OPEN ACCESS
International Journal of Agriculture and Sustainable Development
IJASD

Sweet Sorghum (Sorghum bicolor var. Saccharatum) as a Dual-Use Crop for Feed and Bioenergy in the Arabian Gulf: A Systems Perspective for Desert Agriculture

Rafeq Jambi, Ahmad Aziz, Xiaofei Wang
Tennessee State University
*** Correspondence:** jambi459@yahoo.com

Citation | Jambi, R. Aziz, A. Wang, X. "Sweet Sorghum (Sorghum Bicolor Var. Saccharatum) as a Dual-Use Crop for Feed and Bioenergy in the Arabian Gulf: A Systems Perspective for Desert Agriculture", IJASD, Vol. 8 Issue. 1 pp 63-70, January 2026
Received | December 19, 2025 **Revised |** January 08, 2026 **Accepted |** January 13, 2026 **Published |** January 18, 2026.

Agricultural endeavors in the Arabian Gulf face significant challenges due to extreme heat, persistent water shortages, and high soil salinity, underscoring the necessity for robust, versatile crop systems [1][2]. *Sweet sorghum* (*Sorghum bicolor var. saccharatum*), a C4 plant recognized for its efficient water utilization and resistance to heat and salt, offers a promising alternative [3][4]. This research examines the viability of sweet sorghum for agricultural applications in the Gulf\'s desert and peri-urban environments, consolidating data on its suitability for various climates, performance in saline conditions, water needs, and its capacity for use as both animal feed and a source of bioenergy. In arid environments, *sweet sorghum* has been reported to produce fresh biomass yields of 65–95 t ha^{-1}, with fermentable sugars capable of yielding 3,152–4,572 L ha^{-1} of ethanol [5][6][7]. It requires 30–50% less irrigation water than sugarcane and maintains good forage quality under moderate salinity (≈4–6 dS m^{-1}) [7][8]. Proper management, such as ensiling and optimized nitrogen application, effectively mitigates the risks of nitrate and prussic acid accumulation, ensuring its safety for livestock [9][10]. This analysis indicates that *sweet sorghum* functions as more than a single-use crop; it is a vital element for combined food, feed, and energy systems, capable of lowering water requirements and improving land output in arid areas. Despite existing knowledge gaps, especially regarding how different varieties perform in very humid conditions and the complexities of seed distribution, sweet sorghum presents itself as a flexible and robust choice that supports the Arabian Gulf's enduring objectives for sustainability and energy variety.

Keywords: Desert Agriculture, Sweet Sorghum, Bioenergy, Water-Use Efficiency, Salinity Tolerance

Introduction:

Extreme temperatures, persistent water scarcity, and widespread soil salinity are just a few of the particular environmental issues facing the Arabian Gulf region that significantly limit agricultural productivity [11]. The challenging circumstances necessitate the creation of robust, multipurpose crop systems that can support the production of renewable energy, provide livestock feed, and increase food security all at once. Finding and optimizing crops that can flourish in these conditions is crucial since traditional farming methods are becoming unsustainable because of their heavy reliance on energy-intensive irrigation and depletion of limited freshwater resources.

Sorghum bicolor variety, or sweet sorghum. In the arid and semi-arid regions of the world, saccharatum has become a very promising option for sustainable agriculture. Because it is a C4 plant with excellent photosynthetic efficiency, high water-use efficiency, and an innate resistance to heat and salinity, it is particularly well-suited to the harsh climate of the area. The biomass provides a nourishing forage for cattle, and the stalks, which are rich in fermentable sugars, are a valuable feedstock for bioethanol. Because of its dual-purpose potential, sweet sorghum is positioned as a key component of integrated food-feed-energy systems, providing a clear route to lowering dependency on imports, preserving valuable water resources, and achieving renewable energy goals.

Despite its recognized potential, a holistic, systems-level understanding of sweet sorghum's role within the Arabian Gulf's unique agricultural landscape is still lacking. Much of the existing literature focuses on isolated agronomic traits or specific case studies, failing to provide an integrated perspective on its multifaceted contributions. This study aims to fill that gap by providing a comprehensive synthesis of current knowledge on sweet sorghum's dual-use potential for feed and bioenergy in the Arabian Gulf, with the following objectives:

Evaluate the climate adaptability and performance of sweet sorghum under the extreme environmental conditions of the region.

Assess its tolerance to saline soils and its water-use efficiency in arid agricultural systems, incorporating recent quantitative data.

Synthesize evidence on its end-use quality for both livestock feed (including safety) and bioenergy production (ethanol yields).

Analyze its economic viability and regeneration potential within the context of desert and urban-fringe agriculture.

Identify key knowledge gaps to guide future research toward successful pilot-scale implementation and adoption.

Novelty and Contributions:

This systems-level synthesis offers a novel and integrated perspective on sweet sorghum's potential within the Arabian Gulf's agricultural systems. Its primary contributions are [5]:

Integrated Dual-Purpose Assessment: Moving beyond single-use evaluations, this study provides a holistic analysis of sweet sorghum's combined value for both livestock feed and bioenergy, highlighting synergies and trade-offs within the specific context of the Gulf.

Quantitative Synthesis for Arid Regions: By consolidating recent quantitative data on yields, water-use efficiency, and ethanol production from arid environments, this work provides robust, empirical support for sweet sorghum's resilience and productivity.

Strategic Alignment with Regional Goals: The research explicitly links sweet sorghum cultivation to the Arabian Gulf's long-term sustainability and energy diversification targets, presenting a strategic blueprint for regional agricultural development [12].

Identification of Critical Knowledge Gaps: This study identifies the key knowledge gaps, such as cultivar performance in high humidity and local seed system development, that currently hinder widespread adoption, providing a clear roadmap for future research.

Approach and Evidence Synthesis:

This study employs a systematic systems-level synthesis to evaluate the potential of sweet sorghum as a dual-use crop in the Arabian Gulf. The methodology integrates a comprehensive review of existing literature, with a focus on recent advancements (2021–2026), to provide a current and evidence-based perspective.

Peer-reviewed studies, institutional reports, and extension resources published primarily between 2005 and 2025 were examined using databases including Google Scholar, ScienceDirect, Wiley Online Library, MDPI, and Frontiers. Additional materials were sourced from international organizations such as the Food and Agriculture Organization (FAO) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Earlier foundational studies were included where necessary to contextualize crop physiology and stress tolerance.

Findings were synthesized thematically across six analytical dimensions, including climate adaptability, soil and salinity response, water regimes, end-use quality, safety considerations, and regeneration and economic viability. Extracted variables included climate conditions, soil characteristics, irrigation strategies, cultivar performance, biomass and sugar yield, ethanol potential, forage nutritive value, and livestock safety indicators. Emphasis was placed on studies conducted in arid and semi-arid regions with climatic or edaphic similarities to the Arabian Gulf.

The synthesis prioritizes functional relevance to desert farming systems, focusing on how sweet sorghum integrates into food–feed–energy pathways under resource-limited conditions rather than on individual experimental outcomes in isolation.

Evidence Synthesis Process:

A broad search of the literature was conducted, including academic and grey literature in databases including Scopus, Web of Science, and Google Scholar using keywords such as "sweet sorghum," "Arabian Gulf," "arid agriculture," "water-use efficiency," "salinity tolerance," and "bioenergy." Titles and abstracts were screened for methodological rigor, and full-text articles were critically appraised. Quantitative metrics (e.g., yield, water-use efficiency) and qualitative information (e.g., end-use quality, economic viability) were extracted and synthesized thematically to identify overarching patterns and insights [13][9].

Environmental Climate Fit:

Sweet sorghum (*Sorghum bicolor* var. *saccharatum*) has demonstrated strong adaptability to the climate challenges prevalent in the Arabian Gulf. This crop belongs to the C4 group, which means it uses sunlight and water more efficiently than many traditional crops. Because of this physiology, it can continue growing and producing biomass even in very hot and dry environments where other plants usually fail. Studies have consistently reported that sorghum needs less water than maize or sugarcane to reach comparable yields, making it a better fit for arid and semi-arid regions [14].

One of the most important traits for the Gulf region is heat tolerance. Temperatures in the summer can reach above 45°C, which stresses most crops. Sweet sorghum, however, has been shown to keep its growth steady and continue accumulating sugars in its stalks under such conditions. Research shows that chlorophyll activity and sugar production remain stable even under extreme heat, something maize and sugarcane struggle with [3].

Drought resistance is another reason this crop is promising. Work from ICRISAT and FAO has shown that sweet sorghum maintains respectable yields even with reduced irrigation, and in some cases under rainfed conditions. Its water-use efficiency (WUE) is higher than that of many conventional crops, and even when water is limited, the °Brix (sugar concentration) remains high enough for syrup or ethanol production. Field trials in India, Africa, and parts of the Middle East confirm that sorghum can deliver useful yields when other crops face major reductions.

In short, the ability of sweet sorghum to handle both high heat and low water availability makes it one of the most climate-adapted crops for the Arabian Gulf. Its resilience ensures that, unlike maize or sugarcane, it can be considered a realistic option for agriculture in desert conditions.

Soil and Salinity Response:

Soil conditions in the Arabian Gulf are among the toughest for agriculture, with most areas dominated by sandy desert soils that have low organic matter and poor water-holding capacity. Around cities and coastal zones, soils may also contain higher salinity or variable textures such as sandy loam or silty sand. These conditions make crop production difficult, but sweet sorghum has shown an ability to grow in such challenging environments.

Sorghum is naturally more tolerant of saline conditions than many crops [15]. Studies report that sweet sorghum can maintain growth and yield at moderate salinity levels where crops like maize or wheat decline sharply. Even though high salinity reduces total biomass, sugar concentration in the stalks (Brix) often remains stable, which means the crop can still be useful for ethanol or syrup production. This is particularly important for the coastal soils of the Arabian Gulf, where groundwater often has elevated salt levels.

Soil fertility also plays a role. Research indicates that adding organic matter such as compost or manure improves sorghum performance in sandy soils by increasing water retention and nutrient availability. This suggests that with relatively simple amendments, sweet sorghum can adapt to the common soil types surrounding desert cities in Saudi Arabia and neighboring Gulf states.

Overall, the evidence shows that sweet sorghum can withstand both poor sandy soils and moderate salinity, making it a practical candidate for agriculture in desert and coastal regions of the Arabian Gulf.

Water Regimes (mineral/ irrigation):

Water scarcity is one of the biggest constraints on agriculture in the Arabian Gulf. Irrigation relies heavily on desalination or groundwater extraction, both of which are energy-intensive. Any crop grown in this region must therefore demonstrate high water-use efficiency and flexibility under different irrigation conditions.

Sweet sorghum has been widely studied under deficit irrigation and with nontraditional water sources, such as brackish and reclaimed water. Research has shown that while reduced irrigation decreases total biomass, sorghum often maintains sugar content in the stalks, allowing continued ethanol production and forage use. In many trials, sorghum produced more output per unit of water than maize or sugarcane, making it more water-productive in dryland systems.

Another advantage is the crop's tolerance to saline or partially treated wastewater. Studies in arid zones confirm that sweet sorghum can handle irrigation with moderate salinity levels without major losses in °Brix. This is highly relevant for Gulf agriculture, where blending freshwater with brackish sources is common.

Taken together, the evidence suggests that sweet sorghum can perform under full irrigation, deficit regimes, or brackish/reclaimed water systems. This flexibility gives it a clear advantage in water-limited regions like the Arabian Gulf, where irrigation costs and availability are major barriers to sustainable farming.

End-Use Quality:

One of the major advantages of sweet sorghum is its versatility. The crop produces multiple outputs that make it attractive for regions like the Arabian Gulf, where efficiency and diversification are essential. The stalks contain fermentable sugars that can be processed into syrup or bioethanol; the grains can be used for human food or animal feed; and the biomass can be harvested as forage for livestock. This "food-feed-fuel" triad makes sweet sorghum more valuable than many other crops that provide only a single use.

Research on ethanol potential has reported yields ranging between 6,000 and 8,000 liters per hectare under favorable conditions. Importantly, even under stress conditions such as deficit irrigation or moderate salinity, sugar concentration (Brix) in the stalks remains relatively stable, meaning the crop can still produce fermentable sugars even when biomass yield is reduced. For livestock, *sweet sorghum* forage shows acceptable crude protein (CP) and fiber values (NDF, ADF), often comparable to maize silage, though fiber levels can be slightly higher. These results indicate that *sweet sorghum* can provide both renewable energy and feed without compromising quality.

Safety Considerations:

While sweet sorghum is promising as a forage crop, there are safety issues that must be managed carefully. Like other sorghums, it can accumulate prussic acid (hydrogen cyanide, HCN) and nitrates under certain stress conditions, such as drought, frost, or at very young growth stages. These compounds can be harmful to livestock if consumed in high amounts. However, studies show that proper management practices significantly reduce the risk. For example, ensiling (fermenting the forage before feeding) lowers HCN levels, and delaying harvest until plants are mature also minimizes both nitrate and prussic acid content.

Reports from extension bulletins and animal nutrition trials confirm that, when managed properly, sweet sorghum forage can be fed safely to cattle, sheep, and goats without negative effects on performance. Therefore, while risks exist, they are not a barrier to adoption if farmers follow basic safety protocols.

Regeneration, Seed Supply, and Economics:

Another important factor for the Arabian Gulf is how farmers can sustain the production of sweet sorghum over multiple seasons. Two main approaches exist: ratooning (allowing the plant to regrow from stubble after the first harvest) and reseeding. Studies show that ratooning can provide a useful second harvest with reduced input costs, though yields are often slightly lower than the first cut. This system saves both labor and seed, which is critical in resource-limited settings.

Seed supply is also a key issue for the region. Since sweet sorghum is not yet widely grown in the Gulf, initial seed may need to be sourced from the United States or other countries where commercial varieties are available. If trials are successful, local multiplication programs could provide long-term access to adapted cultivars.

From an economic perspective, sweet sorghum is attractive because it produces both feed and fuel while using less water than forage or sugarcane [16]. Partial budgeting studies suggest that when water savings and by-products are accounted for, sweet sorghum can be more profitable in dryland systems than traditional forage crops like Rhodes grass or alfalfa. These factors position it as a crop that can support food security, renewable energy goals, and economic sustainability in the Arabian Gulf.

Discussion and Implications:

When all six analytical dimensions are considered together, sweet sorghum (*Sorghum bicolor* var. *saccharatum*) shows strong potential for agriculture in the Arabian Gulf. The evidence highlights its ability to operate in extreme environments while producing multiple valuable outputs.

In terms of environmental–climate fit, sweet sorghum continues producing biomass and sugars even under very high temperatures. However, the potential impact of high humidity, common in coastal Gulf areas, on promoting fungal diseases should be investigated. While many studies report tolerance above 40°C, in Saudi Arabia and neighboring Gulf states, summer temperatures often exceed 45–50°C. Under such heat, bare soils and non-vegetated lands can become several degrees hotter than planted fields. Research shows that vegetative cover lowers ground surface temperature by shading the soil and reducing heat reflection. In this way, planting sweet sorghum could help moderate local microclimates. This is significant because the heavy use of air conditioning in the region contributes both to high energy demand and additional heat release into the environment. If crops like sweet sorghum are adopted more widely, they could indirectly reduce nighttime heat intensity, potentially lowering AC demand and improving living conditions.

For soil and salinity response, Saudi Arabia is dominated by sandy desert soils with very low organic matter, especially away from oases and irrigated areas. Around urban fringes, soils can also be sandy loams or silty sands, often with moderate salinity from irrigation water. Sweet sorghum shows resilience to these conditions, tolerating salinity levels of 4–6 dS/m where maize and other cereals fail. Soil amendments such as compost or manure further enhance its growth by improving water retention. This means sorghum can realistically be grown not only in pure desert soils but also in the mixed soils surrounding Gulf cities.

Regarding water regimes, sweet sorghum has been proven to deliver high yields with less irrigation. Compared to sugarcane and other crops, it uses 30–50% less water to produce similar ethanol yields. Even under deficit irrigation, sorghum maintains sugar concentration (°Brix) in stalks, which is critical for ethanol or syrup production. In practical terms, this means sorghum can produce 40–60 liters of ethanol per ton of stalk, and total yields may reach 6,000–8,000 L/ha under favorable conditions. This efficiency provides a renewable energy pathway: stalk sugars can be fermented into bioethanol, offering a local alternative to fossil fuels and reducing dependence on oil-based energy.

For end-use quality, sweet sorghum's strength lies in its versatility. It provides grain for food and feed, syrup or ethanol for bioenergy, and biomass for forage. Forage crude protein values are typically around 7–10%, which is adequate for cattle and small ruminants. This multi-use profile makes it especially valuable in Gulf agriculture, where maximizing returns from limited land and water is critical.

Safety considerations remain important for livestock feeding. Sorghum can accumulate nitrates and prussic acid (HCN), especially when stressed by drought or harvested too early. These compounds can be toxic to animals if unmanaged. However, ensiling reduces HCN content by 50–70%, and delaying harvest until maturity reduces nitrate levels. Studies confirm that, when managed properly, sweet sorghum forage is safe for cattle, sheep, and goats, making it a reliable source of feed.

Finally, regeneration and economics add to its practicality. Ratooning allows for a second harvest with 25–30% lower input costs compared to replanting. Seed sourcing is initially a challenge, but varieties from the United States can be imported for Gulf trials, and if successful, seed multiplication programs could be developed locally. Economically, sorghum outperforms Rhodes grass and alfalfa in water productivity and offers the additional benefit of renewable energy production. This positions it as a strong contributor not only to food security but also to Saudi Arabia's Vision 2030 goals of renewable energy, reduced food imports, and sustainable desert agriculture.

In my opinion, the biggest strength of sweet sorghum is how it combines resilience (heat, drought, salinity tolerance) with versatility (food, feed, and biofuel). Unlike crops that demand constant inputs, sorghum adapts to the Gulf's harsh realities and even provides solutions to broader challenges such as high AC energy demand and dependence on imports. If scaled carefully, it could reshape agriculture in the region.

Results:

This section presents the synthesized findings on sweet sorghum's performance and potential within the Arabian Gulf, drawing upon recent literature and quantitative data.

Agronomic Performance and Yields:

Sweet sorghum demonstrates robust agronomic performance in semi-arid environments. Studies report fresh biomass yields ranging from 65–95 t ha^{-1}, with converted sugar yields (CSY) reaching up to 7.82 Mg ha^{-1} under optimized conditions. These figures underscore its capacity for substantial productivity in challenging climates table 1.

Table 1. Range of fresh biomass yield, converted sugar yield (CSY), theoretical ethanol yield, and Brix content reported for sweet sorghum.

Metric	Value Range / Specific Value	Source
Fresh Biomass Yield	65–95 t ha^{-1}	1
Converted Sugar Yield (CSY)	Up to 7.82 Mg ha^{-1}	1
Theoretical Ethanol Yield	3,152–4,572 L ha^{-1}	1
Brix Content	16.32% to 20.28%	1

Metric Value Range / Specific Value Source:

Fresh Biomass Yield 65–95 t ha^{-1}. Converted Sugar Yield (CSY) Up to 7.82 Mg ha^{-1}. Theoretical Ethanol Yield 3,152–4,572 L ha^{-1}. Brix Content 16.32% to 20.28%.

Water-Use Efficiency and Salinity Tolerance:

High water-use efficiency (WUE) and considerable salinity tolerance are critical traits for sustainable agriculture in the Arabian Gulf. Sweet sorghum typically requires 30–50% less irrigation water than sugarcane. Crop Water Productivity (CWP) for stalk yield ranges from 35.04–35.91 kg m^{-3}, and for ethanol, it is 1.05–1.08 L m^{-3}. The crop can tolerate soil salinity up to 6.8 dS m^{-1} and water salinity up to 4.5 dS m^{-1} without significant yield loss. Beyond these thresholds, a 16% yield reduction per unit increase in salinity has been observed table 2.

Table 2. Water use efficiency, irrigation reduction potential, and salinity tolerance characteristics of sweet sorghum compared with conventional bioenergy crops.

Metric	Value Range / Specific Value	Source
Irrigation Water Reduction (vs. sugarcane)	30–50% less	1
Crop Water Productivity (Stalk Yield)	35.04–35.91 kg m^{-3}	1
Crop Water Productivity (Ethanol)	1.05–1.08 L m^{-3}	1
Soil Salinity Tolerance	Up to 6.8 dS m^{-1}	2
Water Salinity Tolerance	Up to 4.5 dS m^{-1}	2

Metric Value Range / Specific Value:

Irrigation Water Reduction (vs. sugarcane) 30–50% less Crop Water Productivity (Stalk Yield) 35.04–35.91 kg m^{-3} Crop Water Productivity (Ethanol) 1.05–1.08 L m^{-3} Soil Salinity Tolerance Up to 6.8 dS m^{-1} Water Salinity Tolerance Up to 4.5 dS m^{-1}.

Dual-Use Potential for Feed and Bioenergy:

Sweet sorghum's versatility is evident in its ability to provide both high-quality livestock feed and a sustainable feedstock for bioenergy. Its biomass can be safely ensiled for animal feed , while its fermentable sugars are efficiently converted into ethanol, with recovery rates of 10 to 55 liters per metric ton of crushed stalks. This dual functionality makes it a key component for integrated food-feed-energy systems.

Conclusion:

Across six analytical dimensions—environmental climate fit, soil and salinity response, water regimes, end-use quality, safety considerations, and regeneration and economics—the evidence consistently shows that sweet sorghum can adapt to extreme heat, tolerate poor and saline soils, and deliver valuable outputs under limited water availability. This systems-level synthesis confirms the significant potential of sweet sorghum as a strategic dual-use crop for the Arabian Gulf

The crop's ability to thrive at temperatures often reaching 45–50°C, combined with its high water-use efficiency, makes it particularly well suited to the Gulf's challenging environment. Its multi-use profile supports food, feed, and fuel production, with ethanol yields reported at 6,000–8,000 L/ha and forage values comparable to maize silage. While safety concerns such as nitrate and prussic acid accumulation may occur, management practices, including ensiling and delayed harvest, can effectively reduce these risks and ensure safe livestock feeding.

From an economic perspective, ratooning systems can reduce production costs and improve long-term sustainability. Initial seed sourcing from the United States could support early pilot trials in the region, while the development of local seed multiplication programs would strengthen long-term adoption. Economically, the crop also has the potential to stimulate regional value chains in bioenergy and livestock production [17].

The broader implications of adopting sweet sorghum in Gulf agriculture are substantial. Strategically, it may help reduce reliance on imported food and feed. Environmentally, its lower water requirements could generate significant water savings in a water-stressed region [18]. At the same time, integrating sweet sorghum into regional farming systems aligns with broader sustainability goals, supporting renewable biofuel production, water conservation, and agricultural resilience.

Sweet sorghum, therefore, represents more than just a crop—it offers a pathway to balance food security, energy diversification, and environmental sustainability in desert agriculture. However, realizing this potential will require addressing key knowledge gaps, particularly regarding cultivar performance under Gulf conditions and the development of reliable seed supply systems. With appropriate research investment, policy support, and farmer adoption, sweet sorghum could become a cornerstone of sustainable farming systems in the Arabian Gulf and other regions with similar arid climates.

Recommendations: To facilitate the successful adoption of sweet sorghum in the Arabian Gulf, we propose the following recommendations:

Cultivar Trials and Selection: Conduct extensive field trials to identify and develop cultivars best adapted to local soil conditions, extreme heat, and humidity.

Development of Local Seed Supply Systems: Establish robust local seed production and distribution systems to ensure a reliable supply of high-quality, climate-adapted seeds.

Pilot-Scale Implementation: Initiate pilot-scale projects to demonstrate the practical feasibility and economic viability of sweet sorghum in various agricultural settings.

Policy Support and Incentives: Develop supportive policies and economic incentives to encourage the adoption of sweet sorghum cultivation and utilization.

Further Research on Integrated Systems: Continue research into optimizing integrated food-feed-energy systems, focusing on nutrient cycling, pest management, and economic modeling.

Public Awareness and Education: Launch educational campaigns to raise awareness among farmers, extension workers, and the public about the benefits and best practices of sweet sorghum cultivation.

By systematically addressing these recommendations, the Arabian Gulf can harness the full potential of sweet sorghum to build more resilient, water-efficient, and sustainable agricultural systems for the future.

References:

[1] Mustafa El-Rawy, Heba Fathi, "Potential Effects of Climate Change on Agricultural Water Resources in Riyadh Region, Saudi Arabia," *Sustainability*, vol. 15, no. 12, p. 9513, 2023, [Online]. Available: https://www.mdpi.com/2071-1050/15/12/9513

[2] "Beyond Scarcity: Water Security in the Middle East and North Africa." Accessed: Feb. 22, 2026. [Online]. Available: https://www.worldbank.org/en/topic/water/publication/beyond-scarcity-water-security-in-the-middle-east-and-north-africa

[3] A. Almodares, M. R. Hadi, "Production of bioethanol from sweet sorghum: A review," *Int. J. Agric. Sci.*, vol. 9, no. 2, 2019, [Online]. Available: https://www.internationalscholarsjournals.com/articles/production-of-bioethanol-from-

sweet-sorghuma-review.pdf

[4] Lilianna Głab, Józef Sowiński, "Sustainable Production of Sweet Sorghum as a Bioenergy Crop Using Biosolids Taking into Account Greenhouse Gas Emissions," *Sustainability*, vol. 11, no. 11, p. 3033, 2019, [Online]. Available: https://www.researchgate.net/publication/333461497_Sustainable_Production_of_Sweet_Sorghum_as_a_Bioenergy_Crop_Using_Biosolids_Taking_into_Account_Greenhouse_Gas_Emissions

[5] M A ; Alsanad, E I R Emara, "Optimizing Bioethanol (C2H5OH) Yield of Sweet Sorghum Varieties in a Semi-Arid Environment: The Impact of Deheading and Deficit Irrigation," *Water*, vol. 16, no. 10, p. 1456, 2024, doi: https://doi.org/10.3390/w16101456.

[6] C.V. Ratnavathi, K. Suresh,B.S. Vijay Kumar, M. Pallavi, V.V. Komala, N. Seetharama, "Study on genotypic variation for ethanol production from sweet sorghum juice," *Biomass and Bioenergy*, vol. 34, no. 7, pp. 947–952, 2010, [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0961953410000577

[7] " Sweet sorghum—A potential alternate raw material for bio-ethanol and bio-energy." Accessed: Feb. 22, 2026. [Online]. Available: https://www.researchgate.net/publication/26507813_Sweet_sorghum-A_potential_alternate_raw_material_for_bio-ethanol_and_bio-energy

[8] Rodrigo Rafael da Silva, José Francismar de Medeiros, "Ionic Response and Sorghum Production under Water and Saline Stress in a Semi-Arid Environment," *Agriculture*, vol. 13, no. 6, p. 1127, 2023.

[9] Food and Agriculture Organization of the United Nations, "Sorghum and millets in human nutrition," *Rome Food Agric. Organ. United Nations ; Lanham, MD UNIPUB*, 1995, [Online]. Available: https://archive.org/details/sorghummilletsin00food

[10] "Sweet sorghum: food, feed, fodder and fuel crop." Accessed: Feb. 22, 2026. [Online]. Available: https://www.researchgate.net/publication/277231164_Sweet_sorghum_food_feed_fodder_and_fuel_crop

[11] Afreen Siddiqi, Laura Diaz Anadon, "The water–energy nexus in Middle East and North Africa," *Energy Policy*, vol. 39, no. 8, pp. 4529–4540, 2011, [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0301421511003065

[12] Behnaz Saboori, Noor Alhuda Alhattali, Tarig Gibreel, "Agricultural products diversification-food security nexus in the GCC countries; introducing a new index," *J. Agric. Food Res.*, vol. 12, p. 100592, 2023, [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2666154323000996

[13] "Sweet Sorghum: A Smart, Multipurpose Crop." Accessed: Mar. 10, 2026. [Online]. Available: https://www.researchgate.net/publication/345807558_Sweet_Sorghum_A_Smart_Multipurpose_Crop

[14] D. Midmore, "Rainfed Agriculture: Unlocking the Potential. Comprehensive Assessment of Water Management in Agriculture Series 7. Edited by S. P. Wani, J. Rockstrom and T. Owels. Wallingford, UK: CABI (2009), pp. 310, £85.00. ISBN 978-1-84593-389-0.," *Exp. Agric.*, vol. 46, no. 1, pp. 115–115, Jan. 2010, doi: 10.1017/s0014479709990664.

[15] E. V. Maas and G. J. Hoffman, "Crop salt tolerance–current assessment," *ASCE J Irrig Drain Div*, vol. 103, no. 2, pp. 115–134, Jun. 1977, doi: 10.1061/jrcea4.0001137.

[16] P. Srinivasa Rao, C. Ganesh Kumar, and B. V. S. Reddy, "Sweet Sorghum: From Theory to Practice," *Charact. Improv. Sweet Sorghum Cultiv.* , pp. 1–15, 2013, doi: 10.1007/978-81-322-0783-2_1.

[17] "India eyes sweet sorghum as alternative feedstock to boost ethanol production | S&P Global." Accessed: Mar. 10, 2026. [Online]. Available: https://www.spglobal.com/energy/en/news-research/latest-news/agriculture/111124-india-eyes-sweet-sorghum-as-alternative-feedstock-to-boost-ethanol-production

[18] "(PDF) Production of bioethanol from sweet sorghum: A review." Accessed: Sep. 18, 2025. [Online]. Available: https://www.researchgate.net/publication/228616516_Production_of_bioethanol_from_sweet_sorghum_A_review