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Rice Production: Current Challenges and Future Prospects

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Drastic climate change is deteriorating rice cultivation, which directly causes global instability, hunger malnourishment, and food insecurity. Implementation of innovative technologies like precision irrigation, development of improved rice varieties, nanotechnology, and biotechnology is crucial for water conservation, abiotic stress tolerance, and cost-effectiveness. Yield improvement, resilience, and ecological sustainability offers a way to encounter rising food demands. However, cooperation among academia, farmers, and policy regulators is vital for their efficient implementation. Adoption of innovative technologies is essential to ensure that rice cultivation flourish regardless of the intricacies of contemporary agriculture.

Keywords: Rice farming challenges, Sustainable rice cultivation, Food security, Water scarcity in agriculture, Yield enhancement strategies

Rice is a chief food source for about 3.5 billion people worldwide. It is a monocot crop. Being ranked as second in worldwide production, its farming varies immensely by environmental conditions [1]. Rice, a kharif crop, usually requires vast amount of water for its cultivation, so cultivated in rainy seasons. While its harvest takes place from September to November [2]. Rice consumption is rising in developed regions like North America and the European Union due to dietetic divergence and migration. Per capita rice consumption has increased over the last two decades (1970-90) at varying rates across countries, from 2.4 percent/year in Italy to 8.2 percent/year in the UK. Escalating production costs and the need for higher income are driving farmers to boost yields and intensify cultivation to meet global food demands [3]. Farming acts as the primary source of income for about 50% of the global population. In Pakistan, agriculture contributes significantly to the GDP (21.4%) and employs 45% of the total labor force (Govt. of Pakistan, 2012-13). Around 63% of Pakistan's rural population depends on agriculture for their livelihoods (World Bank, 2012). Despite its importance, the average yield of crops in Pakistan lags behind other countries (FAO, 2008). Rice cultivation faces similar challenges, with national yields 73% lower than global averages (PCST, 2003). In 2011-2012, rice was grown on 2.571 million hectares with a production of 6.16 million tons and an average yield of 2396kg/ha (GOP, 2011-12). Rice is the third-largest produce in Pakistan after wheat and cotton, contributing significantly to foreign exchange earnings. In 2011-2012, Pakistan's rice exports totaled 2.08 billion US dollars (Pakistan Bureau of Statistics). Despite its potential, the regular produce of rice in Pakistan remains near to the ground due to poor production practices and various challenges faced by farmers throughout the production and marketing processes [4]. Expanding rice cultivation faces constraints due to water scarcity, urban expansion in Asia, and high costs in developing new lands. As, shown in Figure 1, factors like limited returns from high-yield varieties, declining productivity, pressures from both biotic and abiotic stresses, and rising production costs further contribute to reduced cultivation and yield growth [5].

Major rice production problems:

Low Temperature:

Cold stress poses a significant challenge in rice cultivation globally, particularly affecting yield during crucial reproductive stages. Rice, being sensitive to cold, suffers yield losses when exposed to low temperatures, which disrupt its growth and development. Optimal growth occurs within temperatures ranging from 25°C to 35°C. Cold exposure impacts all growth stages of rice, leading to reduced seedling vigor, tillering, and increased plant mortality. Critical stages vulnerable to low temperature damage include sprouting, flowering, and filling. Among these, flowering is particularly sensitive to cold, occurring approximately 10–12 days before heading [1]. High temperatures during June replantation reduce rice production, while the minimum temperatures boost leaf emergence speed, increasing yield during this stage [2].

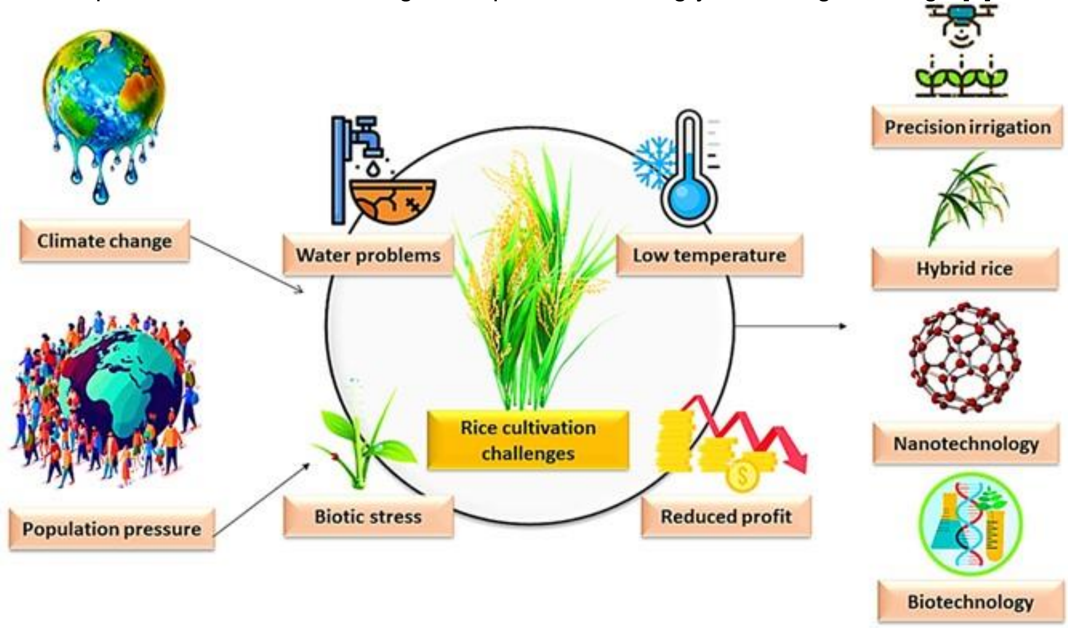

Figure 1: Conceptual framework addressing rice major production challenges and innovative technologies to boost rice production

Water Problems:

Water is crucial for rice production, with over half of rice-growing areas irrigated. It's estimated that more than 4-5,000 liters of water are used to produce 1 kg of rice in many regions. Enhancing water use efficiency is essential, achieved through better water control, crop management, and irrigation technologies [3].

As, Rice cultivation requires more water compared to other crops, with approximately 75% of the world's water resources and 80% of Asia's water resources dedicated to rice farming. Conventional rice cultivation methods, such as flooding and puddling followed by seedling uprooting, are facing challenges due to water scarcity and labor shortages in major rice-producing regions [6].

Biotic Stresses:

Each year, crop yields are jeopardized by a range of factors, from extreme temperatures to bacterial infections. Bacterial leaf blight, caused by *Xanthomonas oryzae* pv. *oryzae* (Xoo), is a widespread issue in rice plants, leading to substantial yield losses of up to 60% or billions in economic terms [6].

And pests significantly reduce crop yields, causing substantial losses in production. In India, pests lead to a 33% production loss, with weeds, insects, diseases, and other pests contributing varying percentages. Minimizing these losses is crucial for productivity [7].

Yield gap

In irrigated rice farming, there's a yield gap between farmers and research stations. Achieving higher yields like those in California and Australia in the EU under similar conditions is challenging. Closing this gap requires comprehensive efforts, including supportive government policies, proper land management, efficient water use, quality inputs, access to credit, and institutional support. Understanding rice yield components is crucial for improvement. The "Ricecheck" method in Australia has been key, focusing on optimal field practices and nitrogen management to boost yields [3].

Reduced profitability in rice farming

Declining returns from rice farming have become a pressing issue, impacting rural economies in both developed and developing countries. Initially, improved yields promised increased profits, but since 1995, international rice prices have plummeted while production costs have surged. This imbalance has triggered a cycle of diminishing returns, exacerbating poverty among small-scale farmers. Additionally, in industrialized nations, high production costs have undermined competitiveness, prompting concerns over the future of rice farming, particularly if subsidies are reduced. Japan, for example, has witnessed a steady decline in both rice production and harvested area since 1985 despite its significance as a staple crop [5].

Innovative technologies to boost rice production:

Water saving irrigation techniques

Water scarcity in rice-growing nations threatens food security, impacting production, quality, and affordability. Overuse of water leads to soil deprivation and reduced efficiency, worsened by climate change. Efforts to enhance agricultural water productivity are crucial to alleviate freshwater demand. Research aims to reduce water usage and explore alternative techniques such as (i) the alternate moistening and aeration method of irrigation, (ii) the aerobic rice system, (iii) the system of rice strengthening, (iv) saturated soil culture, (v) direct seeded rice, and (vi) drip-irrigation [8].

Hybrid rice technology

A "hybrid" refers to the primary generation resulting from crossing heritably diverse parents. The commercial hybrid denotes to a superior F1, which not only outpaces the better parent but also shows substantial yield dominance over the best high-yielding inbred variety of similar duration. Hybrid rice varieties, developed using male sterility systems, have been commercialized globally, boosting yields by 1–1.5 tons per hectare. These hybrids, covering about 1 million hectares in 2003, offer stability, early maturity, and increased productivity, appealing to farmers diversifying income sources [9].

Nanotechnology

Nanotechnology offers promising avenues for enhancing rice breeding and improving food security. Genome editing, like CRISPR/Cas9, allows researchers to introduce beneficial traits into rice cultivars. Nano-urea has potential to boost rice productivity and profitability, while nano-K and nano-S can enhance nutrient efficiency and plant growth. Rice leaf area and grain yield can be increased by exogenous spray of CuO and ZnO nanoparticles. Improvement in rice chlorophyll content and drought stress tolerance is possible by combine application of Silicon and Selenium nanoparticles. So, nanoparticles application is an ultimate solution to mitigate rice cultivation challenges [7].

Biotechnology

Conventional methods lead to the immense rice yield reduction which can be resolved by biotechnology initiatives and genetic engineering. Molecular tools like gene pyramiding and quantitative trait loci mapping etc. have been driving force in development of biotic and abiotic stress resistant varieties. Researchers are making efforts to commercialize molecular tools but there's still a long way to go. [10].

CONCLUSION

The alarming rice cultivation problems is a state of global emergency. And we are at the verge of global food insecurity and economic instability which demands concerted attention from the scientific community. However, amidst these challenges lie promising prospects for the future of rice cultivation. Precision irrigation, nanotechnology, genetic engineering, and other innovative technologies along with promising efforts of policymakers offers resilience, abiotic stress tolerance, and improved rice productivity. Irrepressible population pressure projects 18% increase in rice consumption which can be mitigated by implementation of innovative technologies and collaborative efforts of stakeholders.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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