequencies. Other studies indicated that aggressive mechanical practices, such as fraise mowing, may improve herbicide efficacy by physically removing growth points (Raimondi et al. 2020; Richardson et al. 2020). For *S. indicus*, however, information remains limited, highlighting the need for additional research on chemical–mechanical integration.

Targeted application methods have also shown promise. Rope-wick applicators (weed wipers) delivering concentrated glyphosate or hexazinone reduced impacts on desirable forage (Dias et al. 2024). Although effective in suppressing *S. indicus* at the treated-clump level, the overall contribution of this approach is constrained by limitations in operational precision and scalability. Hexazinone remains the most extensively studied and frequently reported herbicide for chemical control of *S. indicus*; however, its efficacy is variable and strongly influenced by application timing, rate, and environmental conditions.

Hexazinone is highly susceptible to leaching because of its high water solubility of 33,000 mg L⁻¹ and low affinity for soil particles, as indicated by a low soil adsorption coefficient ($K_{oc} = 54 \text{ ml g}^{-1}$) (Felding 1992). Consequently, downward movement beyond the root zone is more likely, particularly during summer periods characterized by frequent rainfall. In a greenhouse study, Dias et al. (2025) evaluated seven simulated rainfall accumulation levels (0, 6, 12, 25, 50, 100, and 200 mm) across two hexazinone rates and demonstrated that increasing rainfall significantly influenced herbicide efficacy based on both visual control and biomass reduction. Approximately 49 mm and 92 mm of rainfall were required to achieve 50% visual control and biomass reduction for hexazinone applied at 0.56 and 1.12 kg ai ha⁻¹, respectively. Consistent with these findings, field experiments showed that peak hexazinone performance occurred from mid-June through mid-August when applications were followed by 10 to 75 mm of rainfall within the first 7 d after treatment.

Beyond hexazinone, several other active ingredients have been evaluated primarily in turfgrass systems or in the management of invasive and caespitose grass species with high seed production, rather than directly on *S. indicus* populations. Indaziflam, a cellulose biosynthesis inhibitor with moderate to low soil mobility, has demonstrated effective pre- and early postemergence control of invasive perennial and annual grasses by reducing seedling establishment and seedbank replenishment (Alonso et al. 2011; Brosnan et al. 2012; Sebastian et al. 2017). Acetolactate synthase (ALS)-inhibiting herbicides such as imazapic, nicosulfuron, and metsulfuron-methyl have shown variable efficacy against caespitose grass species depending on growth stage and application timing, primarily in systems other than *S. indicus*-infested pastures (Takano et al. 2023). Terbutylazine, a PSII inhibitor used as an atrazine substitute, has been evaluated mainly for its residual activity on grass weeds, with performance closely linked to soil organic matter content and sorption dynamics (Tasca et al. 2018; Wang et al. 2010).

Because these active ingredients have been tested largely on species other than *S. indicus*, they were not included among the core studies of this systematic review. Nevertheless, their documented activity on invasive, tuft-forming grasses suggests potential relevance for future research targeting *S. indicus* management, particularly under tropical and subtropical pasture conditions. Mesotrione, an HPPD inhibitor widely used in maize (*Zea mays* L.), is rapidly degraded in soil (Carles et al. 2017). When applied in combination with other active ingredients, mesotrione has shown activity against monocotyledonous species and provides selectivity under certain application conditions for some forage grasses used in

pasture establishment in Brazil (Dan et al. 2011). Under Brazilian conditions, Braz et al. (2025) demonstrated that mesotrione alone was ineffective, but combinations with triazines (atrazine, terbutylazine) substantially increased control efficacy while maintaining selectivity in *U. humidicola*, indicating potential for tropical systems. However, mesotrione is not labeled for forage crops in the United States, whereas indaziflam (Rejuvra®) is approved for use in grazed lands and hayfields and thus cannot be categorized as having the same regulatory status. In Brazil, mesotrione is registered primarily for maize and not for forage systems, although experimental studies have explored its potential under tropical conditions.

It is important to note that most of these herbicides, including indaziflam, mesotrione, and ALS inhibitors, are highly injurious to many forage species, including bahiagrass. Therefore, studies evaluating the regrowth of forage grasses following herbicide application are highly desirable.

Preventive management with preemergence herbicides is becoming increasingly important. Under greenhouse conditions, indaziflam completely inhibited *S. indicus* seedling emergence, resulting in 100% suppression relative to the non-treated control across all evaluated rates and assessment periods (Howard et al. 2023). In addition, the high soil persistence of indaziflam supports prolonged residual activity, reinforcing its potential role in preventing recruitment from the soil seedbank. This strategy is especially relevant, because *S. indicus* produces seeds with high dormancy and long persistence in the soil that can remain viable for 2 to 10 yr (Padilla et al. 2013). This extended seed longevity poses a significant challenge to long-term control and reinforces the need for preventive management approaches.

Despite these advances, the literature exhibits a pronounced geographic bias, with most research conducted in the subtropical United States, particularly in Florida, and an increasing number of studies emerging from Georgia. Although low soil fertility and high grazing pressure occur in several pasture systems in Florida, important differences remain between these regions and Brazilian systems. Pastures in the biomes Cerrado and Caatinga are characterized by highly weathered soils with strong acidity and aluminum toxicity, marked seasonality in rainfall with prolonged dry periods, and forage systems dominated by warm-season *C₄* species under extensive grazing regimes. These factors influence herbicide persistence, plant recovery, and reinfestation dynamics, limiting the direct extrapolation of findings from U.S. studies. Expanding research in these underrepresented environments is therefore essential to develop management strategies that are broadly applicable across tropical and subtropical systems.

Overall, the literature reviewed between 1980 and 2025 shows that chemical control of *S. indicus* has been achieved primarily through postemergence herbicide applications, with hexazinone consistently reported as the most effective option when environmental and management conditions are favorable. Notably, recent field studies explicitly demonstrate that the success of hexazinone-based management programs depends on aligning application timing and dose with prevailing rainfall patterns, reinforcing precipitation as a central driver of control reliability (Dias et al. 2025). Across studies, successful control with hexazinone was closely associated with adequate soil moisture and precipitation following application, which enhanced root uptake and translocation, whereas reduced rainfall or dry conditions frequently resulted in inconsistent or short-lived control. Preventive strategies using residual herbicides such as indaziflam demonstrated strong suppression of seedling emergence, highlighting the importance of

targeting recruitment from the soil seedbank rather than relying solely on postemergence control.

In addition, studies integrating chemical control with pasture management practices, particularly nitrogen fertilization, consistently reported improved recovery and competitiveness of desirable forage species, reinforcing the need to link weed suppression with forage stimulation. Although much of the available evidence originates from the southeastern United States, *S. indicus* is a widespread problem across tropical and subtropical pasture systems worldwide, and the limited number of field-based studies conducted under diverse edaphoclimatic conditions restricts the transferability of current recommendations. Expanding research across a broader range of environments is therefore essential to refine integrated management strategies and support more reliable, long-term control of *S. indicus*.

Funding statement. This research received no specific grant from any funding agency or the commercial or not-for-profit sectors.

Competing interests. The authors declare no conflicts of interest.

References

- [APG] Angiosperm Phylogeny Group (2016) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. Bot J Linn Soc 181:1–20
- [WFO] World Flora Online (2025) *Sporobolus indicus* (L.) R. Br. <https://www.worldfloraonline.org/taxon/wfo-0000901192>. Accessed: August 16, 2025
- Adjei MB, Mullahey JJ, Mislavy P, Kalmbacher RS (2003) Smutgrass Control in Perennial Grass Pastures. SS-AGR-18. Gainesville, FL: University of Florida, Florida Cooperative Extension Service. <https://ufdc.ufl.edu/ir00008862/00001>. Accessed: January 12, 2026
- Alonso DG, Koskinen WC, Oliveira RS, Constantin J, Mislankar S (2011) Sorption–desorption of indaziflam in selected agricultural soils. J Agric Food Chem 59:13096–13101
- Andrade CMS, Dias-Filho MB (2018) Alternativas para o manejo de capim-navalha e capim-capeta em pastagens na Amazônia. Pages 34–48 in Guimarães ACD, Inoue MH, Ikeda FS, eds. Estratégias de manejo de plantas daninhas para novas fronteiras agrícolas. Viçosa, MG, Brazil: Sociedade Brasileira da Ciência das Plantas Daninhas; Cáceres, MT, Brazil: Universidade do Estado de Mato Grosso, Editora UNEMAT
- Baaijens GJ, Veldkamp JF (1991) *Sporobolus* (Gramineae) in Malaysia. Blumea 35:393–458
- Bauer N, Verloove F (2023) The accelerated spread of a neophyte introduced to Europe long ago—first occurrence of *Sporobolus indicus* (Poaceae) in Hungary. Acta Bot Croat 82:1–7
- Bray SG, Officer D (2007) Weedy *Sporobolus* Grasses—Best Practice Manual. Brisbane: State of Queensland. 45 p
- Braz GBP, Nascimento HLB, Bilego UO, Bastos LO, Sousa MMP (2025) Associações herbicidas aplicadas em pós-emergência no controle de capim-capeta (*Sporobolus indicus*) em pastagem cultivada. Weed Control J 24:e202500872
- Brosnan JT, Breedon GK, McCullough PE, Henry GM (2012) PRE and POST control of annual bluegrass (*Poa annua*) with indaziflam. Weed Technol 26:48–53
- Bustamante MMC, Silva JS, Scariot A, Sampaio AB, Mascia DL, Garcia E, Sano E, Fernandes GW, Durigan G, Roitman I, Figueiredo I, Rodrigues RR, Pillar VD, de Oliveira AO, Malhado AC, et al. (2019) Ecological restoration as a strategy for mitigating and adapting to climate change: lessons and challenges from Brazil. Mitig Adapt Strateg Glob Change 24:1249–1270
- Cáceres NT (2021) Plantas daninhas em pastagens: biologia, manejo e controle. Viçosa, Brazil: Editora UFV. 321 p
- Carles L, Joly M, Joly P (2017) Mesotrione herbicide: efficiency, effects, and fate in the environment after 15 years of agricultural use. CLEAN Soil Air Water 45:1700011

- Clayton WD, Phillips SM, Renvoize SA (1974) *Sporobolus*. In Polhill RM, ed. Flora of Tropical East Africa: Gramineae. London: Crown Agents for Overseas Governments and Administrations. 176 p
- Clifford HT, Bostock PD (2007) Etymological Dictionary of Grasses. Berlin: Springer. Pp 255–284
- Dan HA, Barroso, ALL, Dan LGM, Procópio SO, Oliveira Jr. RS, Constantin J, Feldkircher C (2011) Supressão imposta pelo mesotrione a *Brachiaria brizantha* em sistema de integração lavoura-pecuária. Planta Daninha 29:861–867
- Dias JC, Mncube TL, Sellers BA, Ferrell JA, Enloe SF, Vendramini JM, Moriel P (2024) Effectiveness of integrating mowing and systemic herbicides applied with a weed wiper for *Sporobolus indicus* var. *pyramidalis* management in Florida. Invasive Plant Sci Manag 17:114–122
- Dias JC, Mncube TL, Sellers BA, Ferrell JA, Enloe SF, Vendramini JM, Moriel P (2025) *Sporobolus indicus* var. *pyramidalis* management in response to hexazinone rates, rainfall, and application timing in Florida pasture systems. Invasive Plant Sci Manag 18:e17
- Dias-Filho MB (2011) Degradação de pastagens: processos, causas e estratégias de recuperação. 4th ed. Belém, PA, Brazil: Embrapa Amazônia Oriental. 61 p
- Dias-Filho MB (2015) Controle de capim-capeta [*Sporobolus indicus* (L.) R. Br.] em pastagens no Estado do Pará. Comunicado Técnico 268. Belém, PA, Brazil: Embrapa Amazônia Oriental. 7 p
- Dias-Filho MB (2023) Degradação de pastagens: conceitos, processos e estratégias de recuperação e de prevenção. Belém, PA, Brazil: Edição do autor. 72 p
- DiTomaso JM, Kyser GB (2013) Weed control in natural areas in the western United States. Davis: Weed Research and Information Center, University of California. 544 p
- Felding G (1992) Leaching of atrazine and hexazinone from *Abies nordmanniana* plantations. Pestic Sci 35:271–275
- Ferrell JA, Mullahey JJ (2006) Effect of mowing and hexazinone application on giant smutgrass (*Sporobolus indicus* var. *pyramidalis*) control. Weed Technol 20:90–94
- Ferrell JA, Mullahey JJ, Dusky JA, Roka FM (2006) Competition of giant smutgrass (*Sporobolus indicus*) in a bahiagrass pasture. Weed Sci 54:100–105
- Flora e Funga do Brasil (2025) Poaceae Barnhart. In Jardim Botânico do Rio de Janeiro. <https://floradobrasil.jbrj.gov.br/FB193>
- Howard J (2020) Smutgrass (*Sporobolus indicus* var. *indicus*) control and identification in perennial pasture in Texas. Master's thesis. College Station: Texas A&M University. 78 p
- Howard ZS, Nolte SA, Hussey M, Treadwell ML, Sellers B (2023) Evaluation of chemical control and seasonal application options for smutgrass (*Sporobolus indicus*). Weed Technol 37:530–536
- Kissmann KG (1991) Plantas infestantes e nocivas. Vol 1. Jaboticabal: BASF Brasileira. 981 p
- Lorenzi H (2000) Plantas daninhas do Brasil: terrestres, aquáticas, parasitas e tóxicas. 3rd ed. Nova Odessa, Brazil: Instituto Plantarum. 672 p
- Mendes KF, Silva AA (2022) Plantas daninhas: herbicidas. 2nd ed. Viçosa, Brazil: Oficina de Textos. 182 p
- Mislevy P, Martin FG, Hall DW (2002) West indian dropseed/giant smutgrass (*Sporobolus indicus* var. *pyramidalis*) control in bahiagrass (*Paspalum notatum*) Pastures. Weed Technol 16:707–711
- Mislevy P, Shilling DG, Martin FG Hatch SL (1999) Smutgrass (*Sporobolus indicus*) control in bahiagrass (*Paspalum notatum*) Pastures. Weed Technol 13:571–575
- Padilla C, Sardiñas Y, Febles G, Fraga N (2013) Strategies for controlling the degradation of grasslands invaded by *Sporobolus indicus* (L.) R. Br. Cuban J Agric Sci 47:113–117
- Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Jennifer M Tetzlaff JM, Akl EA, Brennan SE, Chou R, Glanville J, Grimshaw JM, Hróbjartsson A, Lalu MM, et al. (2021) The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews. BMJ 372:n71
- Palmer B (2012) *Sporobolus* spp.—weedy *Sporobolus* grasses. Pages 569–575 in Julien M, McFadyen R, Cullen J, eds. Biological Control of Weeds in Australia. Sydney: CSIRO Publishing
- Peterson PM, Hatch SL, Weakley AS (2003) *Sporobolus* R. Br. Pages 115–139 in Barkworth ME, Capels KM, Long S, Piep MB, eds. Flora of North America North of Mexico. Volume 25. New York: Oxford University Press
- Peterson PM, Romaschenko K, Arrieta YH, Saarela JM (2014) A molecular phylogeny and new subgeneric classification of *Sporobolus* (Poaceae: Chloridoideae: Sporobolinae). Taxon 63:1212–1243
- Pilger R (1956) Gramineae II. Subfamilies: Micrairoideae, Eragrostideae, Oryzoideae, Olyroideae. Pages 1–168 in Melchior H, Werdermann E, eds. Die natürlichen Pflanzenfamilien. 2nd ed. Volume 14d. Berlin, Germany: Duncker & Humblot
- Quattrocchi U (2006) CRC World Dictionary of Grasses. Boca Raton, FL: CRC Press. 1132 p
- R Core Team (2022) R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing. <https://www.R-project.org/>
- Rai PK, Singh JS (2020) Invasive alien plant species: their impact on environment, ecosystem services and human health. Ecol Indic 111:1–21
- Raimondi R, Constantin J, Mendes R, Oliveira R, Rios F (2020) Glyphosate-resistant sourgrass management programs combining mowing and herbicides. Planta Daninha 38:e020215928
- Rana N, Sellers BA, Ferrell J, MacDonald G, Silveira M, Vendramini J (2013) Impact of soil pH on bahiagrass competition with giant smutgrass (*Sporobolus indicus* var. *pyramidalis*) and small smutgrass (*Sporobolus indicus* var. *indicus*). Weed Sci 61:109–116
- Rana N, Sellers BA, Ferrell JA, MacDonald GE, Silveira ML, Vendramini JM (2015) Integrated management techniques for long-term control of giant smutgrass (*Sporobolus indicus* var. *pyramidalis*) in bahiagrass pasture in Florida. Weed Technol 29:570–577
- Rana N, Wilder BJ, Sellers BA, Ferrell JA, MacDonald GE (2012) Effects of environmental factors on seed germination and emergence of smutgrass (*Sporobolus indicus*) varieties. Weed Sci 60:558–563
- Regmi S, Devkota P, Sellers BA, Dubeux J Jr, Sales CAR, Mathew S, Daramola OS (2023) Bahiagrass response and smutgrass control with hexazinone coapplied with liquid urea ammonium nitrate. Page 95 in Proceedings of the 76th Annual Southern Weed Science Society Annual Meeting. Champaign, IL: Southern Weed Science Society
- Richardson MD, Brosnan JT, McCalla JH, Breeden GK (2020) Fraise mowing can improve herbicidal control of bermudagrass. Agron J 113:3789–3799
- Santos MV, Ferreira FA, Freitas FCL, Ikeda AK, Oliveira FLR, Rocha DCC, Lima JGV, Silva FNAV, Assis FGV (2008) Tolerância do Tifton 85 (*Cynodon* spp.) e da *Brachiaria brizantha* ao glyphosate. Planta Daninha 26:353–360
- Sebastian DJ, Fleming MB, Patterson EL, Sebastian JR, Nissen SJ (2017) Indaziflam: a new cellulose-biosynthesis-inhibiting herbicide provides long-term control of invasive winter annual grasses. Pest Manag Sci 73:2149–2162
- Sellers BA, Rana N, Dias JLC, Devkota P (2023) Smutgrass Control in Perennial Grass Pastures. Ona: University of Florida IFAS Extension Bulletin SS-AGR-18/AA261. 4 p
- Shaner D (2014) Herbicide Handbook. 10th ed. Champaign, IL: Weed Science Society of America. 513 p
- Shay NJ, Baxter LL, Basinger NT, Schwartz BM, Belcher J (2022) Smutgrass (*Sporobolus indicus*) control in bahiagrass is improved with applications of herbicide and fertilizer. Weed Technol 36:700–707
- Shay NJ, Baxter LL, Basinger NT, Secor WG, Burt JC, Hancock GA, Schwartz BM, Belcher J (2024) Evaluating shifts in species distribution following herbicide and fertilizer applications for smutgrass (*Sporobolus indicus*) control in bahiagrass. Weed Technol 38:1–22
- Shrestha S, Adkins SW, Graham GC, Loch DS (2003) Phylogeny of the *Sporobolus indicus* complex based on internal transcribed spacer (ITS) sequences. Aust Syst Bot 16:165–173
- Shrestha S, Graham G, Loch D, Adkins SW (2012) Molecular marker tools for identification of weedy *Sporobolus* species in Australia. Pak J Weed Sci Res 18:609–617
- Simon BK, Jacobs SWL (1999) Revision of the genus *Sporobolus* (Poaceae, Chloridoideae) in Australia. Aust Syst Bot 12:375–448
- Simpson MG (2010) Diversity and classification of flowering plants. Pages 181–274 in Simpson MG, ed. Plant Systematics. 2nd ed. Amsterdam: Elsevier
- Soreng RJ, Peterson PM, Zuloaga FO, Romaschenko K, Clark LG, Teisher JK, Gillespie LJ, Barberá P, Welker CAD, Kellogg EA (2022) A worldwide phylogenetic classification of the Poaceae (Gramineae) III: an update. J Syst Evol 60:476–521

- Takano HK, Benko ZL, Zielinski MM, Hamza A, Kalnmals CA, Roth JJ, Riar DS (2023) Discovery and mode-of-action characterization of a new class of acetolactate synthase-inhibiting herbicides. *J Agric Food Chem* 71:18227–18238
- Tasca AL, Puccini M, Fletcher A (2018) Terbuthylazine and desethylterbuthylazine: recent occurrence, mobility and removal techniques. *Chemosphere* 202:94–104
- The Plant List (2013) Version 1.1. <http://www.theplantlist.org/>. Accessed: December 2, 2025
- Vélez-Gavilán J (2022) *Sporobolus indicus* (smut grass). In CABI Compendium. <https://doi.org/10.1079/cabicompendium.117307>
- Wang H, Lin K, Hou Z, Richardson B, Gan J (2010) Sorption of the herbicide terbuthylazine in forest soils amended with biosolids and biochars. *J Soils Sediments* 10:283–289
- Wickham H (2016) *ggplot2: Elegant Graphics for Data Analysis*. New York: Springer. 260 p
- Wilder BJ, Sellers BA, Ferrell JA, MacDonald GE (2011) Response of smutgrass varieties to hexazinone. *Forage Grazinglands* 9:1–7
- Wunderlin RP, Hansen BF, Franck AR, Essig FB (2025) *Atlas of Florida Plants*. Tampa: Institute for Systematic Botany, University of South Florida. <https://florida.plantatlas.usf.edu>
- Yang X, Baskin CC, Baskin JM, Zhang W, Huang Z (2012) Degradation of seed mucilage by soil microflora promotes early seedling growth of a desert sand dune plant. *Plant Cell Environ* 35:872–883
- Yang X, Dong M, Huang Z (2010) Role of mucilage in germination of *Artemisia sphaerocephala* achenes exposed to osmotic stress and salinity. *Plant Physiol Biochem* 48:131–135
- Young JA, Evans RA (1973) Mucilaginous seed coats. *Weed Sci* 21:52–5