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The role of planting systems in improving maize yield under limited irrigation regimes

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Abstract
Limited water availability is a significant challenge for maize (*Zea mays* L.) production in many parts of the world. Efficient water use is crucial for sustaining crop yields under water-scarce conditions. This review explores the role of different planting systems in improving maize yield and water productivity under limited irrigation regimes. By examining recent research, we highlight the impact of various planting techniques, including row spacing, planting density, and mulching, on maize growth, yield, and water use efficiency. The findings provide insights into optimizing planting systems to enhance maize productivity in water-limited environments.

Keywords: Maize, *Zea mays*, limited irrigation, planting systems, yield, water productivity, water use efficiency

Introduction

Maize (*Zea mays* L.) is a staple food crop globally, with significant importance for food security, especially in developing countries. It provides essential nutrients and serves as a critical source of food, feed, and industrial raw material. In 2020, global maize production reached approximately 1.12 billion metric tons, with the United States, China, and Brazil being the top producers. However, the increasing frequency of droughts and water scarcity, exacerbated by climate change, poses a substantial threat to maize production, particularly in arid and semi-arid regions. Water availability is a key determinant of maize yield. Under limited irrigation conditions, optimizing planting systems becomes essential to ensure sustainable maize production. Traditional irrigation practices are often insufficient to meet the water demands of crops, leading to reduced yields and economic losses. In regions like sub-Saharan Africa and South Asia, where water resources are limited, there is an urgent need to adopt efficient agricultural practices that maximize water use efficiency and enhance crop performance. Row spacing, planting density, and intercropping are critical components of planting systems that can significantly influence maize yield under limited irrigation. Narrow row spacing has been shown to improve canopy closure and light interception, reducing soil evaporation and conserving soil moisture. For instance, studies have demonstrated that reducing row spacing from 75 cm to 50 cm can increase maize yield by up to 15% due to better resource utilization. Similarly, optimizing planting density can balance intra-specific competition and resource use efficiency, crucial for maximizing yield under water-limited conditions. Intercropping, the practice of growing two or more crops simultaneously on the same field, offers numerous benefits for maize production. Intercropping with legumes, such as soybean or cowpea, can enhance soil fertility through nitrogen fixation, improve water use efficiency, and reduce pest and disease incidence. Research indicates that intercropping maize with legumes can increase maize yield by 10-20%, depending on the specific cropping system and environmental conditions.

Main Objective of the paper

The main objective of this paper is to explore and evaluate the impact of different planting systems on maize yield under limited irrigation regimes, providing insights and recommendations for optimizing water use efficiency and enhancing crop performance in water-scarce environments.

Reviews of Literature

Row spacing is a crucial factor influencing light interception, plant competition, and water use efficiency in maize cultivation. Several studies have investigated the effects of different row spacings on maize yield under limited irrigation. A study by Andrade *et al*. (2002) demonstrated that narrower row spacing (50 cm) improved light interception and reduced soil evaporation, resulting in higher maize yields compared to wider rows (75 cm). Similarly, Royo *et al*. (2017) found that row spacing of 60 cm optimized water use efficiency and increased grain yield in water-limited conditions. Conversely, research by Sharratt and McWilliams (2005) indicated that very narrow row spacing (less than 50 cm) could lead to increased plant competition for water and nutrients, potentially reducing yield under severe water stress. Planting density, or the number of plants per unit area, directly affects maize growth and yield. Optimal planting density can enhance water use efficiency by maximizing soil moisture utilization. Studies by Liu *et al*. (2010) and Zhang *et al*. (2017) showed that moderate planting densities (60,000-70,000 plants per hectare) achieved the highest yields and water productivity under limited irrigation. Higher densities increased competition for limited water resources, while lower densities underutilized available soil moisture. However, excessive planting density can negatively impact root development and increase susceptibility to drought stress. Research by Iqbal *et al*. (2018) emphasized the importance of balancing planting density to optimize yield and water use efficiency.

Mulching is a planting technique that involves covering the soil with organic or inorganic materials to conserve soil moisture, reduce evaporation, and improve soil health. A study by Kahlon *et al*. (2013) found that plastic mulch significantly increased maize yield and water use efficiency under limited irrigation by reducing soil water loss and maintaining higher soil moisture levels. Similarly, organic mulches, such as straw or crop residues, improved soil moisture retention and reduced weed competition, leading to higher yields (Gao *et al*., 2017).

However, the effectiveness of mulching can vary depending on the type of mulch used and local environmental conditions. Research by Liu *et al*. (2014) indicated that while mulching generally benefits maize yield, its impact can be influenced by soil type, temperature, and rainfall patterns. Ridge and furrow planting systems create alternating raised beds and furrows, which can improve water infiltration and root zone moisture availability. Yang *et al*. (2017) demonstrated that ridge and furrow planting significantly enhanced maize yield and water use efficiency under limited irrigation by improving soil moisture distribution and reducing water runoff. This technique also facilitated better root development and nutrient uptake. Intercropping involves growing maize with other crops in the same field, which can improve resource utilization and increase overall productivity. Research by Li *et al*. (2011) showed that maize-legume intercropping systems improved soil moisture utilization and enhanced maize yield under limited irrigation. The legume component helped fix atmospheric nitrogen, improving soil fertility and reducing the need for chemical fertilizers. Conservation agriculture practices, including minimal soil disturbance, crop rotation, and cover cropping, can improve soil structure and moisture retention. A study by Hobbs *et al*. (2008) indicated that conservation agriculture significantly increased maize yield and water productivity by enhancing soil health and reducing water evaporation. These practices also improved soil organic matter content, further enhancing water retention capacity.

Impact of Planting Systems on Maize Yield

Planting systems play a significant role in influencing maize yield, particularly under limited irrigation regimes. Row spacing, planting density, and intercropping are crucial factors that determine how effectively maize plants utilize available resources such as water, nutrients, and light. Row spacing affects maize yield by influencing canopy closure and light interception. Narrow row spacing promotes quicker canopy closure, reducing soil evaporation and conserving soil moisture. This is especially beneficial under limited irrigation conditions where water conservation is critical. Optimal row spacing can also improve root distribution, enhancing water and nutrient uptake, leading to better plant health and higher yields. Research has demonstrated that narrower row spacing can significantly increase maize yield by improving water use efficiency and light interception.

Planting density determines the level of competition among maize plants for resources. High planting density increases competition, which can reduce individual plant performance if the competition for water and nutrients becomes too intense. Conversely, low planting density may result in underutilization of resources, leading to lower overall yield. Finding the optimal planting density is essential for maximizing yield under limited irrigation. Studies suggest that a planting density of 8-10 plants per square meter often provides the best balance between competition and resource utilization, ensuring adequate access to water and nutrients without excessive competition.

Intercropping involves growing two or more crops simultaneously on the same field, improving resource use efficiency and providing mutual benefits to the intercropped species. Intercropping can lead to complementary use of water, nutrients, and light, with deep-rooted crops accessing resources from deeper soil layers and shallow-rooted crops utilizing resources from the upper layers. Intercropping maize with legumes, for instance, can enhance soil fertility through biological nitrogen fixation by the legumes, benefiting maize growth. This practice can also help reduce pest and disease incidence by disrupting the habitat and life cycle of pests. Studies have shown that intercropping maize with legumes can improve maize yield by enhancing nitrogen availability and water use efficiency.

Water Use Efficiency (WUE) is a critical measure of how effectively a planting system utilizes available water to produce biomass and yield. Improving WUE is essential for maintaining maize productivity under limited irrigation. Techniques such as mulching, which reduces soil evaporation and retains soil moisture, can significantly enhance WUE. Developing and using drought-tolerant maize varieties can also improve WUE and ensure stable yields under water-limited conditions. Precision irrigation techniques, such as drip irrigation, deliver water directly to plant roots, minimizing water loss and further improving WUE.

Research in semi-arid regions has found that reducing row spacing and intercropping maize with legumes can significantly enhance WUE and increase maize yield. For instance, reducing row spacing from 75 cm to 50 cm can improve WUE by 10-15%, while intercropping maize with pigeon pea has been shown to increase WUE by 18%. These practices lead to better soil moisture utilization, reduced evaporation, and enhanced overall productivity.

In conclusion, the choice of planting system is crucial for determining maize yield under limited irrigation regimes. Optimizing row spacing, planting density, and intercropping can significantly improve water use efficiency and crop performance. By adopting these practices, farmers can enhance maize productivity even under conditions of water scarcity. Sustainable agricultural practices, such as using drought-tolerant varieties and precision irrigation, further support the goal of achieving high yields with limited water resources.

Conclusion

The optimization of planting systems is crucial for enhancing maize yield under limited irrigation regimes, a necessity driven by climate change and increasing water scarcity. This study highlights the significant impact of row spacing, planting density, and intercropping on maize productivity and water use efficiency. Narrow row spacing improves canopy closure, light interception, and reduces soil evaporation, leading to better water conservation and higher yields. Optimal planting density balances resource utilization and competition among plants, ensuring efficient water and nutrient uptake. Intercropping, particularly with legumes, enhances soil fertility, reduces pest incidence, and improves overall water use efficiency through complementary resource use. Research indicates that these planting systems, when optimized, can significantly boost maize yield under water-limited conditions. Techniques such as mulching, the use of drought-tolerant varieties, and precision irrigation further support sustainable maize production by maximizing water use efficiency and maintaining stable yields. Farmers adopting these practices can achieve higher productivity even in regions with limited water availability, contributing to food security and sustainable agricultural development. In conclusion, the strategic implementation of optimized planting systems is essential for mitigating the challenges posed by limited irrigation. By focusing on row spacing, planting density, and intercropping, alongside advanced agricultural techniques, it is possible to enhance maize yield, ensure efficient water use, and support sustainable farming practices in water-scarce environments.

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