Journal of Agriculture and Rural Development Studies
Volume 2 – Issue 4 – 2025
ISSN Online 3061-2756
www.imadr.jards.ugal.ro

DOI https://doi.org/10.35219/jards.2025.4.12

Rice Production: A Scientific Perspective on the Challenges of Climate Change and Global Demand

Raghad S. Mouhamad*

ARTICLE INFO

Article history:
Received: November 07, 2025
Accepted: December 15, 2025
Published: December 17, 2025

Keywords:
Salt-Tolerant Rice Varieties, Salinity Challenges, Rice farming, Semi-arid region

ABSTRACT

Climate change and increasing world demand bring unprecedented challenges to rice, a basic food for more than 50% of the people in the world. The crop needs much water and is thus very sensitive to an increased scarcity of water and changes in climate patterns. Iraq has for many years been known for fertile land with extended irrigation systems but is now facing severe constraints in maintaining sustainable rice production due to high temperatures, decreased water, and soil degradation. Over the past few decades, global rice demand has increased due to population growth, urbanization, and improved economic conditions. However, meeting this demand calls for productivity and innovative sustainable agricultural practices that take care of the environment and other ecological structures. The southern parts of Iraq have a great economic and cultural heritage associated with rice cultivation, particularly under traditional, highly water-intensive cultivation of Anbar-33. Moreover, decreasing flow volumes of the Tigris and Euphrates resulting from upstream water management and prolonged periods of drought have drastically reduced the available water for agriculture. Such problems need to be dealt with in a comprehensive manner. Resilient systems that have emerged, such as the System of Rice Intensification (SRI), which require less water and chemical inputs, have already shown promise of increasing production. Recently, modern irrigation technologies such as localized irrigation and under-the-ground irrigation have been suggested to reserve water. Yet, limitations in Iraq's farming sector including a lack of knowledge by the farmers, unsupportive policies, and economic inequality mean that these practices are not easily adopted. Besides, the agricultural background in Iraq implies hope of resilience and recovery: since the country at one point managed to provide enough cereals in the years 1970-1980, it has since lost several decades due to wars and conflicts, embargos, and mismanagement of natural resources. Reviving rice output today isn't just about food safety; it steps towards bringing back farm sustainability plus economic balance. Even as Iraq faces the effects of climate change head on, new solutions, teamwork in research, and steps in policy need to happen to beat the hurdles against rice farming. Through tapping into the rise of science and building cross-border ties, Iraq can steer through these intricate shifts, guaranteeing a path forward for cultivating rice even as challenges mount from nature and society.

1. Introduction

The increasing rapid climate change and the demand for rice at the international level are major challenges of the agricultural sector in Iraq. The major threats include irregular rainfall distribution, high rates of temperature rise, and increased extreme climatic conditions—a scenario that is exacerbated by

*Scientific Research Commission, Baghdad, Iraq. E-mail address: raghad.s.mouhamad@src.edu.iq (R. S. Mouhamad)

most challenges to crop productivity (Al-Kadhim and Al-Hassan, 2023). Rice is a staple in Iraq; therefore, it needs large amounts of water, especially during the most critical growing stages. These further stresses the already limited water resources in the country (Hassan et al., 2023). High international demand for rice due to increased human population and economic growth further calls for sustainable agricultural practices as an approach to ensure food security and, at the same time meeting environmental sustainability criteria (Al-Tamimi et al., 2022).

The challenges of socio-economics facing Iraq have thwarted the successful adoptions of such solutions even though great efforts have been invested in implementing new agricultural methodologies; for example, System of Rice Intensification (SRI) and drip irrigation. A major part of the challenge would again require the government to provide support and adequately train farmers on how to adopt and effectively implement these practices (Hassan et al., 2023). The findings of Al-Khalidi and Al-Masri (2014) revealed that improved irrigation techniques would enhance the productivity of agriculture to very sustainable levels. Up to the 70s and 80s, fertile land and irrigation from the Tigris and Euphrates rivers saw Iraq self-sufficient in grain production. But conflict effects and even economic sanctions over the years took a heavy toll on the agricultural industry, reducing productivity and increasing the country's dependence on food imports (Hanna, 2002; Al-Saadi, 1995). For decades now, as articulated in the FAO (2005) and Al-Rawi and Al-Hamadi (2007), major challenges have been experienced in the southern regions surrounding water scarcity and ineffective resource management, both of which have direct effects on rice production. Recent studies have pinpointed the factor of salinity stress as a major challenge to food security in Iraq, with over half of the cultivated rice lands falling victim to salinity. The cultivation of salt-tolerant rice varieties has proved to be a solution that is feasible for such areas, and that it leads to productivity (Munns and Tester, 2008). Other factors such as climate changes, high temperatures, and prevailing drought conditions have deteriorated the quality of crops and lessened the yield. Hence, more research is needed on optimal practices for rice cultivation (Aziz et al., 2015; Kosova et al., 2013). Collaboration with international research institutions like the International Rice Research Institute (IRRI) would be the right approach to take the steps necessary for enhancing rice productivity in an unfavorable environment. Such collaboration became possible in the last couple of years, directed at salt-tolerant rice genotypes for the salty regions, where southern Iraq and the Ganges Delta in Bangladesh have been the focal point of IRRI intervention (IRRI Annual Report, 2022; Al-Araji et al., 2023).

1.1. Objectives of the Study

This study explores how environmental stressors, on-farm conditions, and socio-economic factors influence rice production in arid regions, especially in the context of water scarcity, climate variability, and rising global demand. The objective is to highlight practical, evidence-based strategies that can enhance food security, increase productivity, and support the long-term resilience of farming communities.

1.2. Justification of the Study:

Iraqi rice production is at a turning point, with climate change, water shortages, salinity soil, and growing global demand putting increasing stress on both farmers and the environment. Because rice requires large amounts of water, it is particularly vulnerable to drought, higher temperatures, and reduced flows in the Tigris and Euphrates rivers. These problems are particularly serious in southern Iraq, where rice plays a central role not just as a food crop but also in supporting the local economy, culture, and community traditions. While there are modern approaches available—like improved irrigation, water-conserving techniques, and salt-tolerant rice varieties—these practices are still rarely used. support Limited, proper training for farmers, and policies that fail to translate research into actionable practices have slowed the adoption of solutions. This gap between what is known and what is applied continues to make sustainable production a challenge in the Iraq. This study is therefore important to provide a thorough understanding of the environmental, agricultural, and socio-economic factors that shape rice farming in Iraq. It aims to generate insights that can guide realistic strategies to improve productivity, resource management, and resilience in the sector. Its goal is to identify practical strategies that increase productivity, conserve water, and build resilient farming systems. By linking research with action, the study aims to support food security and help rebuild sustainable rice farming in Iraq under mounting environmental and societal pressures.

2. Literature review

The literature highlights Rice is the major caloric source for more than half of the world's population, and demand is expected to rise further, particularly in Asia and Africa, where population growth and dietary changes are accelerating (Ansari et al., 2021; Farooq et al., 2023). This growing need for rice is unfolding at a time when climate change is reshaping agricultural systems worldwide. Higher temperatures, irregular rainfall, extreme climatic events, and increased pest and disease pressures have all been identified as major factors reducing rice yields and affecting grain quality (Rezvi et al., 2022); (Li et al., 2025); (Fei et al., 2020); (Zhao et al., 2022). Among the challenges facing rice cultivation, water scarcity stands out as one of the most critical. Rice cultivation is heavily dependent on irrigation; hence, any alteration in precipitation or water availability jeopardizes critical rice-producing regions (Algarni et al., 2025; Habib Ur Rahman et al., 2022; Joseph et al., 2023).Although a few localized environments may experience slight yield improvements due to specific climatic conditions, the overall trend across Southeast Asia, South Asia, and Africa points toward declining production. This decline raises concerns about the future of global food security and the stability of rice markets (Wu et al., 2020); (Saud et al., 2022); (Guidigan et al., 2025).Researchers have suggested several techniques to adapt to these demands. Some of these efforts are to make rice varieties that can handle environmental stress, to improve the nutrient content of rice through biofortification, to use precision agriculture technologies, to make irrigation more efficient, to change planting schedules, and to give farmers more policy support (Algarni et al., 2025; Rezvi et al., 2022; Farooq et al., 2023; Li et al., 2024; Joseph et al., 2023; Gao et al., 2025; Rahman & Zhang, 2022). Individuals are not capitalizing on these readily accessible opportunities. Numerous agricultural communities lack the requisite institutional support, training, or resources to adopt these novel approaches (Ansari et al., 2023; Hussain et al., 2020). The findings unequivocally indicate the necessity for a comprehensive strategy encompassing innovative technologies, enhanced agricultural practices, and synchronized governmental initiatives to safeguard rice production against climate change. Without a strategy such as this, it will increasingly become more challenging to farm rice and ensure sufficient food for all (Farooq et al., 2023; Li et al., 2025; Habib Ur Rahman et al., 2022).

3. Research Methodology

This review adopts a descriptive and analytical methodology to examine the challenges and opportunities in rice production in Iraq under climate change, salinity stress, and rising global demand. The study synthesizes findings from peer-reviewed literature, institutional reports, and collaborative research initiatives. The increasing rapid climate change and the demand for rice at the international level are major challenges of the agricultural sector in Iraq. The major threats include irregular rainfall distribution, high rates of temperature rise, and increased extreme climatic conditions—a scenario that is exacerbated by most challenges to crop productivity (Al-Kadhim and Al-Hassan, 2023). Rice is a staple in Iraq; therefore, it needs large amounts of water, especially during the most critical growing stages. These further stresses the already limited water resources in the country (Hassan et al., 2023). High international demand for rice due to increased human population and economic growth further calls for sustainable agricultural practices as an approach to ensure food security and, at the same time meeting environmental sustainability criteria (Al-Tamimi et al., 2022). The challenges of socio-economics facing Iraq have thwarted the successful adoptions of such solutions even though great efforts have been invested in implementing new agricultural methodologies; for example, System of Rice Intensification (SRI) and drip irrigation. A major part of the challenge would again require the government to provide support and adequately train farmers on how to adopt and effectively implement these practices (Hassan et al., 2023). The findings of Al-Khalidi and Al-Masri (2014) revealed that improved irrigation techniques would enhance the productivity of agriculture to very sustainable levels. Recent studies have pinpointed the factor of salinity stress as a major challenge to food security in Iraq, with over half of the cultivated rice lands falling victim to salinity. The cultivation of salt-tolerant rice varieties has proved to be a solution that is feasible for such areas, and that it leads to productivity (Munns and Tester, 2008). Other factors such as climate changes, high temperatures, and prevailing drought conditions have deteriorated the quality of crops and lessened the yield. Hence, more research is needed on optimal practices for rice cultivation (Aziz et al., 2015; Kosova et al., 2013). The study based on the collaborative research International Rice Research explored genetic diversity and response in 92 rice genotypes (31st IRSSTN-SS1 and 31st IRSSTN-SS2) under salt stress conditions (50 mM NaCl, Ece = 6 ds/m-1). The main focus of this study was to determine how genetic diversity affects the response of rice to nutrient availability under salinity. Rice grains are particularly more nutrient deficient; most of the nutrients are extremely concentrated in rice bran (pericarp, and seed coat, nucellus, and aleurone layer), and the nutrient contents represent approximately 28% to that found in polished white rice after milling (Aziz et al., 2015). Grain quality of rice is greatly influenced by salt stress imposed during the flowering, vegetative, and grain-filling stages (Sakina et al., 2015; Kumar et al., 2014; 2015; Kshirsagar et al., 2014).

4. Result and Discussion

4.1 Challenges in Rice Production in Iraq: Economic and Social Factors, Technological Adoption, and Climate Change Impacts

The agriculture sector has traditionally been the economic mainstay of Iraq; during 2001, it contributed approximately 6.1% to its GDP (Figure 1). In 1980s and 1970s, Iraq could fully achieve grains self-sufficiency because there was fertile land and good irrigation systems supported by the Tigris and Euphrates rivers. Such conditions would make this country one with guaranteed food security through agriculture. The impact of war and embargos had already greatly negative effects on the agricultural sector. This has turned the situation in Iraq from an exporter to an importer of food. Agricultural output dropped drastically between 1990 and 2000 because the past wars led to ill mismanagement which wore out irrigation systems and the available water resources could not sustain the food requirements of the population; thus, the nation has to raise food imports (Al-Saadi, 1995). In the hunger circle that placed Iraq in by the end of the second decade of the twenty-first century was to have become one of the major nations that import rice even though it has arable land. It never exceeded 4-5 million hectares on an annual basis out of 8 million hectares of arable land (FAO, 2005). As for problems with water shortage, they persist in the rice production sector, especially in the Euphrates region (Al-Rawi and Al-Hamadi, 2007). Challenges in social and economic issues hinder the adoption of such technologies at an increased rate. Training of farmers as well as the provision of resources and government support needs to be put in place for these solutions to be sustained. Initiatives that take part should be developed in an effort to work against the stakes of climate change and the increasing demand attaining rice globally. In terms of technology, rice production in Iraq can be significantly improved in a resilient and sustainable manner under such technologies as intensive irrigation and drip irrigation provided that there is effective coordination between the farmers and the government institutions.

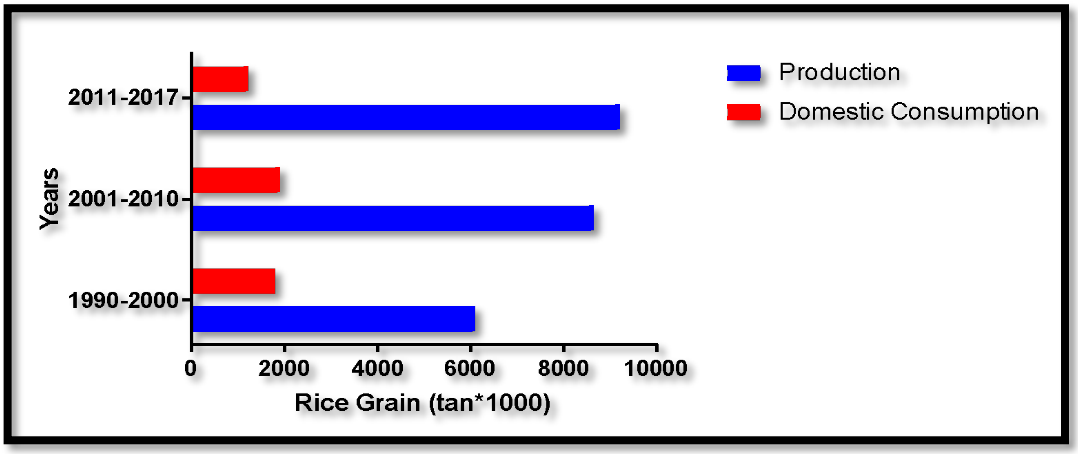

Figure 1. Rice Production and Domestic Consumption for market from 1990-2017

Source: Mouhamad et al., 2025

Water flows in the Euphrates were dramatically spotted by agriculture as lagging as 2014 (figure 2). This came after the upstream hydropower projects resumed, further deteriorating the situation. Irrigation infrastructure rehabilitation also led to reduced agricultural production, including rice production at the time of enhancing food imports. Specific to the period 2014–2016, this was the year when Iraq experienced one of its worst water crises ever, reflected in a comprehensive drop in crop production in Iraq. There was no change from 2017 to 2018 in the scarcity of water in the southern part of Iraq. The government-initiated steps like the cultivation of drought-resistant crops. However, this proved unsuccessful for ensuring good outcomes in terms of food security. Most foodstuffs are still to be imported into the country (Al-Saadi, 2017). Iraq witnessed 'long drought periods' between 2019 to 2021, thereby exerting more pressure on agriculture (Al-Masry, 2020; FAO, 2020). In 2022, the situation further worsened due to climate change impacts, resulting in decreased rainfall and increased temperatures (Al-Kadhim and Al-Hassan, 2023). Even with better irrigation and soil management practices, the ability of Iraq to realize its food requirements is constrained by water availability and the extent of arable land (FAO, 2023).

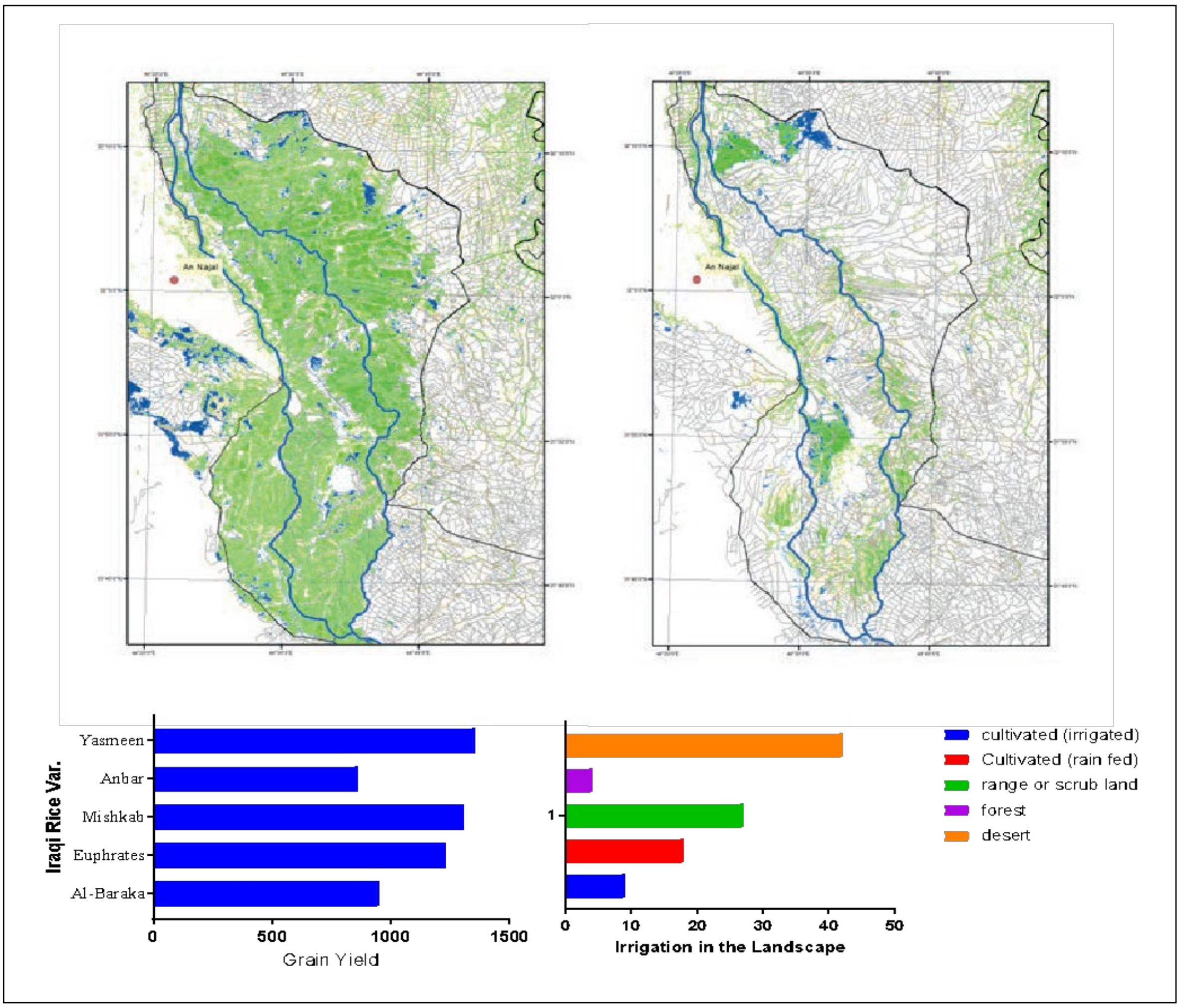

Figure 2. Iraq Area Rice, Grain Area, Grain Yield in varitypes

Source: Mouhamad et al., 2025

4.2 Impacts of Climate Change on Iraq: Historical Trends, Future Projections, and Regional Vulnerabilities

The historical and projected air temperature trends over Iraq from 1950 to 2100 show high increases with anthropogenic climate change as the major driver. Data for the past years shows that there has been a rise of about 2.3°C from 1950 to 2020, mainly due to the greenhouse gas emissions and land-use changes. Future projections at different RCPs indicate further warming. The less aggressive RCP2.6 projection places temperatures at 27.1°C by the end of the century, with substantial efforts on mitigation. The more aggressive projection, RCP8.5, puts temperatures at 31.9°C by the end of the century, more than 7.1°C higher than today's current temperatures, under high emission scenarios. Such changes are likely to aggravate more existing critical challenges, including low agricultural productivity, fierce desertification, and water scarcity. This is through enhanced rates of evapotranspiration, which are soon to be further aggravated by the loss of Iran's Urmia and Hamun wetlands, as well as Iraq's Central Marshes. This study goes a step further to endorse previous global assessments, such as those of the IPCC, in identifying the wider Middle East as a global "hot-spot region" for impacts of climate change in the world. Therefore, the use of both prescribed forms of adaptive strategies and sustainable resource management form a global-best practice requirement in minimizing future impacts. The IPCC 2021 report declares that the Middle East is likely one of the most vulnerable regions to the impacts of climate change. It still mentions that the rise in temperatures is likely to exceed the global average. This is in line with the projections also made for Iraq. According to the same source, the temperatures in this particular region will rise between 4-6°C by the end of the century, a scenario similar to that of Iraq, according to what was predicted under high emission scenarios. Several previous regional studies (Al-Zubari et al., 2020) have also indicated a very significant temperature rise of about 2-3°C between 1950 and 2020. Projections recently suggested that temperatures might rise above 30°C by the end of the century under high emission scenarios (e.g., RCP8.5). Similar findings were reported by Elagib and Mansour (2017). Several areas of Iraq are expected to have up to 7°C warming by 2100, with reduced rainfall as a side effect, which will even worsen desertification and water scarcity challenges. Other studies, such as that of Al-Khader et al. (2019) results show relatively modest warming, with the maximum warming by 2100 being about 4 °C, for some regions of Iraq, considering regional factors like land use and resource management. Therefore, the high emissions scenarios and rural-urban migration are less relevant to where the local land management is properly done and emissions control measures are being enforced.

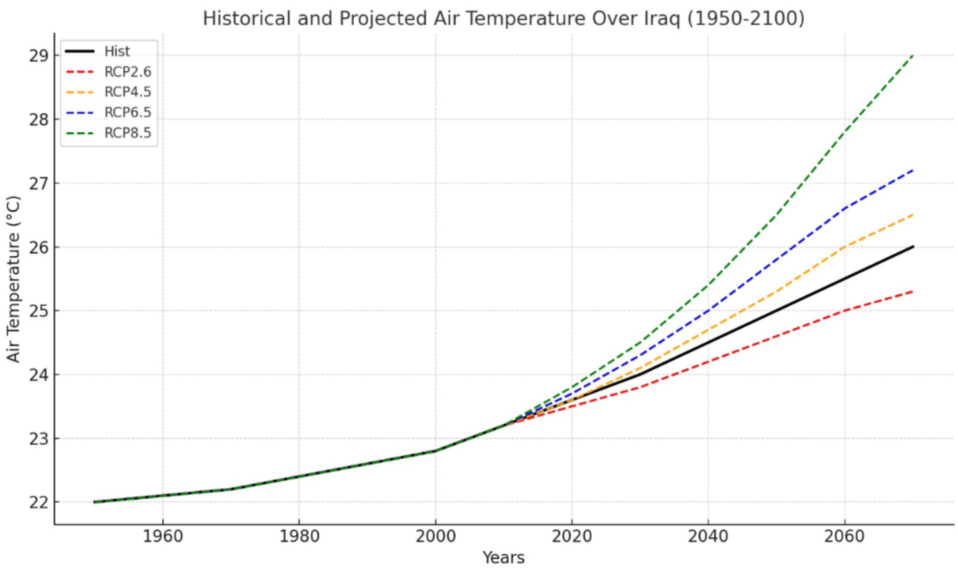

Figure 3. Historical and Projected Temperature Changes in Iraq (1950-2100) Based on RCP Emission Scenarios

Source: Mouhamad et al., 2025

4.3 Rice Salinity Tolerance: Addressing Challenges in Iraq

Salt stress is a major determining factor in food security, most of all in a country like Iraq, with agriculture mostly based on irrigation. Currently, more than half of the rice fields in Iraq are saline, making the adoption of salt-tolerant rice varieties cost-effective and efficient to enhance yields in saline soils (Munns and Tester, 2008). Even though rice happens to be one of the most adaptable crops to exist for saline conditions, its sensitivity towards salt is seen mostly at the time of early establishment, flowering, and grain formation (Ogbodo et al., 2011; Kosova et al., 2013). The accepted level of tolerance for rice stands at an Ece of 3.0 ds/m-1. Furthermore, encroachment into new lands is unwelcome due to problems presented by urbanization to limited arable land by abiotic stresses, including salinity. Therefore, understanding the cellular mechanisms of salt tolerance in the plant will be very important in further improving rice under such conditions. Modification of rice gene strains designed for the rationale of heightened tolerance serves as a very promising solution. The resistance of plants toward stress of salts includes several mechanisms, with the one most significant being that of the cell membrane in efforts to protect the cells of the plant from various environmental stresses (Mansour, 2013; Aziz et al., 2015). It is a major challenge to evolve rice plants for resistance toward salinity since the level of saline in the soil keeps varying both horizontally and vertically within the profile of the ground and further changes with time (Hameed et al., 2011). In the last few years, climate anomalies have critically hit the paddy crop of Iraq through intensified factors that include higher temperature (Latif et al., 2011), drought (Choudhary et al., 2013), and increased soil salinization (Meti et al., 2013). Such ecological shifts raise concern not only with reducing the quality and quantity of crops but also propel further investigations and improvements in the management practices related to rice cultivation. The study based on the collaborative research International Rice Research explored genetic diversity and response in 92 rice genotypes (31st IRSSTN-SS1 and 31st IRSSTN-SS2) under salt stress conditions (50 mM NaCl, Ece = 6 ds/m-1). The main focus of this study was to determine how genetic diversity affects the response of rice to nutrient availability under salinity. Rice grains are particularly more nutrient deficient; most of the nutrients are extremely concentrated in rice bran (pericarp, and seed coat, nucellus, and aleurone layer), and the nutrient contents represent approximately 28% to that found in polished white rice after milling (Aziz et al., 2015). Many studies reported variable grain quality under upland conditions (Hoque et al., 2015). Moreover, grain quality of rice is greatly influenced by salt stress imposed during the flowering, vegetative, and grain-filling stages (Sakina et al., 2015; Kumar et al., 2014; 2015; Kshirsagar et al., 2014). This research would evaluate the variability in grain quality of rice to Iraqi conditions by evaluating two sets of IRSSTN rice. Much research has been done on the development of rice varieties tolerant to salinity (FAO, 2008); research about the nutritional quality of rice under salt conditions is still scanty (Djanaguiraman et al., 2006; Moradi and Ismail, 2007; Cha-um et al., 2007; 2009; Hasamuzzaman et al., 2009). Salt stress reduces plant performance through effects on photosynthesis, protein synthesis, and metabolism related to energy levels in the plant (Joseph et al., 2013). High grain yield does not provide superior nutrient values because the nutritional composition of the rice crop is influenced by many factors, such as plant genetics, soil quality, climatic conditions, and pest pressure at the time of harvest.

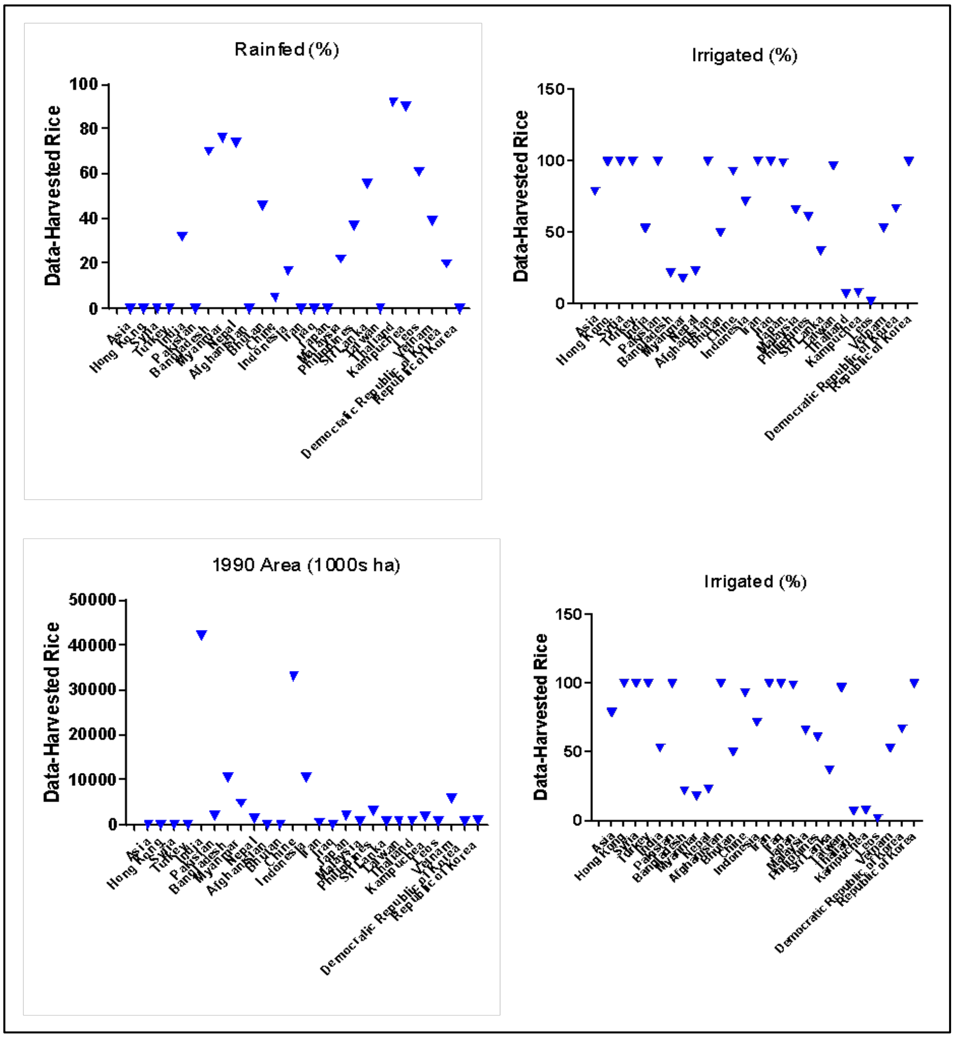

Figure 3. Rice Harvested Areas: Rainfed vs. Irrigated Systems (Global and Iraqi Context)

Source: Mouhamad et al., 2025

It shows data on areas harvested for rice in different countries, under either rainfed or irrigated conditions, with particular categorizations based on how water is managed and flooding levels during the time the crop grows. The percentage of rainfed rice is shown on the top graph where countries like India and Bangladesh are high rainfed-based. Which means those are fully precipitation-dependent systems, where some of its subcategories are drought-potential and deep water, the latter defined as having a water depth greater than 50 cm for some significant number of days. Lower percentage countries have more controlled irrigation systems. The lower graph shows the complete harvested rice area in the year 1990 (measured in thousand hectares). Nations like India and China take the lead with vast cultivated regions, which mirror their stature in worldwide rice output. The facts are taken from FAO Yearbooks, the China Agricultural Yearbook, and other IRRI prints, which group these areas as either irrigated, rainfed, or flood-prone zones. This classification helps understand the distribution of water requiring rice cultivation and its problems; such as flood control, risks of drought, and the necessity of irrigation to sustain high productivity.

4.4 Enhancing Rice Productivity in Salinity-Prone Regions: The Role of IRRI Collaboration

The partnership with the International Rice Research Institute is central to the worldwide endeavour in raising rice productivity, especially under adverse environmental conditions. As most of the world's population depends on rice as their main food, crucial environmental concerns, such as salinity and drought, greatly reduce the yield, especially in regions dependent on irrigated agriculture. These have been developed and evaluated by IRRI, with which we collaborate, for their salt tolerance; among them are 31st IRSSTN-SS1 and 31st IRSSTN-SS2. These varieties are genetically and physiologically designed to empower rice for the mechanisms of adaptation to salinity. They have been successfully deployed in southern Iraq, the Ganges Delta, and the Mekong Delta of Vietnam for which they expressed high resilience to high levels of salinity and at the same time productivity (Al-Araji et al., 2023; Rahman et al., 2020; Tran et al., 2023). This multi-stakeholder partnership does not only aim at quality improvement of rice but also addresses the food security challenges that are accelerated by climate change, empowering farmers to deploy sustainable management practices in saline-affected areas.

Table 1. Performance of Salt-Tolerant Rice Genotypes Across Different Countries

Country	Rice Genotypes	Area (ha)	Yield (ton/ha)	Challenges
Philippines	IRSSTN-SS1, IRSSTN-SS2	500	3.8	Salt stress, water scarcity, agricultural pests
India	IRSSTN-SS1	1,000	4.2	Saline soils, climate variability, fertilizer shortage
Bangladesh	IRSSTN-SS2	800	3.5	High soil and water salinity levels
Vietnam	IRSSTN-SS1	600	3.9	Flooding and salinity in the delta
Thailand	IRSSTN-SS1, IRSSTN-SS2	700	4	Heat stress and water resource shortages
Indonesia	IRSSTN-SS2	900	4.1	Poor soil, lack of agricultural technology
Iraq	IRSSTN-SS1	300	2.8	Severe salinity and lack of technical support
Egypt	IRSSTN-SS1	400	3.7	High temperatures and water resource shortages

Source: Own author research

The performance of these rice genotypes in different countries was essentially a result of the diversity of environmental factors and agricultural practice. Good performance was recorded in the Philippines and India. The benefits were increased productivity as a result of better irrigation and fertilizers. In Bangladesh and Iraq, yields were below the global mean yield though genotypes showed reasonable tolerance to high salinity. In Indonesia, good performance was realized due to environmentally sound agricultural practices, particularly soil and water management. In Egypt, good heat stress resistance was observed in those genotypes, which makes cultivation possible in new agricultural lands. This collaboration shows how important it is to work with IRRI in improving the production of rice worldwide. Main aspects—of salt tolerance and high productivity under all environmental conditions— are critical toward food security for environmentally challenged regions, such as Iraq. The use of rice genotypes

IRSSTN-SS1 and IRSSTN-SS2 marks a very critical step in responding to those challenges and contributing to food security at the globe.

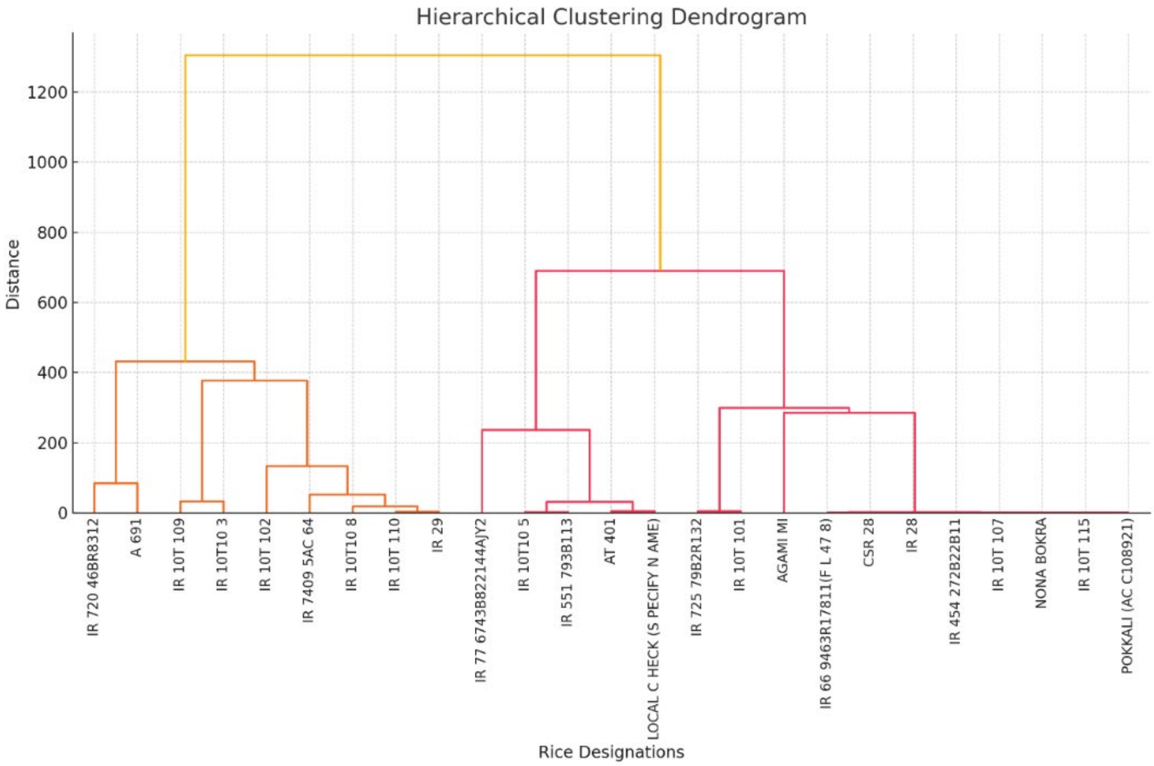

Figure 4. Hierarchical Clustering of Rice Varieties Based on Environmental Adaptability and Yield

Source: Mouhamad et al., 2025

The relative yield data of various categories of rice plants from different locations (IRRI, AMRRS, Annamalainagar, and Trichy) pointed towards large and significant interactions due to environmental adaptation and performance. Such varieties as IR 77674-3B-B-2-4-2-14-AY4, are high yielding up to 2.0, while IR 10T 107 and IR 68144-2B-2-2-3-2 expressed yield levels between 1.0 and 1.4, which indicates dissimilarity in nature of the environment. There is regional variability, as shown by IR 72593-B-13-3-3-1 giving yields of 1.3 and 405 at IRRI and AMRRS, respectively, therefore, this underscores the requirement for breeding efforts to be based on specific locations. Some such as CSR 28 (1.9) and A 691 (1.8) have continued to perform very well across the test environments and, therefore, should be considered for further testing. Traditional varieties, on the other hand, such as POKKALI (1.3) and NONA BOKRA (1.4), are moderate yielding but important for characters like salt tolerance. Strains that give less than 1.5 tons in all places could get help from focused breeding work to improve tolerance to stress and plant characteristics. These numbers show how important yield stability and environmental adaptability are in programs to breed rice, helping to make tough, strong strains made for particular areas.

Journal of Agriculture and Rural Development Studies
Volume 2 – Issue 4 – 2025
ISSN Online 3061-2756
www.imadr.jards.ugal.ro

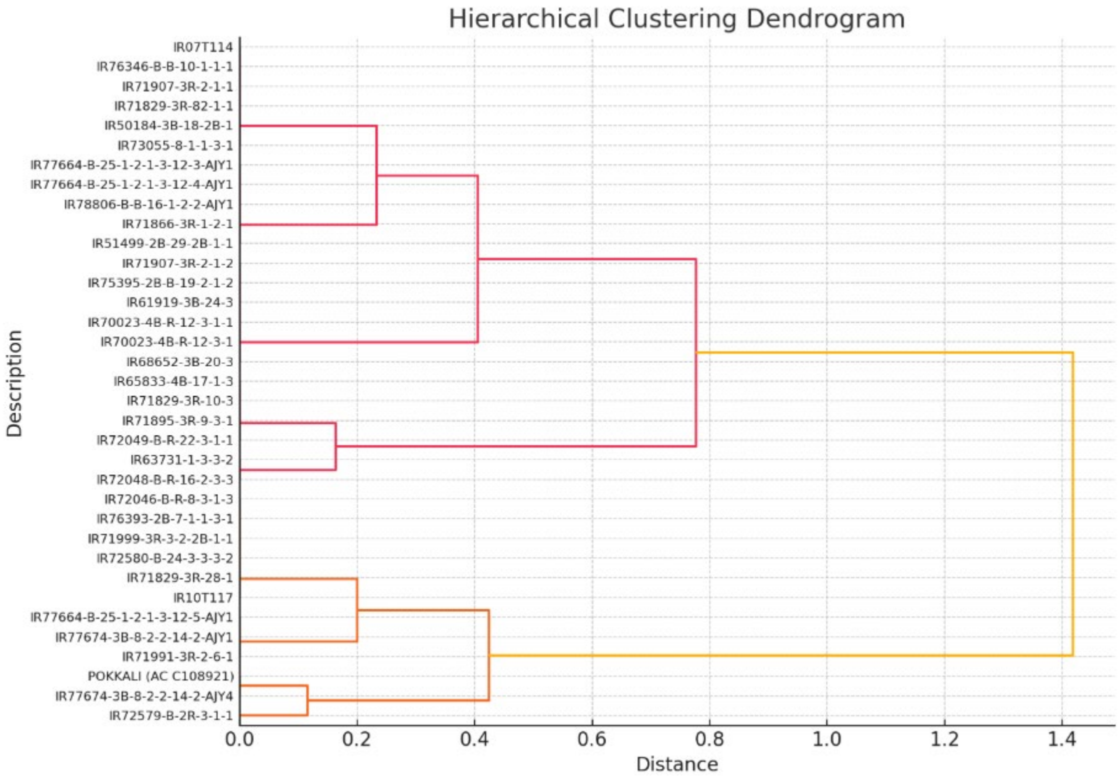

Figure 5. Distribution of Salt-Tolerant Rice Varieties in Regions Facing Salinity Challenges

Source: Mouhamad et al., 2025

The dendrogram of hierarchical clustering presented above shows the grouping of rice varieties according to similarities in traits such as yield, resistance, and tolerance to stresses, or adaptability to the environment. Close merges at short distances between two varieties such as IR77664-B-5-1-2-1-3-12-4-AY1 and IR77664-B-5-2-1-3-12-4-AY1 indicate high similarity, hence promising equally under similar conditions. Very distinct clusters are seen. One cluster has modern varieties, e.g., IR77023-4B-N-12-3-1 and IR70023-4B-N-12-3-1. A second distinctive cluster comprises the traditional varieties, e.g., POKKALI and IR72579-B-2R-3-1-1, which are very far apart at about 1.4. It indicates differences and, therefore, possibilities for combining varied breeding strategies. Differences between groups at distances less than 0.2–0.4 indicate similar environmental conditions. Greater distances of more than 1.0 indicate specific characteristics, e.g., salt tolerance. This study reinforced the fact that acclimatizing varieties in an extensive yield trial regime enhances the potential of identifying material specifically adapted to defined ecological regions based on myriad agronomic studies and interactions.

5. Conclusions and Recommendations

Rice farming in Iraq is under growing pressure. Hotter temperatures, shrinking water supplies, and soil degradation have weakened traditional practices, lowering both yields and grain quality. Farmers in heavily irrigated areas feel this strain most, and rising global demand adds further challenges. Although better irrigation methods, salt-tolerant rice, and improved fertilizer use could help, few farmers have the training or support to apply them effectively. Tackling these problems requires careful water management, planting resilient varieties, restoring soil health, and giving farmers practical, hands-on guidance. Policies should focus on linking research with real farming practices and promoting approaches that are both productive and sustainable. By addressing environmental, technical, and economic factors together, Iraq can protect rice production, support rural livelihoods, and strengthen food security over the long term.

Acknowledgements

I sincerely appreciate Scientific Research Commission, Baghdad, Iraq for support this work.

References

1. Al-Araji, M., et al. (2023). *Field performance of salt-tolerant rice varieties in southern Iraq*. International Journal of Rice Science, 28(3), 301-310.
2. Al-Araji, M., Yassin, H., & Hassan, A. (2023). *Developing salt-tolerant rice varieties for Iraq*. Iraqi Journal of Agricultural Science, 29(1), 89-102.
3. Algarni, S., Elshekh, M., Agiza, A., & Nassar, F. (2025). Analyzing the impact of climate change on rice production and strategies for enhancing efficiency, sustainability, and global food security. *International Journal of Innovative Research and Scientific Studies*. https://doi.org/10.53894/ijirss.v8i2.5888.
4. Al-Kadhim, H., & Al-Hassan, S. (2023). *Climate change impacts on Iraqi agriculture*. Journal of Environmental Science, 45(3), 120-132.
5. Al-Khader, A., Abbas, F., & Hameed, A. (2019). Regional climate projections and local impacts in Iraq. Journal of Environmental Studies, 34(2), 45-58.
6. Al-Khalidi, R., & Al-Masri, K. (2014). *Improving irrigation techniques in arid regions*. Water Resources Research, 10(4), 256-269.
7. Al-Masry, H. (2020). *Climate-induced agricultural challenges in Iraq*. Climate Impact Studies, 11(1), 123-132.
8. Al-Obaidi, S., Abdulrahman, M., & Khalaf, T. (2016). *Water crises and agricultural decline in Iraq*. Environmental Impact Journal, 14(2), 77-88.
9. Al-Rawi, M., & Al-Hamadi, T. (2007). *Water resource management in southern Iraq*. Journal of Hydrology and Agriculture, 15(3), 102-115.
10. Al-Saadi, A. (1995). *The impact of sanctions on Iraq's agricultural sector*. Baghdad Agricultural Review, 12(2), 33-42.
11. Al-Saadi, A. (2017). *Drought-resistant crop trials in Iraq: Challenges and opportunities*. Baghdad Agricultural Research Journal, 22(3), 145-153.
12. Al-Saadi, M. (2023). *Rice cultivation and water management in Iraq*. Iraqi Journal of Agricultural Science, 25(2), 40-47.
13. Al-Tamimi, B., Khalaf, J., & Ahmed, N. (2022). *Sustainable rice production under climate constraints*. Sustainability Studies, 20(1), 95-110.
14. Al-Zubari, W., Al-Shaikh, H., & Al-Kuwari, E. (2020). Climate change impacts and adaptation in the Middle East: Regional assessments and case studies. Climatic Change, 163(1), 59-72. https://doi.org/10.1007/s10584-020-02844-1
15. Ansari, A., Lin, Y., & Lur, H. (2021). Evaluating and Adapting Climate Change Impacts on Rice Production in Indonesia: A Case Study of the Keduang Subwatershed, Central Java. *Environments*. https://doi.org/10.3390/environments8110117.
16. Ansari, A., Pranesti, A., Telaumbanua, M., Alam, T., Wulandari, R., Nugroho, B., & , S. (2023). Evaluating the effect of climate change on rice production in Indonesia using multimodelling approach. *Heliyon*, 9. https://doi.org/10.1016/j.heliyon.2023.e19639.

17. Atiyah, Ameerah H., El-Kaaby, Ekhlas A. J., Mouhamad, R. S., Raied, H. & AlAnny, Jenan A. (2017). In Vitro Influence of Drought on Some Physiological Parameters in Callus Induced from Seeds of Four Rice Cultivars (Oryza sativa L.). *International Journal of Multidisciplinary and Current Research, 5*, 1000-1003.
18. Aziz, F., Ahmed, H., & Jasim, N. (2015). *Climate change effects on crop quality in Iraq*. Environmental Studies Journal, 22(3), 145-155.
19. Aziz, T., et al. (2015). *Salt stress impact on rice physiology and breeding strategies*. International Journal of Agriculture and Biology, 17(5), 993-1001.
20. Cha-um, S., et al. (2007). *Improvement of rice production under salinity stress conditions*. Plant Production Science, 10(4), 509-518.
21. Cha-um, S., et al. (2009). *Salinity tolerance and grain quality in rice*. Journal of Plant Research, 122(2), 211-219.
22. Choudhary, M., et al. (2013). *Drought and salinity in rice cultivation: Challenges and solutions*. Agriculture Water Management, 128, 15-27.
23. Djanaguiraman, M., et al. (2006). *Effects of salt stress on rice grain yield and nutritional quality*. Environmental and Experimental Botany, 58(3), 345-353.
24. Elagib, N. A., & Mansour, M. (2017). Water resources impacts of climate change in the Middle East. Environmental Science and Policy, 77, 120-130. https://doi.org/10.1016/j.envsci.2017.09.002
25. FAO (2008). *Improvement of rice production under saline conditions*. FAO Technical Report.
26. FAO. (2005). *Water management challenges in the Middle East*. Food and Agriculture Organization Technical Report.
27. FAO. (2020). *State of agriculture in Iraq: 2020 report*. Food and Agriculture Organization Annual Report.
28. FAO. (2023). *Agricultural development and climate adaptation*. Food and Agriculture Organization Annual Report.
29. Farooq, A., Farooq, N., Akbar, H., Hassan, Z., & Gheewala, S. (2023). A Critical Review of Climate Change Impact at a Global Scale on Cereal Crop Production. *Agronomy*. https://doi.org/10.3390/agronomy13010162.
30. Fei, L., Meijun, Z., Jiaqi, S., Zehui, C., Xiaoli, W., & Jiuchun, Y. (2020). Maize, wheat and rice production potential changes in China under the background of climate change. *Agricultural Systems*. https://doi.org/10.1016/j.agsy.2020.102853.
31. Gao, Y., Cui, J., Zhang, X., Hoogenboom, G., Wallach, D., Huang, Y., Reis, S., Lin, T., & Gu, B. (2025). Cost-effective adaptations increase rice production while reducing pollution under climate change. *Nature Food*, 6, 260 - 272. https://doi.org/10.1038/s43016-024-01113-8.
32. Guidigan, M., Dossou-Yovo, E., Ra-danielson, A., Akpoti, K., Tapily, A., Iboko, M., & Balogun, A. (2025). Mitigating climate change impacts on West African rice yields: Evaluating APSIM-ORYZA and management practices. *Agronomy Journal*. https://doi.org/10.1002/agj2.70113.
33. Habib-Ur-Rahman, M., Ahmad, A., Raza, A., Hasnain, M., Alharby, H., Alzahrani, Y., Bamagoos, A., Hakeem, K., Ahmad, S., Nasim, W., Ali, S., Mansour, F., & Sabagh, E. (2022). Impact of climate change on agricultural production; Issues, challenges, and opportunities in Asia. *Frontiers in Plant Science*, 13. https://doi.org/10.3389/fpls.2022.925548.
34. Hameed, S., et al. (2011). *Soil salinity management in rice cultivation*. Rice Research Journal, 45(1), 98-102.
35. Hanna, S. (2002). *Grain production trends in Iraq: Past and present*. Middle East Journal of Agriculture, 9(1), 45-53.
36. Hasamuzzaman, M., et al. (2009). *Mechanisms of salinity tolerance in rice plants*. Plant Biology and Environment, 1(2), 78-85.
37. Hassan, Z., Abbas, F., & Younis, R. (2023). *Water use efficiency in rice cultivation in Iraq*. Agricultural Water Management 18(2), 77-88.

38. Hoque, M. A., et al. (2015). *Effect of salinity on rice grain quality*. Rice Science, 22(4), 191-200.
39. Hussain, S., Huang, J., Huang, J., Ahmad, S., Nanda, S., Anwar, S., Shakoor, A., Zhu, C., Zhu, L., Xiaochuang, C., Jin, Q., & Zhang, J. (2020). Rice Production Under Climate Change: Adaptations and Mitigating Strategies. , 659-686. https://doi.org/10.1007/978-3-030-49732-3_26.
40. IPCC. (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. https://doi.org/10.1017/9781009157896
41. IRRI (2023). *Rice Varieties and Adaptability*. International Rice Research Institute.
42. IRRI Annual Report (2022). *Rice research and development initiatives*. International Rice Research Institute.
43. IRRI. (2022). *Annual report: Innovations in rice research*. International Rice Research Institute.
44. Joseph, B., et al. (2013). *Salinity effects on rice physiology and growth*. Plant Physiology and Biochemistry, 71, 146-154.
45. Joseph, M., Moonsammy, S., Davis, H., Warner, D., Adams, A., & Oyedotun, T. (2023). Modelling climate variabilities and global rice production: A panel regression and time series analysis. *Heliyon*, 9. https://doi.org/10.1016/j.heliyon.2023.e15480.
46. Kosova, K., et al. (2013). *Salinity stress and plant development*. Functional Plant Biology, 40(9), 943-959.
47. Kosova, K., Kumar, A., & Zada, A. (2013). *Drought stress in cereal crops: Current research*. Plant Stress Research Journal, 18(2), 234-245.
48. Kshirsagar, S., et al. (2014). *Effects of salt stress on rice grain quality*. International Rice Research Journal, 3(2), 125-136.
49. Kumar, P., et al. (2014). *Rice grain quality under salt stress*. Journal of Plant Nutrition, 37(11), 1816-1826.
50. Latif, A., et al. (2011). *Impact of rising temperatures on rice growth and production*. Environmental Science and Technology, 45(6), 1793-1798.
51. Li, C., Camac, J., Robinson, A., & Kompas, T. (2025). Predicting changes in agricultural yields under climate change scenarios and their implications for global food security. *Scientific Reports*, 15. https://doi.org/10.1038/s41598-025-87047-y.
52. Li, S., Wu, F., Zhou, Q., & Zhang, Y. (2024). Adopting agronomic strategies to enhance the adaptation of global rice production to future climate change: a meta-analysis. *Agronomy for Sustainable Development*, 44. https://doi.org/10.1007/s13593-024-00963-7.
53. Mansour, M. M. F. (2013). *Protective role of antioxidants in plant stress tolerance*. Environmental and Experimental Botany, 89, 122-134.
54. Meti, N., et al. (2013). *Salinization and its impact on agriculture*. Salinity and Drought Stress in Plants, 5(2), 111-120.
55. Moradi, F., & Ismail, A. M. (2007). *Responses of rice plants to salinity stress*. Rice Science, 16(4), 217-224.
56. Mouhamad, R. S., Atiyah, A. H., Al-Temimi, A. F. H., Elkaaby, E. A. J. (2019). Changes in Macro Elements Content in Plant Tissues Subjected to Clinostat. Journal of Rice Research, 7, 209
57. Mouhamad, R. S., Ibrahim B. Razaq, Ali S. Fadhel, Shaimaa A. Yousir, Mouhamad, R. S., Ameerah H. Atiyah, Naghum A. Masamsh and Ibrahim B. Razaq (2017). Organic Composition of IRSSTN Genotypes Rice Evaluated Under Iraqi Climate. *Journal of Entomology and Zoology Studies, 5*(5), 1831-1837.
58. Mouhamad, R. S., Jaafar, Z. M., El–Kaaby, E. A. J., Iqbal, M., Arif, N. (2018). Evaluation of Agronomic Traits and Inorganic Nutritional Composition of Rice Seed from IRSSTN Genotypes in Iraq. *Journal of Rice Research, 6*, 189. doi:10.4172/2375-4338.1000189.

59. Mouhamad, R. S., Mutlag, L. A., Al-Khateeb, M. T., Iqbal, M., Nazir, A., Ibrahim, K. M., Mussa, R. A., Jassam, O. H. (2017). Salinity Tolerance at Seedling Stage for Rice Genotypes: In Vitro Analysis. *Net Journal of Agricultural Science, 5*, 114-120.
60. Mouhamad, R. S., Shallal, H. S., Al-Daoude, A. (2019). Microgravity Effects on the Growth, Cell Cytology Properties, and DNA Alterations of Two Iraqi Local Plants. Journal of Rice Research, 7, 207. DOI: 10.4172/2375-4338.1000207.
61. Munns, R., & Tester, M. (2008). *Mechanisms of salinity tolerance*. Annual Review of Plant Biology, 59, 651-681.
62. Ogbodo, C. O., et al. (2011). *Effect of salinity on rice performance*. Environmental and Experimental Botany, 71(3), 232-239.
63. Rahman, A., & Zhang, J. (2022). Trends in rice research: 2030 and beyond. *Food and Energy Security*. https://doi.org/10.1002/fes3.390.
64. Rahman, M. A., et al. (2020). *Evaluation of salt-tolerant rice genotypes under Bangladesh conditions*. Agricultural Science and Technology, 40(5), 234-240.
65. Rezvi, H., Tahjib-Ul-Arif, M., Azim, M., Tumpa, T., Tipu, M., Najnine, F., Dawood, M., Skalický, M., & Brestič, M. (2022). Rice and food security: Climate change implications and the future prospects for nutritional security. *Food and Energy Security*. https://doi.org/10.1002/fes3.430.
66. Sakina, S., et al. (2015). *Salinity during rice flowering and reproductive stages*. Plant Stress and Tolerance, 6(1), 48-56.
67. Saud, S., Wang, D., Fahad, S., Alharby, H., Bamagoos, A., Mjrashi, A., Alabdallah, N., Alzahrani, S., AbdElgawad, H., Adnan, M., Sayyed, R., Ali, S., & Hassan, S. (2022). Comprehensive Impacts of Climate Change on Rice Production and Adaptive Strategies in China. *Frontiers in Microbiology*, 13. https://doi.org/10.3389/fmicb.2022.926059.
68. Tran, M. H., et al. (2023). *Impact of salinity on rice yield in the Mekong Delta*. International Journal of Crop Science, 19(2), 102-110.
69. Wu, F., Wang, Y., Liu, Y., Liu, Y., & Zhang, Y. (2020). Simulated responses of global rice trade to variations in yield under climate change: Evidence from main rice-producing countries. *Journal of Cleaner Production*, 124690. https://doi.org/10.1016/j.jclepro.2020.124690.
70. Zhao, W., Chou, J., Li, J., Xu, Y., Li, Y., & Hao, Y. (2022). Impacts of Extreme Climate Events on Future Rice Yields in Global Major Rice-Producing Regions. *International Journal of Environmental Research and Public Health*, 19. https://doi.org/10.3390/ijerph19084437.