Review

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Review

Ecological Invasion, Impact, and Management of Johnson Grass [*Sorghum halepense* (L.) Pers.] for Sustainable Livestock Production: A Systematic Review

Sive Tokozwayo [1,*], Azile Dumani [1], Monde Rapiya [2], Wandile Mashece [3], Ayanda Kwaza [4] and Siza Mthi [5]

[1] Department of Agriculture, Döhne Agriculture Development Institute, Stutterheim, Eastern Cape, South Africa

[2] Department of Agriculture and Rural Development, Agricultural Research Services, Potchefstroom, North-West, South Africa

[3] Department of Agricultural Sciences and Game Management, Nelson Mandela University, Summerstrand, South Campus, Gqeberha, South Africa

[4] Food Security and Safety Niche Area, Faculty of Natural and Agricultural Sciences, North-West University, Mafikeng, South Africa

[5] Department of Agriculture, Queenstown, Eastern Cape, South Africa

* Correspondence: furaluke@gmail.com

Abstract

Sorghum halepense (Johnsongrass) is widely recognised as one of the most aggressive invasive perennial grasses affecting agricultural and rangeland ecosystems worldwide. Its rapid spread, ecological adaptability, and dual role as both a potential forage resource and a toxic risk to livestock present complex challenges for sustainable livestock production. Despite extensive research on its ecology and management, existing knowledge remains fragmented across multiple disciplines, limiting the development of integrated control strategies. This systematic review synthesises existing scientific evidence on the ecological invasion dynamics, origin and distribution patterns, biodiversity impacts, livestock-related risks, and management strategies associated with *S. halepense*, intending to inform sustainable livestock production systems. A systematic literature review approach was employed to identify and evaluate peer-reviewed and grey literature. Relevant studies were retrieved from major scientific databases, including Google Scholar, PubMed, and ResearchGate, using predefined search terms related to *S. halepense*, invasion ecology, livestock toxicity, and weed management. Articles were screened based on relevance, methodological quality, and thematic alignment with the objectives of the review. The findings indicate that *S. halepense* has successfully invaded diverse agro-ecological regions due to its hybrid origin, polyploid genome structure, prolific seed production, and extensive rhizome system. The species significantly alters plant community composition, reduces biodiversity, and competes with crops and native forage species. Although it may provide forage under certain conditions, its accumulation of cyanogenic compounds and nitrates poses serious poisoning risks to grazing livestock. Current control strategies, including mechanical removal, cultural practices, herbicide application, and prescribed burning, vary in effectiveness and are often limited by ecological constraints, cost, and the increasing emergence of herbicide resistance. The review highlights the need for integrated, ecosystem-based management strategies that balance invasive weed control with sustainable forage production. Future research should prioritise climate-responsive management approaches, improved understanding of invasion ecology, and the development of cost-effective control measures suitable for livestock production systems. A multidisciplinary framework integrating weed science, rangeland ecology, and animal health will be critical for mitigating the ecological and economic impacts of *S. halepense* in invaded landscapes.

Keywords: *Sorghum halepense*; invasive; biodiversity; herbicide-resistance; prescribed burning

1. Introduction

Johnson grass (*S. halepense*) is widely recognised as one of the most aggressive species, native to the Mediterranean-West Asian region. The species has become naturalised across Africa, North and South America, Europe, Asia, and Australia, invading temperate, subtropical, and tropical agroecological-ecosystems [1,2]. Its global proliferation, which was accelerated during the 18th and 19th centuries through contaminated crop seeds and unintentional introduction, illustrates a typical pattern of anthropogenic-assisted invasion into new habitats [3,4]. Johnson grass (*S. halepense*) is listed as a noxious weed in more than 50 countries, where its colonies are found in croplands, disturbed areas, riparian zones, roadsides, and rangelands, often forming dense monocultures that suppress native vegetation [5]. The expansion of Johnsongrass is driven by change of weather patterns, with global temperatures projected to rise by up to 4.5°C, along with a doubling of atmospheric carbon dioxide concentrations. Such conditions create a conducive habitat for the proliferation and enhance the competitive advantage of Johngrass [6].

Once established, the plant outcompetes native grass species by emerging earlier, growing more rapidly and producing higher biomass production than indigenous vegetation [7]. Johngrass is a hybrid derived from *Sorghum bicolor* and *Sorghum propinquum* belongs to the family *Gramineae.* This hybridisation has produced a strong perennial, rhizomatous grass that is highly adaptable in harsh environmental conditions, including both extremely low and high temperatures [8]. The combination of prolific seed production, often exceeding 70, 000 seeds per plant per season, and an extensive underground stem enables rapid colonisation, vegetative persistence, and resilience to disturbance [9]. The species exhibits broad tolerance to extreme conditions such as prolonged drought, low temperatures, and elevated atmospheric carbon dioxide concentrations. Experimental evidence indicates enhanced photosynthesis performance and biomass production under the global warming and carbon dioxide enrichment scenarios, suggesting potential poleward and altitudinal range expansion under projected climate change. Its early seasonal emergence, rapid canopy development, and high resource-use efficiency allow it to outcompete native perennial grasses [9]. As global temperatures are projected to rise significantly over the coming decades, climatic suitability models predict further expansion of Johnsongrass [10,11].

Despite growing recognition of Johnsongrass as an aggressive species, its ecological, agricultural, and livestock-related implications remain insufficiently synthesised in the scientific literature. Due to its extensive rhizome network (underground stems) and high seed production, its eradication is challenging. Consequently, its control requires an integrated strategy [5]. Therefore, this review aimed at providing a systematic evaluation of published literature on the botanical description and ecological characteristics, origin, distribution patterns, impact of biodiversity and livestock, and control measures of *S. halepense.*

2. Materials and Methods

This review was conducted following a systematic literature review approach guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) principles to identify and evaluate the published literature on the *Sorghum halepense* species, as illustrated in Figure 1. Peer-reviewed scholarly and grey literature were identified and obtained using several search engines such as Google Scholar, PubMed, Research Gate, Scopus, Science Direct, institutional repositories, and other relevant websites as a source of secondary data. Access to these databases was provided by the Dohne Agriculture Development Institute (DADI) online library.

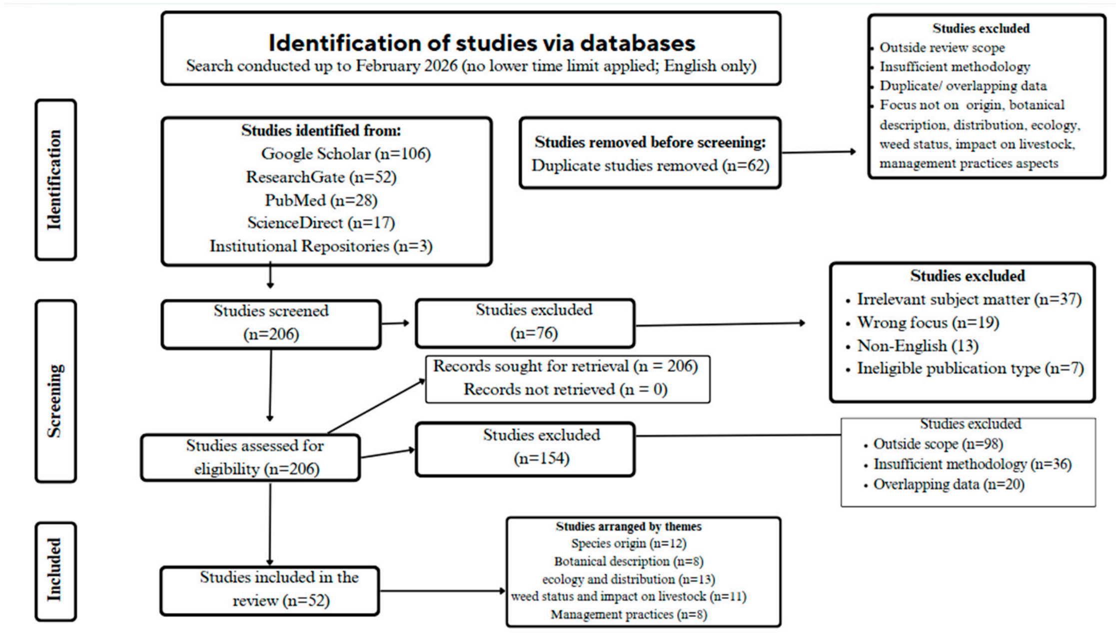

Figure 1. PRISMA diagram-flow showing the screening and selection process for studies included in this review.

The following search strings were applied using keywords such as: "*Sorghum halepense*" or Johnsongrass plant origin, botanical characteristics, distribution, ecological impacts, impact on livestock and management practices. No time limit was applied, and studies published up to the year 2025 were included. However, only English-language sources were considered due to feasibility. Only peer-reviewed articles, theses, dissertations, and government reports, including non-government organisation (NGO) reports addressing Johnson grass origin, botanical classification, distribution, ecological impact, and its impact on agriculture and livestock, were included.

In addition, media reports, opinion pieces, and publications with insufficient methodological details were not considered for this review. The initial search had an outcome of 208 published articles, with 62 duplicates. The duplicates were removed, and the remaining (*n*=146) were further screened by their topics, keywords, and abstracts, and their relevance; 76 articles were further omitted at this stage. From the remaining 70 full-text articles that were reviewed, 18 did not meet the inclusion criteria and were excluded. The main reasons for exclusion were: (i) studies that were outside the thematic scope of this review (for example, papers focused solely on ornamental use), (ii) publications with insufficient methodological detail or evidence, (iii) Overlapping data across different sources, and (iv) studies where the primary focus was unrelated to the scope of this review.

After applying these criteria, 52 articles were retained for the final synthesis and were mentioned in the article bibliography. From the 52 publications, the author(s), year, region, key research focus and major findings were extracted. The extracted information was grouped thematically into six domains: Plant origin, botanical description, distribution, ecology, weed status, impact on livestock, and management practices. A narrative synthesis approach was applied to compare findings, highlight contradictions, and identify knowledge gaps. Potential biases include restricting the review to studies published in English, which was inevitable, and may have excluded relevant works published in other languages.

3. History and Origin of Johnsongrass

The genus sorghum is an economically important member of the *Gramineae* plant family in the *Andropogoneae* tribe, together with maize (Zea mays), sugarcane (Saccharum spp.), and the millets [12]. This genus is divided into five subgenera, namely Chaetosorghum, Eu-Sorghum, Stiposorghum, Parasorghum, and Heterosorghum [13]. Twenty-five species within the genus Sorghum are distributed across these five subgenera [13,14]. The subgenus Eu-Sorghum comprises two well-

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known rhizomatous weed species, namely *S. halepense* (L.). Pers. and *Sorghum propinquum* (Kunth.) Hitchc., including the cultivated species known as *Sorghum bicolor* [14].

[15] highlighted that the species *S. bicolor* and *S. propinquum* are found in the Primary Gene Pool (GP-1), which contains both cultivated and wild species. The natural crossbreeding between these two species resulted in *Sorghum halepense*, a wild species adapted to and native to warmer regions in the Mediterranean areas of Africa and Asia [14]. Hence, several studies reported that *S. halepense* is a naturally hybrid between *Sorghum bicolor* (L.) Moench, an annual, polytypic African species that includes cultivated sorghum, and *Sorghum propinquum* (Kunth) Hitchc., a perennial Southeast Asian species of warm and humid environments [2,14,16]. However, the ancestors of *S. halepense,* namely *S. bicolor* and *S. propinquum, are* believed to share a common ancestor, with an estimated divergence of around 2 million years [17]. In contrast to *S. propinquum,* substantial archaeological evidence suggests that the cultivation and domestication of *S. bicolor* in the central Sahara area 7500-7100 BC and its widespread use as an important crop in Asia and India between 4000-3500BC.

4. Botanical Classification and Description of Johnsongrass

Sorghum halepense (L.) Pers. commonly known as Johnson grass is a perennial grass species in the Gramineae or Poaceae family [18]. Gramineae is a family of grass species, the fifth-largest plant family, in the order of Poales, with a distinct floral arrangement as shown in Figure 2 [19]. Gramineae is a highly economically important cosmopolitan plant family, comprising monocotyledonous flowering plants (grasses) and encompassing approximately 780 genera with almost 12,000 species [20]. The grass family is mainly annual or perennial herbaceous, rarely shrubby; however, comprise some woody plants, including sorghum (cereals), bamboo, reeds, and sugarcane [21]. Johngrass (*S. halepense*) is a naturally occurring hybrid produced between *Sorghum bicolor* (L.) Moench and *Sorghum propinquum* (Kunth) Hitchc [2].

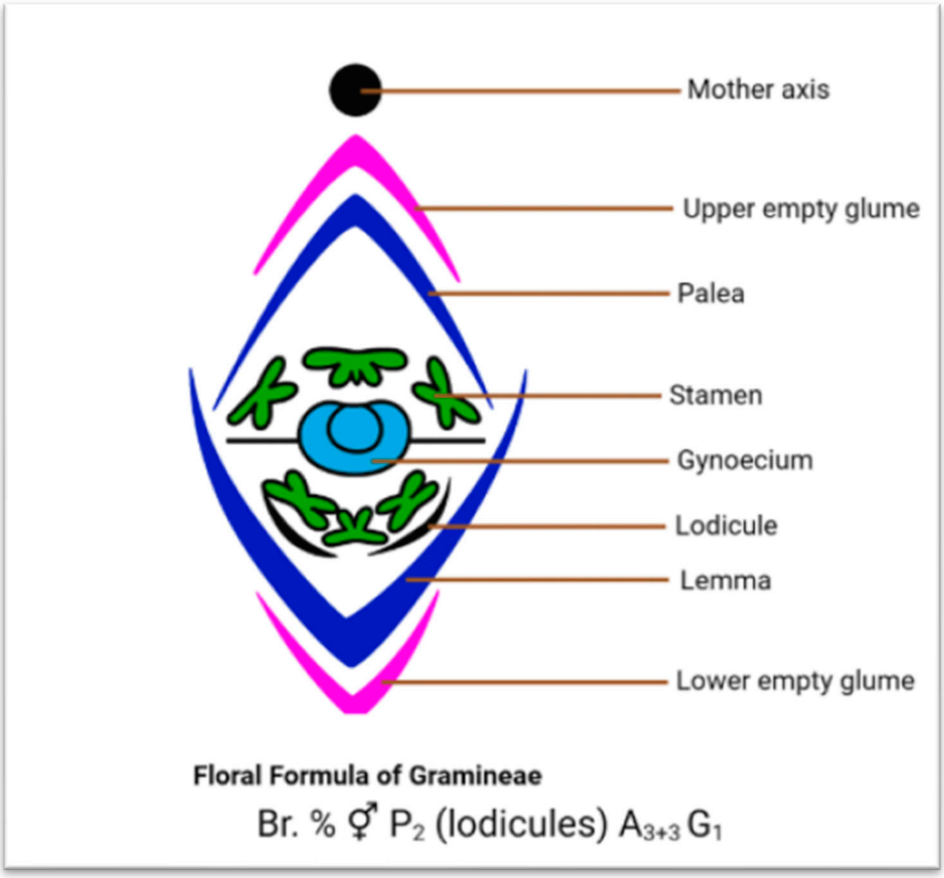

Figure 2. Schematic diagram of the floral structure and formula of the Gramineae family [18].

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Johnsongrass (*S. halepense*) is a narrow-leaved perennial grass with adult plant develop a distinct morphology, reaching up to 2.5m in height and 0.5m -2.0cm stems diameter, often rooting from the nodes with the internodes partially covered with brown scale-like sheaths [22]. The plant has broad leaves that are veined with a prominent white midrib, which can grow up to 60cm in length and 3.3 cm in width [23]. Its inflorescence is a large, erect panicle, at first compact, later spreading, and open, pyramidal, purplish, and hairy panicle that grows up to 50 cm long and 20 cm wide [24,25]. The ovary apex is glabrous; styles are free to the base and yellow, pink, red, purple, or black [26]. When mature, the plant produces an open, purplish panicle (seed head), as shown in Figure 3 [17]. Below-ground stems develop an extensive subterranean rhizome network, which can account for up to 70% of the plant's dry weight [18].

Figure 3. Pictorial representation of Johnsongrass (*S. halepense*) in Eastern Cape communal rangelands [27].

5. Distribution and Spread of Johnson Grass (S. halepense)

Sorghum is a tropical grass grown mainly in Mediterranean parts of the world [28]. Johnsongrass, originating from the Mediterranean regions of Africa and Western Asia, is currently a widespread species with a global footprint [29]. Thus, the species can be found throughout Asia, Africa, Europe, North and South America, and Australia [30]. In Africa, the plant mainly grows throughout West Africa south of the Sahara, to the coast and eastward in Sudan, Ethiopia, and Somalia [30]. Johnson grass is an important livestock fodder in Uganda, Kenya, Tanzania, Rwanda, Burundi, Zambia, Malawi, and the drier areas of Mozambique [29]. In South Africa, *S. halepense* is gradually spreading across the country, particularly in the Western Cape, Gauteng, KwaZulu-Natal, Mpumalanga, Limpopo, and Eastern Cape provinces [31]. In addition, the plant has been identified and is predominantly found in the Buffalo City Metropolitan (BCM), Ndlambe, and Raymond Mhlaba Local Municipalities in the Eastern Cape Province, South Africa.

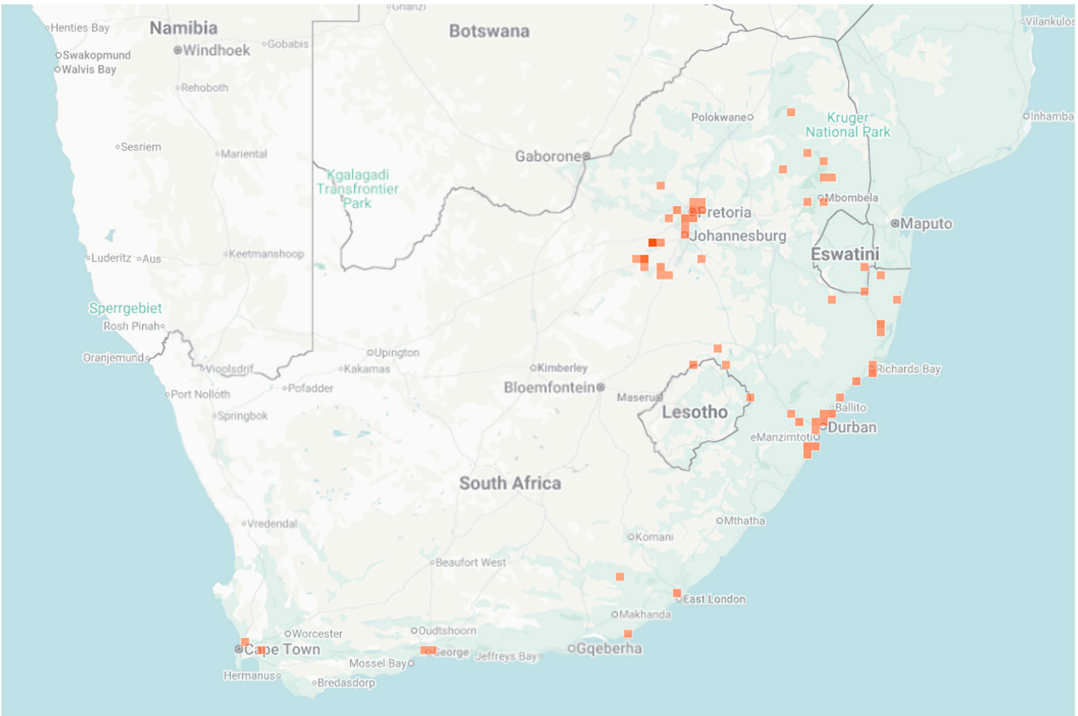

Figure 4. Distribution of *S. halepense* in South Africa [27].

6. Ecological Invasion and Impact of Johnsongrass (S. halepense) on Rangeland Biodiversity

Grasses are typically categorised into annual and perennial species depending on their lifecycle [32]. Thus, annual grasses complete their life cycles in a single year and remain part of the time as seeds [33]. While perennial grasses are long-lived and can survive repeated fires and grazing pressure, they are also capable of spreading through vegetative as well as seed reproduction [34]. These differences are valuable in an ecological sense, as the impacts and potential control strategies would differ for these two broad types. *S. halepense* is a highly reproductive monoecious (self-fertilisation) species producing approximately thousands of seeds per plant in one growing season, which can be viable for up to a decade in the soil [35]. This seed dormancy period substantially enhances its invasiveness and complicates management and eradication efforts [24]. Johnson grass demonstrates a wide range of germination responses at varying soil depths, with nearly 64% at a 1cm depth, decreasing to 30% at 20 -25 cm soil depth [17]. Likewise, the rapid seed germination has led to a high density of S. halepense, resulting in a severe loss of plant diversity, impacting the ecology negatively [36]. Furthermore, its seeds can rapidly establish easily in rangeland and agricultural fields, where they grow more effectively than C4 prairie plants, displacing the indigenous flora diversity [29]. The seeds' dispersal is aided by water, wind, livestock, commercial seed contamination, and contaminated machinery [34].

The vegetative reproduction of Johnsongrass is through the rhizomes, which regenerate easily from small pieces and can grow or remain dormant in a variety of environmental conditions [35]. The enormous, fast-growing rhizome system gives this grass a competitive advantage, allowing it to form dense colonies, displacing desirable vegetation, and restricting tree seedling establishment. Its ecological impact has been evident in soil nutrition, soil temperature, and water content, leading to a C3 species decrease as well as a C4 group biomass increase [26].

At maturity, Johnson grass has a higher leaf area, which is a host of numerous pests, nematodes, and fungal pathogens for annual crops such as the sorghum midge and leaf spot diseases [32]. As such existence of this plant in rangelands poses an increasing invasion risk, threatens agriculture, economic development, and human health [35]. Johnsongrass occurs in temperate, subtropical, and tropical regions where it frequently occurs in ditches, field borders, cultivated lands, waste places,

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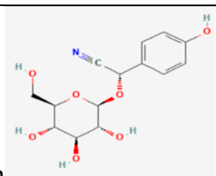
roadsides, other rights-of-ways, creeks, canal banks, and prairies. The plant survives under different conditions, and it usually grows in ditches, field boundaries, cultivated areas, wastelands, roadsides, streams, and canal banks [19].

Land users and researchers have different views regarding the abundance and distribution of S. halepense in grazing lands [36–38]. These varying views can influence the management strategies of S. halepense. This species can provide relatively high nutritional quality forage, with crude protein ranging from 10% to 14% and total digestible nutrient values varying between 55% to 60%. Such nutritional characteristics make the plant a potentially valuable feed resource for livestock, especially during the dry season [39,40]. The comparatively high protein and energy content may improve voluntary intake and animal performance during drier seasons when natural grasses exhibit lower nutritional quality. Nonetheless, the potential nutritional benefits of this species should be considered in the context of this invasive trait and the management challenges it presents, including replacement of native grasses, reduced biodiversity, and increased control expenses. Because of relatively high nutritional benefits and acceptability, cattle often prefer to graze Johnsongrass. Intensive and repeated grazing pressure can weaken the plant, reduce its competitive ability, and in some instances, lead in mortality of individual plants [41]. Moreover, this grass strongly competes with native grasses for soil resources, including water and soil nutrients [24]. Attributed to its greater height and vigorous growth habit, the plant gains a competitive advantage by intercepting sunlight before it reaches the underlying grass layer [38]. This shading effect reduces light availability to shorter grasses, thereby suppressing their growth and regeneration [28]. Consequently, the invasion of this species can lead to reduced native species diversity, decreased rangeland productivity and a decline in plant diversity and ecosystem functioning [42].

7. Impact of Johnsongrass (S. halepense) on Livestock

Johnsongrass contains high concentrations of nitrate and prussic acid (commonly known as hydrocyanic acid), particularly during early stages and following specific climatic events such as first frost or first rain after prolonged drought [43]. Hydrocyanic acid is formed when the Glucosides (sugar compounds) break down in the rumen, freeing the cyanide from the sugar [44]. In addition, Nitrate poisoning in livestock occurs when accumulated nitrates in the plant material are converted to nitrite in the rumen [45]. Subsequently, when Hydrocyanic acid combines with haemoglobin, it creates cyanglobin, which does not carry oxygen [46]. Similarly, nitrate is normally absorbed into the bloodstream and can interfere with oxygen transportation, resulting in clinical symptoms of toxicity [47]. Because methaemoglobin is unable to transport oxygen effectively to body tissues, ruminant animals die from oxygen insufficiency [40]. High concentrations of prussic acid interfere with oxygen supply; an animal may die from asphyxiation within a few minutes when a lethal dose of prussic acid is consumed [48]. Typical symptoms of toxicity include increased respiratory rate, excessive salivation, muscular tremors, and loss of coordination manifested as staggering. In advanced cases, the affected animal may collapse and die suddenly [49]. The risk associated with Johnsongrass to grazing livestock increases during drought conditions, after intensive grazing and trampling, and following frost events, when plants may accumulate higher levels of toxic compounds and produce rapid regrowth. Johnson grass associates with plants that produce prussic acid are listed in Table 1 below.

Table 1. Different plant families, plant sources and types of Cyanogenic Glycosides.

Plant family	**Scientific name of the plant**	**Type of Cyanogenic glycoside**	**Concentration level**	**References**
Gramineae	*Sorghum helepense & bicolor* species	Dhurin 	High	Emendack et al. (2025). Deen *et al*, (2018).

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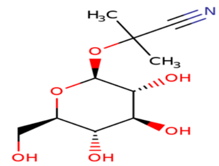
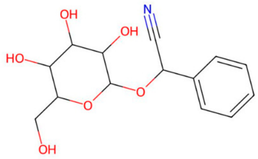
Fabaceae	*Phaseolus vulgaris*	Linamarin 	High	Alcázar-Valle *et al*. (2020).
Rosaceae	*Prunus amygdalus*	Prunacin 	High	Amjadian *et al*. (2020).

Furthermore, the toxic dose of Hydrocyanic acid leading to death in livestock such as cattle and sheep is approximately 2.0mg/kg of body weight [50]. However, the tolerance levels are displayed in Table 2 below.

Table 2. Livestock tolerance to levels of hydrocyanic acid in feed (dry matter basis) [adapted from [51].

Hydrocyanic acid (ppm)	Effect on livestock
Less than 500	Considered safe
500 -750	Slightly toxic, should not be the only source of feed to livestock
>750	Toxic and will cause animal death.

8. Management and Control of Johnson Grass

8.1. Mechanical Control Method

Johnsongrass (*S. halepense*) may be controlled using mechanical control methods such as hand uprooting and mowing. Uprooting and mowing may reduce the aboveground foliage, limit seed production, and prevent seed spread. These practices weaken the plant by reducing its ability to photosynthesise and store energy in its rhizomes [52]. When mowing and uprooting are applied at the right time and appropriate growth stages, mechanical control can contribute to lowering the density of Johnsongrass [53]. Mowing alone may not be an effective control method because the plant produces extensive underground stems known as rhizomes. Furthermore, mowing can be highly costly for communal farmers, as it needs specialised machinery [54]. These underground stems enable the plant to store reserves and regenerate after the aboveground parts have been cut. Although mowing can reduce plant height and seed production, the plant is capable of re-sprouting from the underground stems (rhizomes). Therefore, integration of mechanical practices with other management strategies, such as chemical and burning methods, is often needed to effectively suppress the growth and spread of Johnsongrass [55,56].

8.2. Integrated Methods (Ploughing and Burning)

This practice involves turning the soil to disturb and expose underground stems, which helps expose and remove the underground stems from the soil. Bringing roots to the surface, they may dry out and reduce their ability to regenerate. Deep ploughing is applicable in cultivated croplands rather than in rangelands. Therefore, ploughing should be carefully timed and integrated with other management practices to improve the effectiveness of controlling Johnsongrass. However, ploughing can be very expensive for resource-poor farmers, as it requires the use of specialised machinery [57].

In rangelands, deep ploughing can severely disturb the natural vegetation cover, damage desirable perennial grasses, and accelerate soil erosion. One of the principles of rangeland management is to maintain stable soil structure and vegetation cover; therefore, an intensive soil disturbance approach is not suitable for rangelands. Due to fast growth and high biomass production (fuel load) of Johnsongrass, particularly in warmer and drier climatic conditions, prescribed burning may help suppress the aboveground vegetation. Application of carefully planned prescribed burning can serve as an effective strategy for controlling Johnson grass (*S. halepense*) [58].

8.3. Chemical Control Method

Johnsongrass (*Sorghum halepense*) has shown extreme resistance to some herbicides; for example, Johnsongrass was found to be resistant to glyphosate in a study conducted in Argentina [59]. Given the genetic relationship of Johnsongrass to *Sorghum bicolor*, chemical control of Johnsongrass is difficult, as chemical applications could directly affect native species and create more herbicide-resistant strains [60]. [61] reported that up to 32% of common *Sorghum bicolor* alleles were identified in Johnsongras species. This confirmed that the acquired herbicide-resistance gene can be transferred and widely spread [62]. Johnsongrass may be able to be controlled using acetolactate synthase -inhibiting herbicides like sulfosulfuron, nicosulfuron, primisulfuron or imazapic-acetyl-CoA carboxylase-inhibiting herbicides such as clethodim or sethoxydim or 5-enolpyruvylshikimate-3-phosphate synthase inhibitors like glyphosate [63–65]. [66] reported that appropriate use of these herbicides has shown an 88% to 97% efficacy rate; however, repeated herbicide use can create resistance. In addition, there is a growing concern that Johnsongrass may emerge as a superweed due to the increased likelihood of herbicide-resistant genes transferred among sorghum species, including Johnsongrass [17]. Recently, [67] reported that applying tembotrione at 100 g/ha as a postemergence treatment (15-20 DAS) may significantly reduce the density of *Sorghum halepense* but may also negatively impact other species.

9. Conclusion

Sorghum *halepense* is one of the most aggressive invasive weeds worldwide. Originating from hybridisation between Sorghum bicolor and Sorghum propinquum, the species possesses strong adaptive traits that enable it to thrive across diverse environments. Its rapid growth, prolific seed production, and extensive rhizome system allow it to spread quickly and dominate croplands and rangelands across Africa, Asia, Europe, and Australia. As a result, it suppresses native vegetation, reduces plant biodiversity, and alters ecosystem functioning through strong competition for water, nutrients, and space. Although *S. halepense* can produce substantial forage biomass, its benefits are limited by the risk of livestock poisoning due to nitrate and hydrocyanic acid accumulation, particularly under stress conditions. Managing this species remains challenging because of its reproductive versatility and strong regenerative capacity. Mechanical control can reduce aboveground biomass but is often ineffective alone due to underground rhizomes, while deep ploughing is unsuitable for rangelands. Prescribed burning and chemical control may provide additional options, although herbicide resistance and high costs limit their effectiveness, especially for resource-poor farmers. Future research should focus on developing cost-effective, integrated management strategies, improving early detection and monitoring systems, and enhancing understanding of the species◎ecological responses to climate change. Such efforts are essential to limit the spread of *S. halepense* and protect rangeland biodiversity, agricultural productivity, and livestock health.

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Conflicts of Interest: The authors declare no potential interest.

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