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REVIEW ARTICLE

Harnessing johnsongrass (*Sorghum halepense*): Turning a weed into a resource

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ABSTRACT

Johnsongrass [*Sorghum halepense* (L.) Pers.] is a menace in several crops including grain sorghum, maize, cotton, soybean, etc. due to its ability to compete for space, nutrients, and light. It is classified as one of the world's worst weeds and is a target for eradication efforts worldwide. While prevention remains the most effective strategy for managing its spread to new areas, an alternative approach involves leveraging its economic potential through applications such as animal feed, manure, bioremediation, soil binder, etc. For example, johnsongrass serves as fodder grass in many regions, boasting high protein content (10-12% dry matter) and total digestible nutrients (50-60%). Similarly, it exhibits phytoremediation properties, extracting pollutants from soil and water. Despite its potential, research into the utilization of johnsongrass remains limited. Therefore, this article seeks to consolidate the available knowledge on its economic applications, including its genetic potential in sorghum breeding, role as livestock feed, human health benefits, soil conservation properties, industrial uses, etc. By shedding light on the diverse uses of johnsongrass, this article aims to promote awareness and encourage the transformation of noxious weeds into sources of wealth.

Keywords: Allelopathy, Crop Improvement, Fodder, Phytoremediation, Rhizome, Wild relative

INTRODUCTION

Johnsongrass [*Sorghum halepense* (L.) Pers.], also known as Aleppo grass, native to the Mediterranean region, is an invasive perennial species that invades agricultural pastures and natural plains (Howard 2004). Johnsongrass (2n = 4x = 40) is a naturally occurring hybrid between *S. bicolor* (2n=20) and *S. propinquum* (2n=20), widely found in the Mediterranean to the Middle East, India, Australia, central South America, and the Gulf Coast of the United States. It is the world's sixth most persistent weed, as its infestation is reported in over 53 countries and more than 30 different crops (Peerzada *et al.* 2017). Johnsongrass is found in abundance in several states of India, including Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Maharashtra, Madhya Pradesh, Nagaland, Odisha, Rajasthan, Uttar Pradesh and West Bengal (Majumdar *et al.* 2017, Sankara *et al.* 2019). Johnsongrass grows on a wide range of soil types, survives in diverse ecological habitats, and is usually found along irrigation canals, cultivated fields, field edges, orchards, and pastures (Chambers *et al.* 2002). It displaces the native flora under natural landscapes and affects the biogeochemistry of the invaded soil through its aggressive characteristics (Rout and Callaway 2009, Bais *et al.* 2006). The secondary metabolites produced in the rhizomes have shown a negative effect on popular medicinal plants grown in Iran such as *Ocimum basilicum*, *Nigella sativa*, *Cuminum cyminum*, *Foeniculum vulgare*, *Plantago ovata* and *Plantago psyllium* (Asgharipour and Armin 2010).

Johnsongrass is extremely competitive and has shown a negative impact on a wide range of field crops such as maize, wheat, grain sorghum, soybean, sunflower, sugarcane, cotton, pastures, alfalfa, vegetables, and fruits (Travlos *et al.* 2018). In India, johnsongrass is reported to be one of the important grassy weeds of minor millets such as barnyard and foxtail millet (Dubey *et al.* 2023). Johnsongrass reduces the yield of cotton by 70%, maize by 88-100%, sugarcane by 69%, and soybean by 59-88% (Williams and Hayes 1984, Bridges and Chandler

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1987, Mitskas *et al.* 2003, Dalley and Richard 2008, Barroso *et al.* 2016). Johnsongrass poses an exclusive threat to cultivated sorghum due to its close ancestry and lack of selective herbicide that can control the johnsongrass in sorghum (Bagavathiannan *et al.* 2018).

Below-ground johnsongrass forms large colonies from stout, finger-sized, multi-branched rhizome networks that usually account for up to 70% of the entire plant's dry weight (Paterson *et al.* 2020). Johnsongrass dispersal across fields is typically facilitated by human activities, such as tillage (which spreads both seeds and rhizomes), planting, and harvesting (which spreads seeds). A single plant of johnsongrass can produce up to 80,000 seeds in a single growing season, which remains viable for up to 10 years (Ryder *et al.* 2018). It survives temperatures ranging from -10°C to 40°C (CDFA 2002), however, frost and drought stress induce johnsongrass to produce hydrocyanic acid (HCN) at a level that can be harmful to cattle, sheep, and horses (Henderson 2001). The foliage rich in HCN causes 'bloat' in herbivores due to the accumulation of excessive nitrates. Furthermore, johnsongrass is an alternate host to corn leaf gall, maize dwarf mosaic, wheat streak mosaic, beet yellow viruses, and sorghum midge.

Johnsongrass in crop fields negatively impacts crop production, particularly in maize and sorghum. The potential for gene flow between grain sorghum and johnsongrass complicates its management. In Texas and Nebraska, up to 32% of unique sorghum alleles were identified in johnsongrass populations. The existing scientific evidence strongly suggests that engineered genes and herbicide resistance in sorghum have the potential to transfer to johnsongrass and spread extensively (Morrell *et al.* 2005). The conventional way of management (tillage and herbicide application) is ineffective due to its rapid vegetative proliferation and herbicide resistance (Peerzada *et al.* 2017). Johnsongrass has developed resistance to multiple herbicides utilized across North and South America. Furthermore, there is a growing concern that johnsongrass may emerge as a super weed as there is a heightened probability of herbicide-resistant genes flowing from sorghum to johnsongrass. Johnsongrass has been reported resistant to recommended doses of nicosulfuron, foramsulfuron, primisulfuron-methyl, clethodim, fluazifop, glyphosate, and imazethapyr in the USA, Chile, Mexico, and Venezuela (Heap 2014, Johnson *et al.* 2014). As a result, only very few herbicides available in the market are providing effective control against johnsongrass. The research on its management using chemical herbicides is limited. Dubey and Mishra (2023) reported that the application of tembotrione at 100 g/ha as a post-emergence treatment (15–20 DAS) effectively controlled *Sorghum halepense* compared to other treatments at 30 DAS in sorghum crops.

Johnsongrass, despite being a prime example of a weed, has frequently been overlooked for its potential benefits, prompting extensive eradication campaigns. However, these efforts have largely proven ineffective, placing a considerable financial burden on farmers as well as the government. Scientific literature predominantly emphasizes the detrimental effects of johnsongrass on crops, soil health, and the environment, with limited attention given to its positive attributes. This scarcity underscores the urgent need to delve into the beneficial aspects of johnsongrass and raise awareness within both farming and scientific communities. Presently, there exists a crucial opportunity to conduct a thorough examination of the johnsongrass positive impacts, thereby fostering understanding among agricultural stakeholders. Such endeavors hold the promise of mutually beneficial outcomes, empowering farmers to leverage the weed's potential for wealth creation akin to other plant species. Therefore, the objective of this article was to provide a comprehensive exploration of diverse uses of johnsongrass, facilitating informed decision-making processes regarding its management and utilization.

Genetic material for crop improvement

Sorghum and johnsongrass are two closely related species, with the former belonging to the primary gene pool, while the latter belonging to the secondary gene pool. This means that natural gene flow between sorghum and johnsongrass is possible with little to no difficulty. Johnsongrass has many desirable traits that can be used to increase agricultural productivity, such as resistance to various diseases and insects, and the ability to grow in a wider range of environments than either of its parent plants. It has a better ability to thrive in heat, cold, and salinity conditions to sorghum. Thus, johnsongrass can be used to develop drought-tolerant varieties of sorghum, especially for regions prone to water scarcity (Upadhyaya *et al.* 2019). It can also be used to breed sorghum for multiple harvests (perennialism) from single plantings, thus holding great potential for enhancing fodder production (Cox *et al.* 2002, Glover *et al.* 2010). The genetic novelty from johnsongrass can be used in efforts to breed ratooning/perennial sorghums that better protect 'ecological capital' such as topsoil and organic matter (Glover *et al.* 2010). Johnsongrass has been used to develop perennial sorghum as a bioenergy crop (Price *et al.* 2006).

Biotic stress induced by insect pests and diseases significantly impacts sorghum yield. Over a dozen insect pests and diseases have been documented in sorghum cultivation that directly affects its yield potential. However, the management practices designed to mitigate these infestations often prove ineffective or financially burdensome. Consequently, breeding biotic stress-resistant cultivars through conventional breeding emerges as a sustainable solution. Johnsongrass is reported to be a potential donor species for bringing resistance against green bugs, chinch bugs, and shoot fly in sorghum (Nwanze *et al.* 1995, Dweikat 2005). It can also be used for improving several other traits, including the antioxidant properties of the sorghum grain (Cox *et al.* 2018). Besides that, the johnsongrass was found to harbor N_2-fixing bacterial endophytes in the rhizomes. Therefore, the gene responsible for endophytic nitrogen fixation in johnsongrass can be transferred to sorghum (Rout and Chrzanowski 2009). This could reduce the nitrogen requirement, ultimately helping to narrow a 'yield gap' reflected by 1961–2012 yield gains in the U.S. of only 61% for sorghum versus 323% for maize (Rout *et al.* 2013). Therefore, it is evident that johnsongrass holds considerable potential for sorghum improvement programs due to its interfertility between the two. Although no sorghum hybrids have been developed to date, johnsongrass is actively utilized in sorghum breeding programs. To fully harness the above benefits, careful attention to hybridization techniques and potential ecological impacts are essential.

Feed and fodder potential

In India, the primary reason for the low productivity of the livestock sector is the shortage of feed and green fodder. Dry fodder is predominantly used to feed milk-producing animals, which results in low milk productivity per animal. **Figure 1** provides estimates of demand, supply, and deficit for green and dry fodder in India. As per the figure, India is currently facing a green fodder shortage of ~260 million tonnes (MT) and dry fodder shortage of 83 MT, and this deficit supply is projected to be 186.6 MT of green fodder and 83.3 MT of dry fodder by 2050 (IGFRI Vision 2050). Therefore, there is an urgent need to enhance the availability of green fodder in the country to increase the productivity and sustainability of the livestock sector. Identifying new green fodder and increasing the productivity of existing green fodder are the two vital options to address this gap.

Weeds have remained an important non-conventional source of fodder for some livestock. However, there is a continuous quest for new alternative forage crops to augment the availability of green fodder for livestock and reduce fodder costs, thereby enhancing profitability. Johnsongrass fodder is palatable to cattle, possesses adequate nutritive value, and can be grazed with proper management (Rankins and Bransby 1995). Deer, rodents, quails, geese, and wild turkeys consume johnsongrass (Howard 2004). Johnsongrass was introduced as a perennial warm-season forage crop in North America

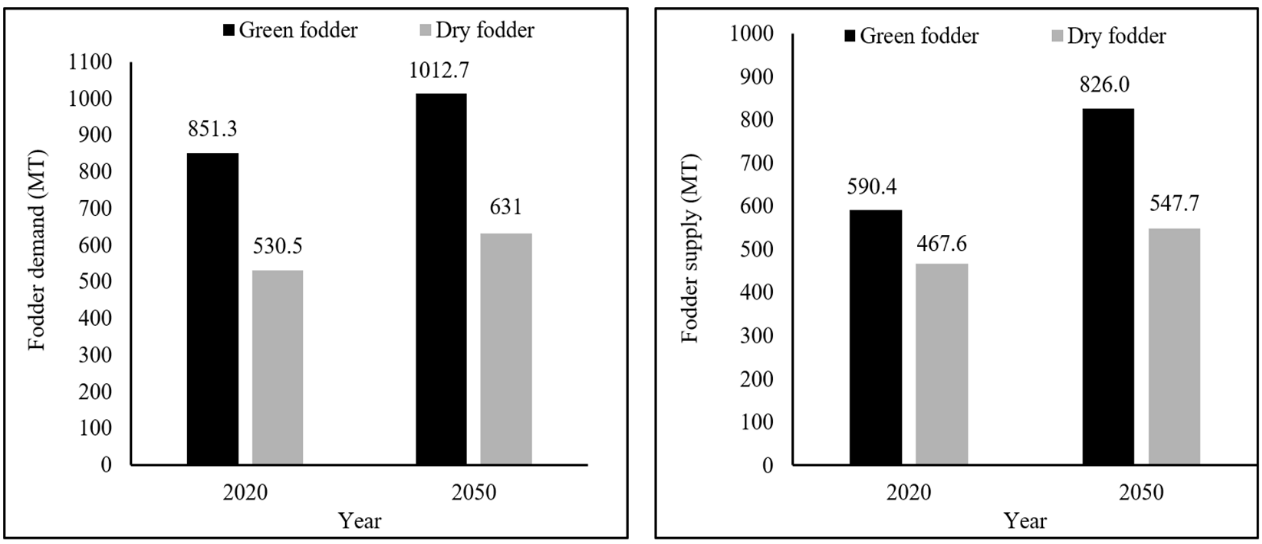

Figure 1. Estimated demand-supply gap of green and dry fodder in India (Source: IGFRI Vision 2050)

in the 1800's (Warwick and Black 1983). Today, it is widely cultivated as a fodder crop on large farms to feed livestock in the United States. Despite its desirable feed characteristics, only a limited number of studies have examined the forage potential of johnsongrass put full stop. The leaves of johnsongrass contain a large amount of protein (10-12% on a dry matter basis) and total digestible nutrients (50-60%) (Natureserve 2009). The nutritional value of johnsongrass justifies the attempts to incorporate it into forage systems and animal production **(Table 1)**.

Johnsongrass has significant forage potential in the sub-tropics for good quality hay and pasture in an emergency (Duke 1983, Kansas Forage Task Force 1998). Johnsongrass can be ensiled for beef cattle (Bass *et al.* 2016). On the contrary, Singh *et al.* (1975) reported johnsongrass hay should be fed only for a limited period, whenever required, as the johnsongrass hay did not increase the body weight of sheep although they showed a positive N balance of 3.4 g/day. Similarly, Kumar and Garg (1997) concluded that johnsongrass can meet the nutrient requirements of Murrah heifers. According to Garg *et al.* (1992), johnsongrass holds comparable nutritional contents to any other cereal fodder and can be solely used as a maintenance ration for sheep based on the chemical composition, nutritive value, and apparent digestibility coefficients. Sinha *et al.* (1986) reported johnsongrass's tolerance to salinity and drought suggests its potential for forage production on salt-affected soils. However, it is recommended to be cautious to put cattle to graze after the occurrence of prolonged drought or frost. These environmental conditions lead to the accumulation of prussic acid in the leaves, which is lethal to grazing animals. These conditions also stimulate the accumulation of nitrates in leaves at toxic levels. Therefore, it is recommended to wait up to two weeks after the drought or frost event. This allows for the dilution of built-in compounds (HCN, nitrates) after plant growth and metabolic functions are restored (Anonymous 2022). The accumulation of toxic compounds in the plant in harsh weather can be prevented by supplementing irrigation. Another condition that favors HCN accumulation in plants is high nitrogen and low phosphorus and potash in soil. Therefore, the excess application of nitrogen should be avoided in johnsongrass. Instead, the money saved in nitrogen fertilizer should be diverted to phosphorus and potassium fertilizer to ensure balanced fertilizer application. Additionally, split applications of nitrogen decrease the risk of prussic acid toxicity.

Table 1. Palatability and fodder quality of johnsongrass

Parameter	Chemical composition (% DM basis)	Reference
Crude protein	10-12	Sherasia *et al.* 2015, Gutiérrez *et al.* 2008
Crude fibre	32 - 37	Sherasia *et al.* 2015
Dry matter	22 - 32	Kumar and Garg 1997
Organic matter	89 - 94	Sherasia *et al.* 2015
Ether extract	1.2-2.5	Kumar and Garg 1997, Sherasia *et al.* 2015
Ash	8.3	Singh *et al.* 1975
Neutral detergent fibre	69- 73	Sherasia *et al.* 2015
Acid detergent fibre	32- 47	Sherasia *et al.* 2015
Total digestible nutrients	52- 63	Alex and Misha 2017
Major minerals (g/kg DM)		
Calcium	0.5-0-6	Sherasia *et al.* 2015
Magnesium	1.81	Gutiérrez *et al.* 2008
Potassium	9.0	Gutiérrez *et al.* 2008
Sodium	2.91	Gutiérrez *et al.* 2008
Phosphorus	0.3	Sherasia *et al.* 2015

Human health benefits

Out of 8000 weeds, only 250 weeds are found to be important for agriculture (Holm *et al.* 1979). Johnsongrass, renowned for its drought resistance, exhibits the remarkable ability to thrive and produce seeds even during severe drought years. This inherent resilience has endowed it with a crucial role as a food reserve during times of famine, offering a vital lifeline in periods of scarcity (Duke 1983). The seed can be eaten as a whole grain like rice or millet, or it can be ground into flour to to make bread, cakes, *etc*. (Uphof 1959, Rapoport *et al.* 1995, Paterson *et al.* 2020). Johnsongrass harbors significant potential for medicinal use, as every part of this plant is used to cure a variety of human ailments **(Table 2)**. In folk medicine, johnsongrass is reported to be cyanogenetic, demulcent, depurative, diuretic and recommended for the treatment of blood and urinary tract disorders (Duke and Wain 1981). The seed contains the bioactive compound p-cymene, a compound used to treat prostatitis (Banoon 2020). Bioactive compounds are generally added to food products for the enhancement of health-promoting properties. The phytochemical analysis of johnsongrass rhizomes showed the presence of cardiac glycosides, flavonoids, terpenes, steroids, saponins, carbohydrates, proteins, gums, and alkaloids. The phytochemical components in plant extracts are biologically active compounds that exhibit a range of beneficial effects, including anti-diabetic, anti-cancer, antifungal, anti-inflammatory, and antibacterial properties. The extracts obtained from johnsongrass rhizome showed the ability to scavenge free radicals, indicating the presence of antioxidant constituents (Shah *et al.* 2021).

Table 2. Phytochemical properties and uses of johnsongrass parts

Property	Plant parts used	Reference
Diuretic	Seed, stem	Tuzlaci and Erol 1998, Mustafa *et al*. 2021, Ahmed *et al.* 2020
Antimicrobial	Whole plant	Khayal *et al.* 2019, Salazar-Lopez *et al.* 2018
Antibacterial	-	Rooh-ul-Anin 2013
Antioxidant	Whole plant; Rhizomes	Shah *et al.* 2021
Demulcent	Seed	Chopra *et al.* 1986
Anti-diabetic	Rhizomes	Shah *et al.* 2021
Antifungal	Shoots	Naeem *et al*. 2021, Javaid *et al.* 2012
Anti-inflammatory	-	Rambabu *et al.* 2016
Anti-cancerous	Rhizomes	Tuzlaci and Erol 1998
Analgesic	Roots	Rajasab and Isaq 2004
Toothache	-	Belda *et al.* 2012

Allelopathic potential

Allopathy refers to the phenomenon where one plant species releases biochemical compounds that inhibit the growth of neighboring plants. It is a natural and environment-friendly technique for weed management. Johnsongrass has a strong allelopathic effect on a wide range of weed species. The impact of allelopathy varies with weed species and the concentration of allelochemical compounds (Sakran *et al.* 2021). Johnsongrass inhibited the germination of barnyardgrass [(*Echinochloa crus-galli* (L.) P. Beauv.)] by 46% and bristly foxtail [(*Setaria verticillata* (L.) P. Beauv.)]by 63%, respectively. (Vasilakoglou *et al.* 2005). Thahir *et al.* (2011) reported the allelopathic potential of johnsongrass on wild oat (*Avena fatua* L.), ryegrass (*Lolium temulentum* Gaud.), grass pea (*Lathyrus sativa* L.), and syrian cephalaria (*Cephalaria syriaca* (L.) Schard). Lalchand *et al.* (2021) reported the allelopathic impact of johnsongrass on the germination of purple nutsedge (*Cyperus rotundus* L.) and jungle rice (*Echinochloa colona* L.).

The allelopathic effect of johnsongrass is due to cyanogenic, glycogenic, and phenolic compounds. These allelochemicals interfere with various physiological processes in target plants, such as seed germination, root development, and nutrient uptake (Stef *et al.* 2013). Ramona *et al.* (2015) reported the presence of inhibitory substances in all the organs of johnsongrass. Studies have identified allelochemicals such as sorgoleone, a potent inhibitor of weed germination and growth, in the root exudates of Johnsongrass. Sorgoleone exhibits herbicidal activity by disrupting essential metabolic processes in target plants, making it a promising candidate for weed management. Therefore, there is immense potential for identifying allelopathic compounds responsible for weed suppression and synthesizing these identified compounds for use as natural herbicides.

Phytoremediation potential

Phytoremediation refers to the use of plants to remove, degrade, or immobilize contaminants from the environment (Gerjardt *et al.* 2017). It is a cost-effective, eco-friendly alternative to traditional remediation methods (Nascimento *et al.* 2014, Sarwar *et al.* 2017). Weeds uptake, metabolize, or accumulate contaminants through various mechanisms, thereby reducing pollution levels. Johnsongrass reduces the risk of heavy metal contaminants through hyperaccumulation (Pinho and Ladeiro 2012). Its extensive root system and vigorous growth make it highly suitable for extracting contaminants from soil and water. Lead (Pb) is one the most toxic environmental pollutant and has nonbiodegradable properties (Lou *et al.* 2013, Pinho and Ladeiro 2012). Johnsongrass is a useful species for Pb immobilization in soil (Salazar *et al.* 2014) and is also effective for phytostabilization of Pb-Zn mine waste (Madejon *et al.* 2002). Johnsongrass has also shown the ability to accumulate lead and nickel (Ni) at a high concentration (Kayal *et al.* 2019). According to Ziarati *et al.* (2015), sixty-day-old johnsongrass accumulated around 0.5 mg of cadmium, 2.2 mg of copper, 1.8 mg of chromium, 1.1 mg of Ni, 3.5 mg of lead, and 0.2 mg of cobalt per kg of dry weight.

Johnsongrass facilitates rhizo-filtration, a process wherein contaminants are filtered and immobilized by root systems, thus preventing their migration into groundwater. Phytoaccumulation involves the concentration of contaminants in above-ground biomass, which can subsequently be harvested for disposal. Johnsongrass has shown potential in extracting Sr (Strontium) from the Sr-affect soil through phytoextraction, a process where plants absorb pollutants from the soil and store them in their tissues. Entry *et al.* (1999) demonstrated that johnsongrass was highly effective at removing Sr in three harvests over 24 weeks, it accumulated 52.6% to 88.7% of the applied Sr. However, phyto-remediation employing johnsongrass is not devoid of challenges. Concerns such as plant invasiveness, potential bioaccumulation of contaminants in edible tissues, and the long duration required for effective remediation necessitate careful consideration and mitigation strategies. Nonetheless, johnsongrass can serve as an asset for phytoremediation in regions contaminated with heavy metals, as many other plant species struggle to germinate and thrive in such environments due to the presence of heavy metal pollutants and adverse weather conditions.

Acridid biomass production

Insects have been consumed by humans as a food source, dating back centuries to early civilizations. The insects provide essential nutrients such as nitrogen, potassium, sodium, iron, and magnesium, which are crucial for the growth and reproduction of various animals including birds (Studier and Sevick 1992). Grasshoppers, a type of insect, are consumed by humans in many parts of the world, including India, sub-Saharan Africa, and Madagascar (Haldar and Malakar 2017, Van Huis 2003, Van Itterbeeck *et al.* 2019). Grasshoppers and locusts belonging to the Orthoptera and the family *Acrididae*, are recognized for their high nutritional value and are increasingly considered as an alternative protein source for livestock industries, particularly in poultry farming. Johnsongrass can serve as a feed for acridid grasshoppers. Research by Mousumi *et al.* (2012) revealed that johnsongrass is the most suitable plant for enhancing the biomass production of acridid grasshoppers compared to other plants such as *Oryza sativa* L., *Triticum aestivum* L., and *Cynodon dactylon*. Therefore, utilizing johnsongrass as feed for acridid grasshoppers will indirectly promote the production of more grasshoppers. These grasshoppers can then be consumed directly by humans as a protein source or utilized as a feed supplement for poultry farming.

Ethnoveterinary uses

Johnsongrass plays a significant role in ethnoveterinary medicine due to its diverse medicinal applications. According to Martinez and Jimenez (2017), johnsongrass serves as an inducer of placental expulsion, particularly in animals. In this traditional practice, the aerial parts of the plant are utilized to facilitate the process. Furthermore, Ghasemi *et al.* (2013) highlight another aspect of its medicinal potential, noting that the leaves and stems of johnsongrass are employed externally for inducing abortion in animals. The plant's ability to aid in placental expulsion and induce abortion highlights its potential as a natural remedy in ethnoveterinary medicine. Similarly, johnsongrass seeds are reported to be the most effective treatment for diarrhea in livestock (Meena *et al.* 2023). These properties underscore the plant's potential as a natural remedy in ethnoveterinary practices. However, its medicinal use should be approached with caution, balancing traditional knowledge with scientific research to ensure safety and efficacy.

Industrial value

The use of agro-industrial waste as a raw material for pulp and paper production has been increasing over the years (Sanchez *et al.* 2016). Among these alternative materials, johnsongrass stands out as a promising candidate due to its compatibility with other raw materials used in pulp and paper manufacturing (Albert *et al.* 2011). Moreover, johnsongrass fibers exhibit exceptional qualities compared to other non-wood fibers, boasting longer lengths and superior derived values, particularly in terms of the slenderness ratio (90.37) and Runkel ratio (1.89). These characteristics hold profound implications for the quality and utility of paper produced from johnsongrass fibers.

The slenderness ratio and Runkel ratio serve as crucial indicators for assessing the suitability of fibrous material for pulp and paper production, further emphasizing the potential of johnsongrass in the paper industry. With an increased slenderness ratio and Runkel ratio, paper made from johnsongrass fibers is expected to possess increased mechanical strength. Consequently, it becomes an ideal material for a wide array of applications such as writing, printing, wrapping, and packaging. Therefore, the utilization of johnsongrass in combination with other raw materials for pulp and paper production presents a promising avenue for sustainable resource management. Its superior fiber characteristics contribute to the production of high-quality paper with increased mechanical strength, catering to various industrial and commercial needs. As efforts to explore alternative raw materials for paper production continue, johnsongrass emerges as a valuable resource with significant potential for the pulp and paper industry.

Anti-corrosive properties

Johnsongrass possesses a myriad of biochemical components that endow it with remarkable anti-corrosive properties. The biochemical analysis of johnsongrass has revealed the presence of vitamins, steroids, saponins, alkaloids, reducing sugars, tannins, glycosides, flavonoids, phenols, terpenes, carbohydrates, and proteins. These chemical structures exhibit characteristics that make them suited to binding to metal surfaces, thereby creating a protective layer. The presence of these compounds in johnsongrass has been extensively studied by researchers such as Hassannejad and Nouri (2018) and Nair (2017). Their findings underscore the potential of johnsongrass as a natural solution for combating corrosion in various industries. When applied to metal surfaces, the biochemical constituents of johnsongrass can effectively adhere to the surface, forming a protective barrier against corrosive agents. The anti-corrosive properties of johnsongrass hold significant implications for a wide range of applications, particularly in industries where corrosion poses a significant challenge. By harnessing the natural protective capabilities of johnsongrass, industries can reduce the need for synthetic anti-corrosive agents, thereby promoting environmentally sustainable practices. Additionally, the use of johnsongrass for corrosion prevention aligns with the growing interest in bio-based materials and green technologies.

Shade and shelter

Throughout history, humans have relied on natural materials for shelter construction, with thatched roofs being one of the earliest forms of roofing. In recent years, there has been a renewed interest in sustainable building practices, leading to the exploration of alternative roofing materials. With its tall, sturdy stems and abundant foliage, johnsongrass possesses qualities that make it well-suited for thatching purposes (Vegda 2012). Additionally, its widespread availability and minimal environmental impact make it an attractive choice for sustainable construction. Thatching with johnsongrass involves harvesting the mature stems and leaves of the plant, followed by cleaning, drying, and bundling them into thatch panels or rolls. These panels are installed in overlapping layers onto a framework of roof beams, providing insulation and protection from the elements. The johnsongrass stem is used to make roof thatch (Vegda 2012). Its cultivation requires minimal inputs such as water and fertilizer, making it a sustainable alternative to conventional roofing materials. Thatch roofs provide excellent insulation properties, keeping interiors cool in summer and warm in winter. Johnsongrass effectively regulates indoor temperatures, reducing the need for artificial heating and cooling. While johnsongrass offers numerous benefits, there are challenges to its widespread adoption. Concerns such as fire resistance, durability, and maintenance requirements need to be addressed through proper treatment and construction techniques.

Manure and compost making

Johnsongrass can be used for the preparation of compost as it is a fast-growing species. According to Schwinning *et al.* (2017) the johnsongrass attained 30 times more biomass at first harvest (50 days after seeding) compared to the big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparius*) and switchgrass (*Panicum virgatum*). On an average, johnsongrass produces biomass of up to 19 tonnes/hectare. To prepare compost from johnsongrass, begin by gathering fresh clippings or biomass. Chop the biomass into smaller pieces to aid decomposition. Layer the chopped johnsongrass with other organic materials, such as kitchen scraps, leaves, or manure, in a compost bin or pile, ensuring a balance of green (nitrogen-rich) and brown (carbon-rich) materials. Regularly turn the compost pile to aerate it and accelerate decomposition. Maintain moisture levels by watering periodically and avoid waterlogging. Monitor compost temperature to reach and sustain 54°C to 65°C to eliminate weed seeds and pathogens. After several weeks to months, the compost, dark, crumbly, and with an earthy aroma, will be ready. The compost prepared from johnsongrass biomass had a pH of 5.18 to 6.92, and calcium and magnesium contents were from 5.82 to 53 mEq/L and 4.94 to 38 mEq/L, respectively (Altai *et al.* 2024). Utilize this nutrient-rich compost to enhance soil structure and fertility in gardens, farms, or landscaping projects.

Role in soil conservation, revegetation and restoration

Soil conservation is crucial for sustainable farming. Revegetation using grass is a widely used method for controlling soil erosion. Johnsongrass emerges as a versatile and resilient species with significant potential in soil conservation, revegetation, and restoration initiatives. Johnsongrass plays a vital role in soil conservation through its extensive root system and erosion control capabilities. Furthermore, the dense canopy formed by johnsongrass foliage intercepts rainfall, minimizing soil surface runoff and erosion. The johnsongrass was found efficient in preventing soil erosion, particularly on steep slopes due to its fibrous roots and extensive thick creeping rhizome network (Holm *et al.* 1979, Bennett 1973). Its rapid growth and ability to establish quickly can help stabilize soils and prevent further degradation of the ecosystem. One johnsongrass plant can produce up to 5,000 rhizomes and up to 13.6 metric tons of rhizomes per acre (Horowitz 1972, McWhorter 1971). By colonizing bare soils and providing habitat for other plant species, johnsongrass initiates the succession process, paving the way for the establishment of diverse plant communities. Additionally, johnsongrass acts as a nurse plant, facilitating the germination and establishment of native vegetation by providing shelter, moisture, and nutrients. Its aggressive growth habit and ability to outcompete native vegetation can pose challenges for biodiversity conservation and ecosystem restoration efforts. Therefore, careful management and monitoring are necessary to prevent the spread of johnsongrass in sensitive habitats and to mitigate potential negative impacts on native ecosystems.

Conclusion

The potential of johnsongrass to serve as a source of income is evident through its various applications. However, harnessing its economic benefits comes with challenges, particularly in managing its intrusion into cultivated areas. While johnsongrass poses significant economic losses when it infiltrates cropping areas, its potential for generating income through activities such as thatching, manure preparation, industrial value addition, and therapeutic purposes cannot be overlooked. In India, this weed has the potential to present several economic benefits such as breeding material, thatching, animal feed, and medicine. Its economic benefits will outweigh its drawbacks compared to countries like the USA and Australia. Overall, this article underscores the importance of exploring and utilizing the beneficial potential of johnsongrass and converting them into sources of wealth.

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