www.cambridge.org/wsc

Review

Cite this article: Schantz MC (2025). Johnsongrass (*Sorghum halepense*): a review of its invasion, management, and spread in the changing climate of the Southern Great Plains. Weed Sci. **73**(e31), 1–7. doi: 10.1017/wsc.2025.7

Received: 3 December 2024 Revised: 29 January 2025 Accepted: 3 February 2025

Associate Editor:

William Vencill, University of Georgia

Keywords:

Biological control; climate change; herbicides; invasive species; mechanical control; tallgrass prairie

Corresponding author: Merilynn Schantz; Email: merilynn.schantz@usda.gov

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-NonCommercial-NoDerivatives licence (https:// creativecommons.org/licenses/by-nc-nd/4.0/), which permits non-commercial re-use, distribution, and reproduction in any medium, provided that no alterations are made and the original article is properly cited. The written permission of Cambridge University Press must be obtained prior to any commercial use and/ or adaptation of the article.

© The Author(s), 2025. Published by Cambridge



Johnsongrass (*Sorghum halepense*): a review of its invasion, management, and spread in the changing climate of the Southern Great Plains

Merilynn C. Schantz¹ 💿

¹Rangeland Research Scientist, USDA, Agricultural Research Service, Grassland Soil and Water Research Laboratory, Temple, TX, USA

Abstract

Johnsongrass [Sorghum halepense (L.) Pers.], an invasive tallgrass, actively inhabits grassland ecosystems of North America. The grasslands ecoregions of the Southern Great Plains are particularly susceptible to *S. halepense* invasion and dominance because of its preferential growth in continental climate zones coupled with its ability to readily colonize recent disturbances associated with declining livestock grazing and anthropogenic energy and housing development. Controlling *S. halepense* via chemical or mechanical inputs can reduce this plant species' abundance temporarily, but are typically followed by *S. halepense* reestablishment. *Sorghum halepense* does, however, provide high-quality forage and appears to withstand the frequent drought and flooding events associated with climate change in Southern Great Plains ecosystems. In this review, the benefits and drawbacks of *S. halepense* in Southern Great Plains grassland ecosystems are discussed and areas where research on this species could be expanded are identified.

Introduction

Johnsongrass [Sorghum halepense (L.) Pers.], a tussock grass from northern Africa and central Asia, actively inhabits grassland ecosystems of North America (Klein and Smith 2021; Paterson et al. 2020; Figure 1). Feltus et al. (2004) suggested that S. halepense is a naturally occurring hybrid between two sorghum species: Sorghum bicolor (L.) Moench, an annual, polytypic African species, which includes cultivated sorghum, and Sorghum propinquum (Kunth) Hitchc., a perennial southeast Asian native of moist habitats (Celarier 1958; Doggett 1976; Paterson et al. 1995). Currently, S. halepense can be found throughout much of Asia, Africa, Europe, North and South America, and Australia (McWhorter 1971). In the United States, S. halepense was initially planted as a forage hay crop (Bennett 1973). As on other continents, however, S. halepense escaped cultivation and spread throughout every U.S. state except for Alaska, Maine, and Minnesota; as far north as Canada; and as far south as Argentina (Hickman et al. 2018; USDA-NRCS 2023; Warwick et al. 1986). Clements and DiTommaso (2012) suggested that the ability of S. halepense to advance longitudinally and establish in regions that were once considered uninhabitable for this species is derived from wide climatic and environmental tolerance, a relatively short generation time, effective forms of reproduction and dispersal, and competitive ability that allows for colonization in numerous environments (Holm et al. 1977; Warwick and Black 1983). Consequently, S. halepense has, for more than a century, been a common weed in cultivated agricultural systems (Heard 1917; Monaghan 1979; Schwinning et al. 2017; Squires and Walsh 2021; Vinall 1921).

The dominance of S. halepense in intact grasslands is a relatively recent occurrence largely due to changes in land management associated with declining livestock grazing, increased energy development (renewable and fossil fuel), and anthropogenic housing development (Klein and Smith 2021; Paterson et al. 2020; Rocateli and Manuchehri 2017). The Southern Great Plains are particularly susceptible to S. halepense because of a preferential climate coupled with rapid land use disturbances (Lakoba et al. 2021; Omernik and Griffith 2014). Barney and DiTomaso (2011) found that S. halepense growth has a 50% to 90% climatic match between all 20 designated ecoregions of the continental United States and was greatest in the plains and prairies. The Great Plains, notably the Southern Great Plains, are also increasingly fragmented due to commercial land development for housing or energy development from windmills, solar farms, or oil and gas production (de Castro and Zenteno 2023; Engle et al. 2008; Scholtz et al. 2018). Land fragmentation creates vulnerability to weed invasions by increasing the number of successful sites for weed seedling establishment (Aicher et al. 2011; Duncan et al. 2009) and supporting seed transport along these recent disturbances, like along roadways (Grman et al. 2015; McConkey et al. 2012); once these species are in the seedbank, established seedlings of invasive species commonly outcompete native species by growing earlier and at higher densities than native plant species (Reid and Holl 2013; Yelenik and D'Antonio 2013). In addition,





Figure 1. Johnsongrass [*Sorghum halepense* (L.) Pers.] diagram and associated distribution map. Illustration by Chris J. P. Grisham and map from USDA-NRCS PLANTS database(USDANRCS2023).

livestock grazing has been decreasing in the Southern Great Plains, as moving livestock among smaller and fragmented paddocks is difficult for producers, while neighboring subdivisions can prove to be problematic neighbors for livestock operations (Brunson et al. 2016; BurnSilver and Mwangi 2007). Some might argue that *S. halepense* would be a preferential weed to eliminate from these systems, as it can outcompete many physiologically similar native tall grasses (Schwinning et al. 2017); others see benefits in *S. halepense*, especially for grazing livestock, as this species can provide high-quality forage throughout the grazing season (Rocateli and Manuchehri 2017; Watson et al. 1980). The objective of this review is, therefore, to provide a background of *S. halepense* invasion and discuss the benefits and drawbacks of this grassland invader in the Southern Great Plains.

Sorghum halepense Growth and Plant Community Characteristics

Sorghum halepense spreads through the rapid development of rhizomes and prolific seed production (McWhorter 1961; Ryder

et al. 2018; Tóth and Lehoczky 2006). It has been shown to produce approximately 100 m of rhizomes per plant each year that are able to withstand subzero winter temperatures with a survival rate of up to 71% (Anderson et al. 1960; Johnson et al. 2003). These rhizome networks can also account for up to 70% of the entire plant dry weight (Paterson et al. 2020). As a self-pollinating plant, *S. halepense* produces up to 80,000 seeds per plant in a single season that can remain viable for up to 10 yr in the soil (Dweikat 2005; McWhorter 1961). *Sorghum halepense* also has a broad seed depth germination rate ranging from 64% at 1 cm-depth to 30% at 20-cm depth, and up to 6% of its seeds can germinate from depths as great as 25 cm (Tóth and Lehoczky 2006).

Once established, S. halepense creates a feedback cycle whereby it can outcompete many native perennial grass species by growing earlier and faster and having higher biomass than functionally similar native perennial grasses (Kelly et al. 2020; Schwinning et al. 2017). Reichmann et al. (2016), for example, reported that during early development, S. halepense plants gained up to 4-fold more biomass than the North American prairie grasses switchgrass (Panicum virgatum L.), little bluestem [Schizachyrium scoparium (Michx.) Nash], and big bluestem (Andropogon gerardii Vitman) within the first 17 d of growth, largely due to increased leaf area, higher atmospheric carbon uptake, and photosynthetic nitrogenuse efficiency. Schwinning et al. (2017) also found that when S. halepense was grown with these same warm-season (C₄) tallgrass species in a greenhouse experiment, native perennial grasses had 95% less biomass compared with when they were grown alone, while S. halepense only lost 11% of non-root biomass.

Response to Climate Disturbances

Extreme climate disturbances, like drought and freezing conditions, are increasing in frequency across the Southern Great Plains (Ojima et al. 2020). Current climate change projections suggest that these climatic extremes will likely become a regular occurrence in the future (Knapp et al. 2020; Lakoba et al. 2021). Clements et al. (2022) further suggest that *S. halepense* will likely expand longitudinally (north and south) due to higher global temperatures at northern and southern latitudes.

Long-term and large-scale research sites are likely the best place to evaluate historical climate effects, as other site-specific data, like plant production and management strategy, typically have an associated recorded history. For this effort, the previous 32 yr of precipitation data at six long-term rangeland research sites in the Southern Great Plains were acquired to gain a better understanding of the dynamic precipitation in these areas. Historical climate data, including precipitation and temperature, were acquired from the gridMET database (https://webapps.jornada. nmsu.edu/weather; Abatzoglou 2013) for the years 1990 to 2022. The six long-term research sites included USDA-Agricultural Research Service sites in Woodward, OK (36.3745°N, 99.2455°W), El Reno, OK (35.5335°N, 97.9549°W), Riesel, TX (31.4755°N, 96.9247°W), and Temple, TX (31.0982°N, 97.3428°W), and research sites associated with Oklahoma State University in Pawhuska, OK (36.6634°N, 96.3410°W) and Texas A&M University in LaCopeda, TX (27.66661°N, 98.20892°W). An ANOVA on the differences in average daily precipitation (mm) at these six sites across the years of 1990 to 2005 and again from 2005 to 2022 was then run using JMP (SAS Statistical Software © 2022, SAS Institute, Cary, NC). Results on precipitation trends from 1990 to 2005 indicate that only 2004 had significantly higher precipitation compared with all other years, and this was only at



Figure 2. Historical average daily precipitation (mm) \pm SE for the years of 1990–2020 across six long-term Southern Great Plains grassland research sites to demonstrate the variation in precipitation from 1990 to 2005 and from 2005 to 2020. Sites are all colocated at long-term plant production monitoring regions in the Southern Great Plains. P-values refer to one-way ANOVA models of year by average daily precipitation, where P < 0.05 refers to a significantly different relationship and P > 0.05 indicates no significant differences in precipitation across years.

the Riesel and Temple, TX, sites; all other sites and years were similar. Drought and flooding had become more frequent for the years 2005 to 2022, where four of the six sites had significantly different precipitation across years, and one site was moderately significant (Pawhuska, OK; P = 0.0596). Across all significant sites, from 2005 to 2022, 2011 was significantly lower and 2015 had significantly higher precipitation (P < 0.05; Figure 2). Collectively, these results indicate that precipitation is becoming more dynamic in recent years, and dynamic precipitation fluctuations will likely facilitate plant species that can withstand these perturbations, which often are plant species with rapid adaptation mechanisms.

Sorghum halepense appears to be well suited to adapt to these changing climate conditions. This is partially because *S. halepense* seeds quickly adapt to modified temperature and water environments (Fletcher et al. 2020). Its physiologically adaptive climate traits, as described earlier, especially in comparison to native species growing in these ecosystems, may result in *S. halepense* becoming a widespread species of concern (Schwinning et al. 2017). Currently, however, there are limited and/or hypothetical expectations on how species and plant communities within ecosystems respond to dynamic climatic cycles like these (Briske et al. 2015; Knapp et al. 2020; Polley et al. 2012, 2019).

Chemical Control of Sorghum halepense

Sorghum halepense is extremely resistant to herbicides (Heap 2012). This is because herbicide-sprayed *S. halepense* plants can cross within selfing populations, store genetic variation in seedbanks, and evolve phenotypic plasticity (Clements et al. 2004). In 2002, for example, a glyphosate-resistant biotype was discovered in Argentina that covered 10,000 ha (Binimelis et al. 2009). Moreover, given its historical link to *S. bicolor* species and strong ability to cross with *S. bicolor*, chemical control of *S. halepense* near *S. bicolor* crops is extremely difficult, as chemical applications could directly affect *S. bicolor* production and potentially create more herbicide-resistant strains of *S. halepense* (Tang and Liang 1988; Warwick and Black 1983). In Texas and Nebraska, for example, Morrell et al. (2005)

reported that up to 32% of unique S. bicolor alleles were identified in S. halepense populations adjacent to long-term S. bicolor production sites. The evidence strongly suggests that engineered genes and herbicide resistance could potentially be transferred into S. halepense and widely disseminated (Morrell et al. 2005). Presently, susceptible S. halepense plants may be able to be controlled using acetolactate synthase-inhibiting herbicides like sulfosulfuron, nicosulfuron, primisulfuron, or imazapic; acetyl-CoA carboxylase-inhibiting herbicides like clethodim or sethoxydim; or 5-enolpyruvylshikimate-3-phosphate synthase inhibitors like glyphosate (McCollough and Shilling 2022). Appropriate use of these herbicides has been shown to result in an 88% to 97% efficacy rate (Johnson et al. 2003). Repeated herbicide use can, however, create herbicide resistance. Hernández et al. (2015), for example, ascertained that recurrent nicosulfuron application to seedling- and rhizome-emerged S. halepense has created resistant S. halepense biotypes with 33 to 46 times higher herbicide resistance than susceptible control plants. Similarly, S. halepense has also shown glyphosate resistance, likely in part because glyphosate has evolved as a preferred herbicide, with more than 8.6 billion kg sold since 1974, coupled with S. halepense's adaptive phenology (Baylis 2000; Benbrook 2016; Fernández et al. 2013; Heap and Duke 2018; Vila-Aiub et al. 2007). Presently, there is an agenda to reduce synthetic herbicide applications, notably glyphosate, as many of these products have recently been identified as carcinogens (IARC 2017; Tarazona et al. 2017; Williams et al. 2016).

Biological Control of Sorghum halepense

Biological control can be an ecologically viable way to tackle weed invasions (McFadyen 1998; Zachariades et al. 2017). Classical biological control includes introducing host-specific, coevolved natural enemies (biological control agents) from a weed's native range to the introduced range to keep the invasive species under control (McFadyen 1998). Historically, however, few invasive grasses have been targeted for biological control (Pemberton and Lee 1996; Schwarzländer et al. 2018). This is likely because there are

Schantz: Sorghum halepense in the Plains

few coevolved enemies of grasses that are host specific (Gill and Blacklow 1984; Pemberton 2002). Witt and McConnachie (2004), for example, noted that in Australia, the biggest obstacle to the biological control of invasive dropseed species (*Sporobolus* spp.) is that there are 13 native *Sporobolus* spp., which will largely govern which agents can be selected for biocontrol. Given the high risk of non-target damage posed to economically valuable crops, like *S. bicolor*, and/or native biodiversity, it is unlikely that biological control will be a practical control mechanism for *S. halepense* in U.S. grasslands (Sutton et al. 2019; Wapshere 1990). Targeted grazing, alternatively, may be a viable control method, as *S. halepense* used as forage can provide multiple socioeconomic benefits to producers that, managers suggest, compensate for negative ecological effects.

Mechanical Control of Sorghum halepense

It has been suggested that S. halepense spread can be well controlled using mechanical inputs like hand weeding, mowing, or tilling (Arle and Everson 1955; Ceseki et al. 2017; Heard 1917; Johnson et al. 2003). Mechanical control is, however, only a temporary fix in most perennial grassland regions, as hand weeding and tillage are impractical in large-scale perennial grasslands, and frequent mowing can deplete carbohydrate reserves of all species, even favoring the invaders (McCollough and Shilling 2022; Simberloff et al. 2012). Entsminger et al. (2017), for example, suggested that frequent mowing (four times per year) produced lower native species abundance along native seeded roadways compared with mowing only once per year or onetime mowing events accompanied by additional seedings of desirable species. Consequently, while mechanical control may not be an effective means to eliminate S. halepense, using mechanical control to reduce weed abundance before seeding desirable species that can fill the niches once occupied by weed species may be an effective ecologically based management strategy.

Sorghum halepense in Rangelands and Pasturelands

Land managers hold conflicting views of S. halepense on native rangelands and introduced pasturelands (Bennett et al., 1973; Hawkins et al. 1958; Rankins and Darrell 1995; Rocateli and Manuchehri 2017). S. halepense provides quality forage with approximately 10% to 14% crude protein and 55% to 60% total digestible nutrients and is preferred by large-mouth herbivores, like horses and cattle, across grassland ecosystems (Bennett et al., 1973; Watson et al. 1980). Cattle show a strong grazing preference for S. halepense and have been known to kill S. halepense plants by overgrazing this species (Andrae 2009; Sherrill 1947). However, S. halepense can contain high amounts of nitrate and prussic acid, also known as hydrocyanic acid, during early life-history stages and following distinct climactic events, like first frost or first rain after prolonged drought (Harris and Shearer 2003; Selk 1988; Slade 1903; Vinall 1921). Nitrate poisoning occurs when accumulated nitrates in the plant material (primarily plant stems) are converted to nitrite in the rumen (Selk 1988). Nitrite is absorbed from the rumen and converts blood hemoglobin to methemoglobin. Because methemoglobin cannot transport oxygen to body tissues, ruminant animals die from oxygen insufficiency (Selk 1988). Prussic acid, alternatively, interferes with oxygen use at the cellular level (Vinall 1921), and animals generally die from asphyxiation within a few minutes when a lethal dose of prussic acid is consumed (Harris and Shearer 2003; Selk 1988; Slade 1903; Vinall 1921). Recommendations from both

researchers and land managers on the best way to manage high nitrate and prussic acid levels are to avoid grazing when the risk of these toxic compounds is high, such as in early spring, after freezing events, or for approximately 10 d following the first rain after prolonged drought (Harris and Shearer 2003). Timing *S. halepense* grazing in the Southern Great Plains can be complicated, however, as the climate in the Southern Great Plains is notably dynamic, and weather patterns are becoming more extreme (Harmel et al. 2003; Ojima et al. 2020).

Grazing Management for Sorghum halepense Invasion

The high forage quality of *S. halepense* and ability to manage this species through grazing has largely limited S. halepense spread in grazing lands (Hawkins et al. 1958; Watson et al. 1980). Heard (1917), for example, suggested that the best eradication measure for S. halepense was to irrigate to establish a good stand followed by heavy sheep grazing. In native rangelands, where soils are undisturbed, S. halepense has more species to compete with and less opportunity to dominate (Paterson et al. 2020). This is especially true when grazing occurs on native rangelands, as livestock show a strong preference for S. halepense, given its forage quality relative to native grasses, and will often preferentially graze S. halepense out of the plant community (Bennett et al., 1973; Watson et al. 1980). Pasturelands, alternatively, differ from native rangelands, as they are periodically plowed every 5 to 20 yr, seeded with productive introduced species, and receive regular fertilization and herbicide management inputs (Sollenberger et al. 2020; USDA-NRCS 2024). Sorghum halepense can, therefore, have a greater ability to dominate pasturelands, as there are fewer physiologically similar species to compete with and reduced competition from broadleaf herbaceous species (Rocateli and Manuchehri 2017). While S. halepense is still preferentially grazed in pasture, many pasturelands have an established grazing system where livestock are rotated throughout the year (Badgery et al. 2017; Paine et al. 1999; Williams and Hammond 1999). Livestock, therefore, may only have access to a specific pasture once per year in rotationally grazed systems. When temporal grazing disturbances are limited by rotation, S. halepense should be quite productive (Paterson et al. 2020; Rocateli and Manuchehri 2017). At a long-term agroecosystem study site in Riesel, TX, for example, areas that are rotationally grazed for more than 10 yr were found to have almost two times the plant production compared with areas that were continuously grazed (unpublished data). It was postulated in this paper that the reason for this high forage availability was the preferential growth of S. halepense in pastures that were not subjected to continuous grazing (unpublished data). While this hypothesis has yet to be tested, as total plant production was not sorted by species, it seems plausible that, especially in pasturelands that have rotational grazing, S. halepense could improve forage availability and forage quality by growing in tandem with seeded introduced species.

Conclusions

Sorghum halepense has been a challenging invader on croplands for decades and has more recently started increasing on intact native range and pasture grassland ecosystems. The spread and dominance of *S. halepense* is not only due to its morphology of rapid development of rhizomes and prolific seed production but also due to changing land use, like less livestock grazing due to higher anthropogenic development on Southern Great Plains grasslands. Once established, S. halepense can outcompete many native perennial grass species by growing earlier and faster and having higher biomass than functionally similar native perennial grasses. S. Sorghum halepense also appears to be well suited to adapting to extreme weather, like frequent drought and flooding that are actively occurring across the Southern Great Plains. While chemical, biological, and mechanical control can be used to control S. halepense, these options are costly and/or impractical to use across much of the Southern Great Plains grazing lands. Alternatively, there can be multiple socioeconomic benefits of having S. halepense on grazing lands, not least among them the potential for higher and more nutritious forage for grazing livestock. It is, however, likely that higher forage availability will only be possible when grazing can be excluded for a period to allow S. halepense to regrow, as S. halepense is often preferentially grazed out of the plant community in continuously grazed systems. There is still much work to be done to fully comprehend the benefits and drawbacks of S. halepense growing on grazing lands, but as this review has indicated, this species should be monitored to balance its increasing spread with greater forage stability and availability in the dynamic climate conditions facing the Southern Great Plains.

Acknowledgments. Thank you to Chris Grisham and David Rowley who assisted in gathering data and reviewing the article. Thank you also to all reviewers and editors who provided quality feedback on this review.

Funding statement. This work was supported by the USDA-ARS CRIS project (no. 3098-21600-001-000D). This research was a contribution from the Long-Term Agroecosystem Research (LTAR) network. LTAR is supported by the U.S. Department of Agriculture. USDA is an equal opportunity provider and employer. Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture. USDA is an equal opportunity provider and employer.

Competing interests. The authors declare no conflicts of interest.

References

- [USDA-NRCS] U.S. Department of Agriculture–Natural Resources Conservation Service (2023) Sorghum halepense (L.) Pers.; Johnsongrasss. Greensboro, NC: National Plant Data Team. https://plants.usda.gov. Accessed: December 10, 2023
- [USDA-NRCS] U.S. Department of Agriculture–Natural Resources Conservation Service (2024) Pasture Resources. https://www.nrcs.usda.go v/resources/data-and-reports/pasture-resources. Accessed: August 20, 2024
- Abatzoglou JT (2013) Development of gridded surface meteorological data for ecological applications and modelling. Int J Climatol 33:121–131
- Aicher RJ, Larios L, Suding KN (2011) Seed supply, recruitment, and assembly: quantifying relative seed and establishment limitation in a plant community context. Am Nat 178:464–477
- Anderson L, Appleby A, Weseloh J (1960) Characteristics of Johnsongrass rhizomes. Weeds 8:402-406
- Andrae J (2009) Grazing impacts on pasture composition. UGA Cooperative Extension Bulletin 1243:1–6
- Arle HF, Everson EH (1955) Johnson Grass Control. Tucson, AZ: College of Agriculture, University of Arizona. 9 p
- Badgery W, Millar G, Broadfoot K, Martin J, Pottie D, Simmons A, Cranney P (2017) Better management of intensive rotational grazing systems maintains pastures and improves animal performance. Crop Pasture Sci 68:1131–1140
- Barney JM, DiTomaso JM (2011) Global climate niche estimates for bioenergy crops and invasive species of agronomic origin: potential problems and opportunities. PLoS ONE 6:e17222

- Baylis AD (2000) Why glyphosate is a global herbicide: strengths, weaknesses and prospects. Pest Manag Sci 56:299–308
- Benbrook CM (2016) Trends in glyphosate herbicide use in the United States and globally. Environ Sci Eur 28:1–15
- Bennett H (1973) Johnsongrass, dallisgrass, and other grasses for the humid south. Pages 333–343 in Heath ME, Metcalfe DS, Barnes RF, eds. Forages: The Science of Grassland Agriculture. 3rd ed. Ames: Iowa State University Press
- Binimelis R., Pengue W, Monterroso I (2009) Transgenic treadmill: responses to the emergence and spread of glyphosate-resistant Johnsongrass in Argentina. Geoforum 40:623–633
- Briske DD, Joyce LA, Polley HW, Brown JR, Wolter K, Morgan JA, McCarl BA, Bailey DW (2015) Climate-change adaptation on rangelands: linking regional exposure with diverse adaptive capacity. Front Ecol Environ 13:249–256
- Brunson MW, Huntsinger L, Kreuter UP, Ritten JP (2016) Usable socioeconomic science for rangelands. Rangelands 38:85-89
- BurnSilver S, Mwangi E (2007) Beyond Group Ranch Subdivision: Collective Action for Livestock Mobility, Ecological Viability and Livelihoods. CAPRi Working Paper 66. Washington, DC: International Food Policy Research Institute. 50 p
- Celarier R (1958) Cytotaxonomic notes on the subsection *Halepensia* of the genus *Sorghum*. Bull Torrey Bot Club 85:49–62
- Ceseki A, Al-Khatib K, Dahlberg JA (2017) Biology and Management of Johnsongrass (*Sorghum halepense*). ANR Publication 8569. Davis: University of California Agriculture and Natural Resources. 11 p
- Clements DR, DiTommaso A (2012) Predicting weed invasion in Canada under climate change: evaluating evolutionary potential. Can J Plant Sci 92:1013-1020
- Clements DR, DiTommaso A (2022) Climate change and the persistence of weeds. Pages 219–243 *in* Upadhyaya MK, Clements DR, Shrestha A, eds. Persistence Strategies of Weeds. London: Wiley
- Clements DR, DiTommaso A, Jordan N, Booth BD, Cardina J, Doohan D, Mohler CL, Murphy SD, Swanton CJ (2004) Adaptability of plants invading North American cropland. Agric Ecosyst Environ 104:379–398
- de Castro RF, Zenteno R (2023) Immigration enforcement, sanctuary policies, and demographic change in California and Texas. Chapter 11 *in* JA Schiavon, R Fernández de Castro, eds. The International Relations of California and Texas with Mexico and the World: Cali-Tex-Mex. New York: Routledge
- Doggett H (1976) Sorghum. Pages 339 *in* N Simmonds, ed. Evolution of Crop Plants. Essex, UK: Longman
- Duncan RP, Diez JM, Sullivan JJ, Wangen S, Miller AL (2009) Safe sites, seed supply, and the recruitment function in plant populations. Ecology 90:2129–2138
- Dweikat I (2005) A diploid, interspecific, fertile hybrid from cultivated sorghum, *Sorghum bicolor*, and the common Johnsongrass weed *Sorghum halepense*. Mol Breed 16:93–101
- Engle DM, Coppedge BR, Fuhlendorf SD (2008) From the Dust Bowl to the green glacier: human activity and environmental change in Great Plains grasslands. Pages 253–271 *in* OW Van Auken, ed, Western North American *Juniperus* Communities: A Dynamic Vegetation Type. New York: Springer
- Entsminger ED, Jones JC, Guyton JW, Strickland BK, Leopold BD (2017) Evaluation of mowing frequency on right-of-way plant communities in Mississippi. J Fish Wildl Manag 8:125–139
- Feltus FA, Wan J, Schulze SR, Estill JC, Jiang N, Paterson AH (2004) An SNP resource for rice genetics and breeding based on subspecies *Indica* and *Japonica* genome alignments. Genome Res 14:1812–1819
- Fernández L, De Haro LA, Distefano AJ, Carolina Martínez M, Lía V, Papa JC, Olea I, Tosto D, Esteban Hopp H (2013) Population genetics structure of glyphosate-resistant Johnsongrass (*Sorghum halepense* L. Pers) does not support a single origin of the resistance. Ecol Evol 3:3388–3400
- Fletcher RA, Varnon KM, Barney JN (2020) Climate drives differences in the germination niche of a globally distributed invasive grass. J Plant Ecol 13(2), 195–203
- Gill G, Blacklow W (1984) Effect of great brome (*Bromus diandrus* Roth.) on the growth of wheat and great brome and their uptake of nitrogen and phosphorus. Aust J Agric Res 35:1–8

- Grman E, Bassett T, Zirbel CR, Brudvig LA (2015) Dispersal and establishment filters influence the assembly of restored prairie plant communities. Restor Ecol 23:892–899
- Harmel RD, King K, Richardson C, Williams J (2003) Long-term precipitation analyses for the central Texas Blackland Prairie. Trans ASAE 46:1381
- Harris B, Shearer J (2003) Nitrate, Prussic Acid (HCN) and Grass Tetany Problems in Cattle Feeding. DS6. Gainesville: Animal Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. 5 p
- Hawkins GE, Kelley W, Smith L (1958) Comparison of Starr Millet, Sweet Sudangrass, Johnsongrass as Dairy Forages. Auburn: Alabama Agricultural Experiment Station Leaflet Circular 60. 4 p
- Heap I (2012) The International Survey of Herbicide Resistant Weeds. www. weedscience.org. Accessed: November 25, 2024
- Heap I, Duke SO (2018) Overview of glyphosate-resistant weeds worldwide. Pest Manag Sci 74:1040–1049
- Heard HC (1917) Johnson grass control. Tucson: University of Arizona, Agricultural Research Station Bulletin 82: 339–355.
- Hernández MJ, León R, Fischer AJ, Gebauer M, Galdames R, Figueroa R (2015) Target-Site resistance to nicosulfuron in johnsongrass (Sorghum halepense) from Chilean corn fields. Weed Sci 63(3), 631–640
- Hickman KR, Goodman L, Elmore D, Buthod A, Duell EB, Craun JN (2018) Oklahoma's Dirty Dozen: Unwanted Invasive Plants. Stillwater: Oklahoma Cooperative Extension Service. 32 p
- Holm LG, Plucknett DL, Pancho JV, Herberger JP (1977) The World's Worst Weeds: Distribution and Biology. Honolulu: University Press of Hawaii. 610 p
- IARC Working Group on the Evaluation of Carcinogenic Risks to Humans (2017) Some Organophosphate Insecticides and Herbicides. Lyon (FR): International Agency for Research on Cancer.
- Johnson WG, Li J, Wait JD (2003) Johnsongrass control, total nonstructural carbohydrates in rhizomes, and regrowth after application of herbicides used in herbicide-resistant corn (*Zea mays*). Weed Technol 17:36–41.
- Kelly S, Fletcher RA, Barney JN (2020) Intraspecific, ecotypic and home climate variation in photosynthetic traits of the widespread invasive grass Johnsongrass. AoB Plants 12:3
- Klein P, Smith CM (2021) Invasive Johnsongrass, a threat to native grasslands and agriculture. Biologia 76:413–420
- Knapp AK, Chen A, Griffin-Nolan RJ, Baur LE, Carroll CJ, Gray JE, Hoffman AM, Li X, Post AK, Slette IJ (2020) Resolving the Dust Bowl paradox of grassland responses to extreme drought. Proc Natl Acad Sci USA117:22249– 22255
- Lakoba VT, Atwater DZ, Thomas VE, Strahm BD, Barney JN (2021) A global invader's niche dynamics with intercontinental introduction, novel habitats, and climate change. Global Ecol Conserv 31:e01848
- McConkey KR, Prasad S, Corlett RT, Campos-Arceiz A, Brodie JF, Rogers H, Santamaria L (2012) Seed dispersal in changing landscapes. Biol Conserv 146:1–13.
- McCullough P, Shilling D (2022) Johnsongrass control in pastures, roadsides, and noncropland areas. UGA Cooperative Extension Bulletin 1513:1-4
- McFadyen REC (1998) Biological control of weeds. Annu Rev Entomol 43:369-393
- McWhorter CG (1961) Morphology and development of johnsongrass plants from seeds and rhizomes. Weeds 9:558-562
- McWhorter CG (1971) Morphology and development of Johnsongrass plants from seeds and rhizomes. Weeds 9:558–562
- Monaghan N (1979) The biology of Johnson grass (*Sorghum halepense*). Weed Res 1961:19
- Morrell PL, Williams-Coplin TD, Lattu AL, Bowers JE, Chandler JM, Paterson AH (2005) Crop-to-weed introgression has impacted allelic composition of johnsongrass populations with and without recent exposure to cultivated sorghum. Mol Ecol 14(7), 2143–2154
- Ojima DS, Aicher R, Archer SR, Bailey DW, Casby-Horton SM, Cavallaro N, Reyes JJ, Tanaka JA, Washington-Allen RA (2020) A climate change indicator framework for rangelands and pastures of the USA. Clim Change 163:1733–1750

- Omernik JM, Griffith GE (2014) Ecoregions of the conterminous United States: evolution of a hierarchical spatial framework. Environ Manag 54:1249–1266
- Paine LK, Undersander D, Casler MD (1999) Pasture growth, production, and quality under rotational and continuous grazing management. J Prod Agric 12:569–577
- Paterson A, Schertz K, Lin Y, Liu S, Chang Y (1995) The weediness of wild plants: molecular analysis of genes influencing dispersal and persistence of Johnsongrass. Sorghum halepense (L.). Pers. Proc Natl Acad Sci USA 92:6127–6131
- Paterson AH, Kong W, Johnston RM, Nabukalu P, Wu G, Poehlman WL, Goff VH, Isaacs K, Lee TH, Guo H (2020) The evolution of an invasive plant, *Sorghum halepense* L. ('Johnsongrass'). Front Genet 11:317
- Pemberton RW (2002) Selection of appropriate future target weeds for biological control. Pages 375–386 *in* Biological Control of Invasive Plants in the Eastern United States. USDA Forest Service Publication FHTET-2002-04. Morgantown, WV: Forest Health Technology Enterprise Team
- Pemberton RW, Lee JH (1996) The influence of extrafloral nectaries on parasitism of an insect herbivore. Am J Bot 83:1187–1194
- Polley HW, Aspinwall MJ, Collins HP, Gibson AE, Gill RA, Jackson RB, Jin VL, Khasanova AR, Reichmann LG, Fay PA (2019) CO₂ enrichment and soil type additively regulate grassland productivity. New Phytol 222:183–192
- Polley HW, Jin VL, Fay PA (2012) Feedback from plant species change amplifies CO₂ enhancement of grassland productivity. Global Chang Biol 18:2813–2823
- Rankins JR, Darrell L (1995) Performance, dry matter intake, digesta kinetics, and ruminal fermentation of steers grazing *Sorghum halepense* at three. Trop Grassl 29:102–110
- Reichmann LG, Schwinning S, Polley HW, Fay PA (2016) Traits of an invasive grass conferring an early growth advantage over native grasses. J Plant Ecol 9:672–681
- Reid JL, Holl KD (2013) Arrival not equal to survival. Restor Ecol 21:153-155
- Rocateli A, Manuchehri M (2017) Johnsongrass in Pastures: Weed or Forage? PSS-2598. Stillwater: Oklahoma Cooperative Extension Service. 4 p
- Ryder N, Dorn KM, Huitsing M, Adams M, Ploegstra J, DeHaan L, Larson S, Tintle NL (2018) Transcriptome assembly and annotation of johnsongrass (*Sorghum halepense*) rhizomes identify candidate rhizome-specific genes. Plant Direct 2:e00065.
- Scholtz R, Polo J, Tanner E, Fuhlendorf S (2018) Grassland fragmentation and its influence on woody plant cover in the southern Great Plains, USA. Landscape Ecol 33:1785–1797
- Schwarzländer M, Hinz HL, Winston RL, Day MD (2018) Biological control of weeds: an analysis of introductions, rates of establishment and estimates of success, worldwide. BioControl 63:319–331
- Schwinning S, Meckel H, Reichmann LG, Polley HW, Fay PA (2017) Accelerated development in Johnsongrass seedlings (Sorghum halepense) suppresses the growth of native grasses through size-asymmetric competition. PLoS ONE 12:e0176042
- Selk G (1988) Nitrate and Prussic Acid Poisoning in Cattle. CR-3272. Stillwater: Oklahoma Cooperative Extension Service. 6 p
- Sherrill W (1947) Blackland pastures: suggestions for their improvement and establishment. Texas Agricultural Extension Service Bulletin 148:1–24
- Simberloff D, Souza L, Nuñez MA, Barrios-Garcia MN, Bunn W (2012) The natives are restless, but not often and mostly when disturbed. Ecology 93:598–607
- Slade HB (1903) Prussic acid in sorghum. J Am Chem Soc 25:55-59
- Sollenberger LE, Newman YC, Macoon B (2020) Pasture design and grazing management. Pages 803–814 in KJ Moore, M Collins, CJ Nelson, DD Redfearn, eds. Forages: The Science of Grassland Agriculture 2. 7th ed. London: Wiley
- Squires CC, Walsh MJ (2021) Sorghum halepense. Pages 391–405 in Biology and Management of Problematic Crop Weed Species. London: Elsevier
- Sutton GF, Canavan K, Day MD, Den Breeyen A, Goolsby JA, Cristofaro M, McConnachie A, Paterson ID (2019) Grasses as suitable targets for classical weed biological control. BioControl 64:605–622

- Tang H, Liang GH (1988) The genomic relationship between cultivated sorghum *Sorghum bicolor* (L) Moench and johnsongrass [*Sorghum halepense* (L) Pers]—a reevaluation. Theor Appl Genet 76:277–284
- Tarazona JV, Court-Marques D, Tiramani M, Reich H, Pfeil R, Istace F, Crivellente F (2017) Glyphosate toxicity and carcinogenicity: a review of the scientific basis of the European Union assessment and its differences with IARC. Arch Toxicol 91:2723–2743
- Tóth V, Lehoczky E (2006) Investigations on the germination depth of Johnson grass (Sorghum halepense [L.] pers). Commun Agric Appl Biol Sci 71:803–808
- Vila-Aiub MM, Balbi MC, Gundel PE, Ghersa CM, Powles SB (2007) Evolution of glyphosate-resistant johnsongrass (*Sorghum halepense*) in glyphosateresistant soybean. Weed Sci 55:566–571
- Vinall H (1921) A study of the literature concerning poisoning of cattle by the prussic acid in sorghum, sudan grass, and johnson grass. J Am Soc Agron 13:267–280
- Wapshere A (1990) Biological control of grass weeds in Australia: an appraisal. Plant Prot Q 5:62–75
- Warwick S, Black L (1983) The biology of Canadian weeds.: 61. Sorghum halepense (L.) Pers. Can J Plant Sci 63:997–1014

- Warwick S, Phillips D, Andrews C (1986) Rhizome depth: the critical factor in winter survival of Sorghum halepense (L.) Pers. (Johnson grass). Weed Res 26:381–388
- Watson VH., Coats RE, Kimbrough LE (1980) Johnsongrass as a forage in Mississippi. Mississippi State University Bulletin 886:1–6
- Williams GM, Aardema M, Acquavella J, Berry SC, Brusick D, Burns MM, de Camargo JLV, Garabrant D, Greim HA, Kier LD, Kirkland DJ (2016) A review of the carcinogenic potential of glyphosate by four independent expert panels and comparison to the IARC assessment. Crit Rev Toxicol 46:3–20
- Williams M, Hammond A (1999) Rotational vs. continuous intensive stocking management of bahiagrass pasture for cows and calves. Agron J 91:11–16
- Witt ABR, McConnachie AJ (2004) The potential for classical biological control of invasive grass species with special reference to invasive Sporobolus spp. (Poaceae) in Australia. Page 198 *in* XI International Symposium on Biological Control of Weeds. Canberra: CSIRO
- Yelenik SG, D'Antonio CM (2013) Self-reinforcing impacts of plant invasions change over time. Nature 503:517–520
- Zachariades C, Paterson ID, Strathie LW, Hill MP, van Wilgen BW (2017) Assessing the status of biological control as a management tool for suppression of invasive alien plants in South Africa. Bothalia 47:a2142