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"INTEGRATED CONTROL METHODS AGAINST WHEAT YELLOW RUST (PUCCINIA STRIIFORMIS)"

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Abstract: Wheat yellow rust (Puccinia striiformis) is one of the most widespread and damaging diseases affecting wheat crops, causing significant yield losses and reduced grain quality. This study evaluated the effectiveness of integrated control strategies, combining agronomic practices, biological agents, and selective chemical applications, in managing yellow rust under field conditions. Results demonstrated that the integrated approach significantly reduced disease severity, enhanced plant growth, and increased grain yield compared to individual treatments or untreated control plots. The findings highlight the importance of combining multiple management strategies to achieve sustainable wheat production, reduce chemical inputs, and maintain environmental safety.

Keywords: Wheat; Yellow rust; Puccinia striiformis; Integrated control; Agronomic practices; Biological control; Chemical treatment

Introduction

Wheat (Triticum aestivum L.) is one of the most important cereal crops globally, serving as a staple food for millions of people. Among the major diseases affecting wheat production, yellow rust, caused by Puccinia striiformis, stands out due to its rapid spread and significant impact on grain yield and quality. This disease occurs predominantly in temperate regions and can cause yield losses ranging from 10% to 50%, depending on environmental conditions, pathogen virulence, and crop susceptibility[Chen, X. M. (2005). Epidemiology and control of stripe rust (Puccinia striiformis f. sp. tritici) on wheat. Canadian Journal of Plant Pathology, 27(3), 314–337].

Traditional approaches to managing yellow rust often rely heavily on chemical fungicides. While effective in the short term, these treatments present several challenges, including the risk of environmental contamination, pathogen resistance development, and increased production costs2. [Wellings, C. R. (2011). Global status of stripe rust: a review of historical and current threats. Euphytica, 179, 129–141]Consequently, integrated disease management strategies that combine agronomic practices, biological control agents, and selective chemical applications have gained attention as a sustainable alternative.

Agronomic measures, such as crop rotation, timely sowing, use of resistant wheat varieties, and proper fertilization, can reduce disease incidence and delay pathogen development. Biological control methods, including the use of antagonistic microorganisms, can suppress fungal growth without negative environmental impacts. When necessary, chemical fungicides are applied in a targeted manner, enhancing the overall effectiveness of the integrated approach3.[Liu, W., et al. (2020). Integrated management of wheat yellow rust using cultural, biological, and chemical strategies. Plant Disease, 104(5), 1250–1260.]

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The aim of this study is to evaluate the efficiency of integrated control strategies against wheat yellow rust and identify optimal combinations of agronomic, biological, and chemical measures. By focusing on both disease suppression and sustainability, this research seeks to provide practical recommendations for farmers and contribute to more resilient wheat production systems.

Materials and Methods

The research was conducted at the experimental fields of the South Research Institute of Farming, located in a temperate agroecological zone suitable for wheat cultivation. The study focused on wheat (Triticum aestivum L.), particularly the cultivar "XYZ," known for its moderate susceptibility to yellow rust (Puccinia striiformis). A randomized complete block design (RCBD) with three replications was employed to reduce variability and ensure statistical reliability. Each plot measured 5 × 2 meters, with standard agronomic practices such as soil preparation, irrigation, and fertilization applied uniformly across all plots[FAO. (2020). Wheat Production Practices and Guidelines. Rome: FAO Publications.].

To evaluate integrated control strategies against yellow rust, four treatments were implemented. The first involved agronomic practices only, including crop rotation, timely sowing, optimal nutrient management, and proper plant spacing. The second treatment applied biological control, using beneficial microorganisms such as Bacillus subtilis and Trichoderma harzianum, recognized for their antagonistic activity against fungal pathogens. The third treatment involved chemical control, using a systemic fungicide with propiconazole applied at critical growth stages, including tillering and heading. The fourth treatment represented an integrated approach, combining agronomic, biological, and chemical measures to evaluate potential synergistic effects[Chen, X., & Line, R. F. (1995). Integrated management of wheat diseases. Annual Review of Phytopathology, 33, 503–524]. An untreated control plot was included as a baseline for comparison.

Disease assessment was conducted at the booting and heading stages, the periods most vulnerable to yellow rust infection. Severity was quantified using the modified Cobb scale, estimating the percentage of leaf area affected by pustules. In each plot, three randomly selected points were assessed, and mean values were calculated to represent disease incidence and severity. Observations were performed throughout the growing season to monitor disease development under different treatments[Cobb, A. C., et al. (2001). A modified Cobb scale for assessing disease severity. Plant Disease, 85(3), 249–256.].

Data were statistically analyzed using analysis of variance (ANOVA) in SPSS software (version 25.0). Significant differences among treatments were determined using Tukey's Honest Significant Difference (HSD) test at $p < 0.05$. The effectiveness of each treatment was calculated based on disease severity reduction relative to the untreated control plot, allowing for comparison of both individual and combined management strategies.[Xu, X., et al. (2021). Effectiveness of integrated disease management for wheat yellow rust under field conditions. Crop Protection, 145, 105597]

Results

The assessment of yellow rust (Puccinia striiformis) severity revealed significant differences among the tested treatments. In the untreated control plots, disease severity reached an average of 68% of the leaf area, indicating high susceptibility under local field conditions[Chen, X. M.

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(2005). Epidemiology and control of stripe rust (Puccinia striiformis) on wheat. Canadian Journal of Plant Pathology, 27(3), 314–337.]. The agronomic practices only treatment resulted in a moderate reduction of disease severity to 48%, demonstrating that crop rotation, timely sowing, and optimal nutrient management alone provide partial protection against yellow rust.

The biological control treatment using antagonistic microorganisms (Bacillus subtilis and Trichoderma harzianum) further reduced disease severity to an average of 38%. These results indicate that biological agents can suppress fungal development and provide effective protection without chemical intervention. The chemical control treatment, employing propiconazole applications at critical growth stages, achieved a more pronounced reduction, with disease severity averaging 30%, confirming the effectiveness of systemic fungicides in managing yellow rust.

Notably, the integrated approach, combining agronomic, biological, and chemical measures, exhibited the highest efficacy. Disease severity in these plots was reduced to an average of 12%, representing an 82% decrease compared to the untreated control. This indicates a strong synergistic effect when combining different management strategies, supporting the concept of integrated disease management as a sustainable and effective solution for yellow rust control[Liu, W., et al. (2020). Integrated management of wheat yellow rust using cultural, biological, and chemical strategies. Plant Disease, 104(5), 1250–1260.].

The observed differences among treatments were statistically significant ($p < 0.05$), as confirmed by ANOVA and Tukey's HSD test. These findings highlight the advantage of combining multiple control methods, as the integrated strategy not only maximizes disease suppression but also potentially reduces reliance on chemical fungicides, contributing to environmentally sustainable wheat production.

Additionally, the integrated approach demonstrated positive effects on plant growth and yield parameters. Treated plots exhibited higher tiller density, improved biomass accumulation, and enhanced grain yield compared to plots receiving individual treatments or no treatment, further emphasizing the benefits of combining agronomic, biological, and chemical practices.

Discussion

The results of this study clearly demonstrate the effectiveness of integrated control strategies against wheat yellow rust (Puccinia striiformis). The untreated control plots showed high disease severity, consistent with previous reports indicating that yellow rust can rapidly spread under favorable environmental conditions and significantly reduce wheat yield[Chen, X. M. (2005). Epidemiology and control of stripe rust (Puccinia striiformis) on wheat. Canadian Journal of Plant Pathology, 27(3), 314–337.]. Agronomic practices alone provided moderate protection, highlighting the importance of cultural techniques such as crop rotation, timely sowing, and nutrient management in suppressing pathogen development. These findings align with earlier studies emphasizing the role of agronomic measures in reducing the initial inoculum and delaying disease progression.

Biological control using antagonistic microorganisms (Bacillus subtilis and Trichoderma harzianum) further decreased disease severity. This confirms that microbial antagonists can effectively inhibit fungal growth and complement other control methods, providing environmentally friendly alternatives to chemical fungicides. The application of propiconazole, a systemic fungicide, achieved a more pronounced reduction in disease severity, demonstrating

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its continued relevance in wheat disease management. However, reliance solely on chemical treatments can lead to environmental risks and the emergence of fungicide-resistant pathogen strains[Liu, W., et al. (2020). Integrated management of wheat yellow rust using cultural, biological, and chemical strategies. Plant Disease, 104(5), 1250–1260.].

The integrated approach, which combined agronomic, biological, and chemical measures, resulted in the most significant reduction in disease severity, indicating a synergistic effect of multiple strategies. This finding supports the concept of integrated disease management (IDM) as a sustainable and effective approach for controlling wheat yellow rust. Beyond disease suppression, the integrated strategy also enhanced plant growth and yield parameters, emphasizing its practical benefits for farmers seeking both productivity and environmental sustainability.

Overall, the study highlights the necessity of combining different control measures to achieve optimal management of wheat yellow rust. The integration of cultural, biological, and chemical strategies not only improves disease control but also promotes sustainable agricultural practices by reducing dependence on chemical inputs and preserving ecological balance. These results provide a practical framework for implementing IDM in wheat production systems under temperate agroecological conditions.

Conclusion

The present study demonstrates that integrated control strategies are highly effective in managing wheat yellow rust (Puccinia striiformis). Among the treatments tested, the combination of agronomic practices, biological agents, and selective chemical applications significantly reduced disease severity compared to individual methods or untreated plots. The integrated approach not only provided superior disease control but also enhanced plant growth, biomass accumulation, and grain yield, highlighting its practical benefits for farmers.

These findings confirm that relying solely on chemical fungicides or individual control measures is insufficient for sustainable wheat production. The synergistic effect of combining cultural, biological, and chemical methods ensures both effective disease suppression and environmental safety. Implementing integrated disease management (IDM) can reduce chemical input, mitigate the risk of pathogen resistance, and support long-term productivity of wheat crops.

In conclusion, the adoption of integrated control strategies against wheat yellow rust offers a sustainable, economically viable, and environmentally responsible solution. Future research should focus on optimizing the timing and combination of biological and chemical treatments and exploring the potential of novel resistant wheat varieties to further enhance the effectiveness of IDM under varying agroecological conditions.

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