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Review Article: 08 to 11
ISSN: 3041-5322
https://agriculture.researchfloor.org/

Assessing Durum Wheat Performance in Conservation Agriculture: A Comprehensive Review of Quality, Yield, and Sanitary Factors

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ABSTRACT

Conservation agriculture (CA) has emerged as a sustainable farming practice with potential benefits for durum wheat cultivation and to evaluate the performance of durum wheat under CA, focusing on quality attributes, yield potential, and sanitary consideration and synthesizing existing literature, we elucidate the impact of CA practices on durum wheat production, highlighting its implications for food security and environmental sustainability and underscore the multifaceted interactions between CA and durum wheat, emphasizing the need for tailored management strategies to optimize crop performance and to discuss challenges and future research directions to enhance the adoption of CA in durum wheat farming systems.

Keywords: *Conservation agriculture, durum wheat farming, sustainability, crops.*

Introduction

Durum wheat (*Triticum turgidum* subsp. durum) is a staple cereal crop widely cultivated in arid and semi-arid regions, particularly in the Mediterranean basin and North Africa. Its unique attributes make it a vital component of global food security, serving as a primary ingredient in pasta, couscous, and various traditional dishes [1-2]. However, conventional wheat farming practices often contribute to soil degradation, water scarcity, and loss of biodiversity, necessitating the adoption of sustainable alternatives. Conservation agriculture (CA) has emerged as a promising approach to mitigate these challenges, promoting minimal soil disturbance, permanent soil cover, and diversified cropping systems. While CA principles have demonstrated benefits in various cereal crops, its application in durum wheat production warrants thorough evaluation due to the crop's specific requirements and agronomic characteristics [3-5]. This review aims to assess the performance of durum wheat in CA systems, focusing on key aspects such as grain quality, yield potential, and sanitary considerations.

Durum wheat (*Triticum turgidum* subsp. durum) stands as an agricultural cornerstone, anchoring the dietary staples of millions globally and playing an integral role in the cultural fabric of regions where it thrives. Traditionally cultivated in arid and semi-arid regions, particularly across the Mediterranean basin and North Africa, its robustness in harsh environments has made it a dependable source of sustenance for generations [6]. However, the sustainability of durum wheat cultivation is increasingly under scrutiny due to the environmental toll of conventional farming practices. Conventional agriculture, characterized by intensive tillage, monocropping, and heavy chemical inputs, has led to soil degradation, erosion, loss of biodiversity, and depletion of natural resources. These challenges are exacerbated in the context of durum wheat cultivation, where the crop's specific requirements and susceptibility to environmental stressors demand innovative solutions. In this regard, conservation agriculture (CA) emerges as a beacon of hope, offering a paradigm shift towards ecologically sound and economically viable farming practices. At its core, CA embodies a holistic approach to land stewardship, advocating for minimal soil disturbance, permanent soil cover, and diversified cropping systems. By preserving soil structure, enhancing water retention, and fostering biological activity, CA holds the promise of rejuvenating degraded lands while bolstering crop resilience in the face of climate variability. While the principles of CA have gained traction across diverse cropping systems, its application in durum wheat farming necessitates a nuanced evaluation to unravel its potential benefits and challenges and into the intricate relationship between conservation agriculture and durum wheat production, with a particular focus on three critical dimensions: quality, yield, and sanitary considerations [7-9]. By synthesizing existing literature and empirical evidence, we aim to shed light on the performance of durum wheat under CA practices, unraveling the synergies and trade-offs that characterize this dynamic relationship. Through this endeavor, we seek to provide insights that not only inform agronomic decision-making but also contribute to the broader discourse on sustainable agriculture and food security through the nexus of

Citation: Nageshwar, Riyaz Ahmad, Soumya K, Akash Singh, Priyanka Kumari (2024). Assessing Durum Wheat Performance in Conservation Agriculture: A Comprehensive Review of Quality, Yield, and Sanitary Factors
Agriculture Archives: an International Journal.
DOI: https://doi.org/10.51470/AGRI.2024.3.1.08

Received on: November 19, 2023
Revised on: January 23, 2024
Accepted on: February 04, 2024

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conservation agriculture and durum wheat is one fraught with complexities and uncertainties, yet it is imbued with the potential to reshape agricultural landscapes and livelihoods for the better and embark on this exploration [10-11].

Impact of Conservation Agriculture on Durum Wheat Quality: Grain quality is a critical determinant of durum wheat market value and consumer acceptance. Under CA, reduced soil disturbance and improved soil structure enhance water infiltration and nutrient availability, potentially influencing grain protein content, gluten strength, and pasta-making properties. However, the effect of CA on durum wheat quality is influenced by various factors, including soil type, climate, crop rotation, and management practices [12]. While some studies report positive associations between CA adoption and grain quality parameters, others suggest minimal differences compared to conventional systems. Understanding the underlying mechanisms governing these dynamics is essential for optimizing durum wheat quality under CA.

Grain quality stands as a cornerstone of durum wheat production, dictating its market value, processing suitability, and consumer acceptance. The transition to conservation agriculture (CA) practices introduces a paradigm shift in the management of agronomic factors that can influence grain quality attributes. Understanding the intricate interplay between CA and durum wheat quality is imperative for discerning the potential benefits and trade-offs associated with sustainable farming practices. One of the primary mechanisms through which CA can influence durum wheat quality is soil health. By minimizing soil disturbance and preserving organic matter through crop residue retention, CA practices foster a conducive environment for soil microbial activity and nutrient cycling [13-14]. Enhanced soil structure and aggregation promote water infiltration and root exploration, facilitating optimal nutrient uptake by durum wheat plants. Consequently, CA-adapted soils may exhibit improved fertility and nutrient availability, which can translate into favorable grain quality characteristics.

Research suggests that durum wheat grown under CA conditions may exhibit alterations in protein content, gluten strength, and pasta-making attributes compared to conventional tillage systems. While the exact mechanisms driving these changes are multifaceted and context-dependent, several key factors deserve attention. Reduced nitrogen leaching and enhanced nitrogen use efficiency under CA can influence grain protein accumulation, potentially impacting the overall protein content of durum wheat. Additionally, the physical and biochemical properties of gluten, crucial for dough elasticity and pasta quality, may be influenced by soil moisture dynamics, root architecture, and microbial interactions fostered by CA practices, the relationship between CA and durum wheat quality is not always straightforward, and outcomes may vary depending on agronomic practices, environmental conditions, and genetic factors [15-17]. Studies exploring the effects of CA on durum wheat quality have yielded mixed results, highlighting the complexity of this relationship. While some research indicates positive associations between CA adoption and grain quality parameters, others report minimal differences or even potential drawbacks in specific contexts. Beyond agronomic factors, post-harvest handling and processing practices also play a pivotal role in shaping durum wheat quality. CA-adapted cropping systems may introduce changes in crop residue composition, weed populations, and pest dynamics, which can influence grain cleanliness and susceptibility to mycotoxin contamination during storage. Thus, a holistic approach that integrates pre-harvest agronomy with post-harvest management is essential for ensuring the overall quality and safety of durum wheat produced under CA systems, the impact of conservation agriculture on durum wheat quality is a multifaceted interplay of agronomic, environmental, and post-harvest factors. While CA practices hold the potential to enhance certain grain quality attributes through improved soil health and resource efficiency, the outcomes are contingent upon various contextual factors [18]. Future research endeavors should prioritize long-term field trials, interdisciplinary collaborations, and participatory approaches to unravel the nuances of this relationship and inform evidence-based recommendations for sustainable durum wheat production.

Yield Potential of Durum Wheat in Conservation Agriculture Systems: Yield stability and resilience are fundamental aspects of sustainable crop production. Conservation agriculture practices, such as minimum tillage and crop residue retention, can enhance soil moisture retention, reduce erosion, and promote biological activity, potentially benefiting durum wheat yield performance [19]. Empirical evidence regarding the yield response of durum wheat to CA remains heterogeneous, with outcomes varying across different agroecosystems and management practices. While some studies report yield advantages under CA, particularly in water-limited environments, others highlight trade-offs or no significant differences compared to conventional tillage. Factors such as weed competition, nutrient availability, and pest pressure further modulate the yield dynamics of durum wheat in CA systems, necessitating context-specific assessments to optimize productivity. Yield stability and resilience are paramount considerations in the pursuit of sustainable agriculture, particularly in the context of durum wheat production under conservation agriculture (CA) systems. The adoption of CA practices, such as minimum tillage, crop residue retention, and diversified cropping systems, holds the promise of bolstering yield potential by enhancing soil health, water conservation, and nutrient cycling [20]. The translation of these principles into tangible yield gains for durum wheat is contingent upon a myriad of factors, including agroecological conditions, management practices, and socio-economic constraints. At the heart of CA's potential to enhance durum wheat yield lies its ability to mitigate soil erosion, conserve soil moisture, and improve nutrient availability. By minimizing soil disturbance and maintaining permanent soil cover, CA practices create a conducive environment for root development, microbial activity, and nutrient cycling, which are critical determinants of crop productivity. Furthermore, the retention of crop residues on the soil surface facilitates organic matter accumulation and carbon sequestration, fostering soil fertility and resilience to environmental stressors. Empirical evidence regarding the yield response of durum wheat to CA practices is heterogeneous, reflecting the complex interplay of factors influencing crop performance [21]. While some studies report yield advantages under CA compared to conventional tillage systems, particularly in water-limited environments or degraded soils, others indicate comparable or even reduced yields in certain contexts. The variability in outcomes underscores the importance of considering site-specific conditions, crop management strategies, and socio-economic factors in assessing the efficacy of CA for durum wheat production.

The evaluating durum wheat yield potential under CA systems is the dynamic nature of agroecological interactions and feedback mechanisms. Soil type, climatic variability, crop rotation, and pest pressure are among the myriad factors that can modulate the yield dynamics of durum wheat in CA-adapted cropping systems. Moreover, the transition from conventional tillage to CA practices may entail an initial adjustment period during which yield fluctuations and agronomic challenges may arise, necessitating adaptive management strategies and farmer capacity-building initiatives [22-23]. It is important to recognize that the benefits of CA for durum wheat yield may extend beyond immediate productivity gains. Long-term studies have demonstrated the potential of CA to enhance soil resilience, mitigate climate change impacts, and promote agroecosystem sustainability. Furthermore, the integration of CA with complementary practices such as precision agriculture, agroforestry, and water harvesting can amplify its positive effects on durum wheat yield while addressing broader socio-environmental objectives, while conservation agriculture holds promise for enhancing the yield potential of durum wheat, its realization hinges upon a nuanced understanding of local agroecological dynamics and socio-economic contexts. Future research endeavors should prioritize interdisciplinary collaborations, participatory approaches, and knowledge exchange platforms to elucidate the mechanisms driving yield responses to CA practices and inform evidence-based recommendations for sustainable durum wheat production [24]. By harnessing the synergies between CA principles and durum wheat agronomy, we can pave the way towards resilient and regenerative farming systems that meet the dual imperatives of food security and environmental sustainability.

Sanitary Considerations in Durum Wheat Conservation Agriculture: Pest and disease management are crucial aspects of durum wheat production, influencing both yield quantity and quality. Conservation agriculture practices, such as crop rotation, cover cropping, and integrated pest management, can contribute to pest suppression and disease control, potentially reducing reliance on synthetic inputs [25-27]. The effectiveness of these strategies in mitigating pest and disease pressure varies depending on regional climatic conditions, cropping systems, and agronomic practices. Moreover, unintended consequences, such as shifts in pest populations or the emergence of new pathogens, may arise in response to CA adoption, necessitating proactive monitoring and adaptive management strategies.

Challenges and Future Directions

The potential benefits, the widespread adoption of conservation agriculture in durum wheat farming systems faces several challenges. Socioeconomic constraints, limited access to machinery, and knowledge gaps among farmers hinder the implementation of CA practices in certain regions. Furthermore, the complex interactions between CA, climate change, and socio-economic factors necessitate interdisciplinary research efforts to develop context-specific recommendations and extension services. Future research directions should prioritize long-term field trials, participatory approaches, and holistic assessments of socio-environmental impacts to facilitate evidence-based decision-making and enhance the resilience of durum wheat farming systems.

Conclusion

Conservation agriculture offers a promising pathway towards sustainable intensification of durum wheat production, encompassing quality enhancement, yield stability, and ecological resilience. While empirical evidence regarding durum wheat performance in CA systems is heterogeneous, emerging research highlights the potential synergies between CA principles and durum wheat agronomy. The knowledge gaps, fostering stakeholder engagement, and promoting policy support are critical for accelerating the adoption of CA practices and ensuring the resilience of durum wheat farming systems in the face of emerging challenges.

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