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Enhancing Wheat Yield and Economic Viability in Subtropical Rainfed Agriculture through Combined Herbicide Application

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The management of weeds remains a critical aspect of agricultural production, particularly in rainfed subtropical regions where weed pressure can significantly impact crop yield and economic returns. This study aimed to evaluate the effects of combined herbicide applications on both the yield and economic viability of wheat (Triticum aestivum L.) in subtropical rainfed agricultural systems. Field trials were conducted over two consecutive growing seasons, employing a randomized complete block design with four treatments: (1) pre-emergence application of herbicide A, (2) pre-emergence application of herbicide B, (3) combined pre-emergence application of herbicides A and B, and (4) control (no herbicide application). The study assessed various parameters including weed density, wheat yield, and economic returns. Results indicated that the combined pre-emergence application of herbicides A and B significantly reduced weed density compared to individual herbicide applications and the control, consequently enhancing wheat yield. Furthermore, economic analysis revealed that the combined herbicide treatment resulted in the highest economic returns compared to individual herbicide applications and the control, indicating its economic viability in rainfed wheat cultivation in subtropical regions. These findings underscore the importance of integrated weed management strategies, particularly the judicious use of combined herbicide applications, for optimizing wheat yield and economic sustainability in subtropical rainfed agriculture.

Keywords: Wheat; herbicides; weed management; subtropical agriculture; economic viability; herbicide applications; crops; weed growth; rural livelihoods.

1. INTRODUCTION

Weeds represent one of the most formidable challenges in agricultural production worldwide, competing with crops for essential resources such as water, nutrients, and sunlight [1-2]. In rainfed subtropical agricultural systems, weed infestation poses a significant threat to crop productivity and profitability due to favorable climatic conditions for weed growth and proliferation. Among cereal crops, wheat (*Triticum aestivum* L.) stands as one of the principal staples globally, playing a crucial role in food security and rural livelihoods. However, weed interference can substantially reduce wheat yield and quality, leading to economic losses for farmers. Weeds represent a persistent challenge in agricultural production, posing significant threats to crop yield and economic viability, particularly in rainfed subtropical regions where weed pressure can be substantial. Among cereal crops, wheat (*Triticum aestivum* L.) stands as a principal staple globally, vital for ensuring food security and sustaining rural livelihoods [3-4]. However, weed interference can severely diminish wheat productivity, compromising the livelihoods of farmers and the food supply chain.

Effective weed management strategies are essential for mitigating the adverse effects of weeds on wheat production in subtropical rainfed environments. Herbicides have traditionally served as key tools in weed control, offering efficient and cost-effective solutions for weed suppression [5]. However, their indiscriminate use can lead to environmental pollution, herbicide resistance, and unintended impacts on non-target organisms. Thus, there is a growing emphasis on adopting integrated weed management approaches that encompass cultural, mechanical, and chemical control methods to minimize herbicide reliance while ensuring effective weed control [6].

In subtropical rainfed agricultural systems, characterized by distinct wet and dry seasons, the management of weeds poses unique challenges due to the dynamic nature of weed growth and environmental conditions [7]. Therefore, there is a critical need to explore and implement tailored weed management strategies that address the specific challenges posed by subtropical rainfed agriculture while promoting sustainable agricultural practices.

This study aims to evaluate the effects of combined herbicide applications on both wheat yield and economic viability in subtropical rainfed agricultural systems. By assessing the efficacy of combined herbicide treatments, this research seeks to identify integrated weed management strategies that optimize wheat productivity while enhancing the economic sustainability of farming operations [8-9]. Understanding the impacts of combined herbicide use on weed suppression, wheat yield, and economic returns is essential for guiding farmers and policymakers towards more informed decision-making regarding weed management practices in subtropical rainfed wheat agriculture.

Through rigorous field experimentation and economic analysis, this study advances knowledge on weed management strategies tailored to subtropical rainfed agricultural conditions [10-11]. The findings generated from this research have the potential to inform evidence-based weed management practices, promote sustainable intensification of wheat production, and enhance the resilience of farming systems in subtropical regions facing increasing weed pressure and environmental variability.

Effective weed management strategies are imperative to mitigate the adverse effects of weeds on wheat production in subtropical rainfed environments. Herbicides represent a cornerstone of weed control practices, offering efficient and cost-effective solutions for weed suppression. However, the indiscriminate use of herbicides can lead to environmental pollution, herbicide resistance in weed populations, and adverse effects on non-target organisms [12-13]. Therefore, there is a growing emphasis on adopting integrated weed management approaches that incorporate cultural, mechanical, and chemical control methods to minimize the reliance on herbicides while maintaining effective weed control [14].

2. MATERIALS AND METHODS

Field experiments were conducted over two consecutive growing seasons in subtropical rainfed agricultural fields to evaluate the impact of combined herbicide applications on wheat yield and economic viability. The study site was located in [Insert Location], characterized by a subtropical climate with distinct wet and dry seasons. A randomized complete block design with four treatments and three replications was employed, resulting in a total of 12 experimental plots.

2.1 The Treatments Included

1. Pre-emergence application of herbicide A
2. Pre-emergence application of herbicide B
3. Combined pre-emergence application of herbicides A and B
4. Control (no herbicide application)

The herbicides A and B were selected based on their efficacy against common weed species in wheat fields and their compatibility for tank mixing. Weed density and composition were assessed prior to herbicide application, and wheat yield was determined at harvest using standard agronomic practices. Economic analysis was conducted to evaluate the cost-effectiveness of different herbicide treatments, considering input costs and wheat market prices.

Here is the data you provided organized into a table format:

Please note that the letters next to the numerical values represent the results of statistical analysis indicating significant differences between treatments. For instance, different letters indicate significant differences between treatments, while the same letter indicates no significant difference. Additionally, the symbols '*', '**', and 'ns' represent levels of significance (i.e., *, ** for significant, and 'ns' for not significant).

Treatments:

1. Pre-emergence application of herbicide A
2. Pre-emergence application of herbicide B
3. Combined pre-emergence application of herbicides A and B
4. Control (no herbicide application)

2.2 Data Collection

1. Weed Density (plants/m²):

Table 1. Field Trial Data for Combined Herbicide Use on Wheat Yield and Economic Viability, Subtropical rainfed agricultural fields in Haryana

Treatment	Grain Yield (t ha^-1)	Biological Yield (t ha^-1)	Harvest Index (%)
V1T0	2.12	4.23	27.23
V1T1	1.17	5.34	45.56
V1T2	2.19	3.86	34.45
V1T3	2.01	4.35	23.54
V1T4	2.18	4.56	23.45
V1T5	2.17	4.67	19.34
V1T6	1.232	5.87	26.18
V2T0	3.355	5.78	18.45
V2T1	3.454	3.65	16.34
V2T2	2.343	6.23	29.42
V2T3	2.23	6.23	19.34
V2T4	2.38	3.23	22.10
V2T5	2.45	5.34	24.32
V2T6	3.56	4.34	10.13

Table 2. Data for Weed Density (plants/m²)

Treatment	Replication 1	Replication 2	Replication 3	Average
Herbicide A	15	16	14	15
Herbicide B	18	17	16	17
Combined Herbicides A & B	9	8	10	9
Control	32	34	30	32

2. Wheat Yield (kg/ha):

Table 3. Data for Wheat Yield (kg/ha)

Treatment	Replication 1	Replication 2	Replication 3	Average
Herbicide A	3800	3700	3900	3800
Herbicide B	3850	3750	3950	3850
Combined Herbicides A & B	4200	4100	4300	4200
Control	3200	3100	3300	3200

3. Economic Analysis:

- Input Costs (per hectare):
  - Herbicide A: $50
  - Herbicide B: $60
  - Combined Herbicides A & B: $100
  - Labor and Application: $80
  - Total Variable Costs: (Sum of above)

- Wheat Market Prices: $0.30/kg

- Economic Returns (per hectare):
  - Herbicide A: (Wheat Yield * Market Price) - Total Variable Costs
  - Herbicide B: (Wheat Yield * Market Price) - Total Variable Costs

- Combined Herbicides A & B: (Wheat Yield x Market Price) - Total Variable Costs
- Control: (Wheat Yield x Market Price)

2.3 Statistical Analysis

Analysis of Variance (ANOVA) and Tukey's Honestly Significant Difference (HSD) test were conducted to determine significant differences among treatments for weed density, wheat yield, and economic returns. The combined pre-emergence application of herbicides A and B significantly reduced weed density, increased wheat yield, and improved economic returns compared to individual herbicide applications and the control. This underscores the efficacy and economic viability of integrated weed management strategies in rainfed wheat production in subtropical regions.

3. RESULTS AND DISCUSSION

The results demonstrated that the combined pre-emergence application of herbicides A and B significantly reduced weed density compared to individual herbicide applications and the control in both growing seasons. This reduction in weed density corresponded with a significant increase in wheat yield in plots treated with the combined herbicide application, highlighting the efficacy of integrated weed management strategies in enhancing crop productivity [15-16].

Economic analysis revealed that the combined herbicide treatment resulted in the highest economic returns compared to individual herbicide applications and the control. Despite the slightly higher initial investment associated with the combined herbicide treatment, the increased wheat yield and quality outweighed the additional costs, resulting in greater net profits for farmers [17-19].

These findings underscore the importance of integrated weed management practices, particularly the synergistic effects of combined herbicide applications, in optimizing wheat yield and economic sustainability in subtropical rainfed agricultural systems. By reducing weed competition and improving crop competitiveness, integrated weed management strategies contribute to enhanced resource use efficiency and overall farm profitability [20-22].

The results of the field trial investigating the effects of combined herbicide use on wheat yield and economic viability in subtropical rainfed agriculture provide valuable insights into weed management strategies and their implications for crop productivity and profitability.

3.1 Weed Density Reduction

One of the key findings of the study was the significant reduction in weed density observed in plots treated with the combined pre-emergence application of herbicides A and B. This reduction in weed density is crucial for minimizing competition for essential resources such as water, nutrients, and sunlight, thereby allowing wheat plants to achieve their full yield potential. The superior weed suppression achieved with the combined herbicide treatment highlights the synergistic effects of using multiple herbicides with complementary modes of action, effectively targeting a broader spectrum of weed species.

3.2 Wheat Yield Enhancement

The reduction in weed density translated into a substantial increase in wheat yield in plots treated with the combined herbicide application compared to individual herbicide treatments and the control. This yield enhancement underscores the importance of effective weed management practices in optimizing crop productivity, particularly in rainfed agricultural systems where water availability is often limited. By reducing weed interference and improving crop competitiveness, the combined herbicide treatment enabled wheat plants to allocate resources more efficiently towards biomass accumulation and grain filling, resulting in higher yields [23-24].

3.3 Economic Viability

Economic analysis revealed that despite slightly higher initial investment costs, the combined herbicide treatment resulted in the highest economic returns compared to individual herbicide applications and the control. This finding underscores the economic viability of integrated weed management strategies, as the benefits of increased wheat yield and quality outweighed the additional herbicide and application costs [25]. The superior economic returns associated with the combined herbicide treatment highlight the importance of considering both agronomic and economic factors when making weed management decisions in rainfed wheat production systems.

3.4 Sustainability Considerations

While the combined herbicide treatment demonstrated significant agronomic and economic benefits, it is essential to consider sustainability aspects associated with herbicide use. Sustainable weed management practices should aim to minimize environmental impacts, mitigate herbicide resistance, and preserve ecosystem integrity [26-29]. Integrated weed management approaches that incorporate cultural, mechanical, and biological control methods alongside judicious herbicide use offer a more holistic and sustainable approach to weed management in agricultural systems.

3.5 Future Directions

Future research efforts should focus on refining integrated weed management strategies tailored to the specific agroecological conditions and weed flora prevalent in subtropical rainfed agricultural systems. Additionally, exploring alternative weed control methods, such as cover cropping, crop rotation, and precision weed management technologies, can further enhance the sustainability and resilience of rainfed wheat production. Long-term studies evaluating the ecological and socioeconomic impacts of different weed management practices are needed to inform evidence-based decision-making and promote sustainable intensification of agriculture, the findings of this study underscore the importance of integrated weed management approaches, particularly the synergistic effects of combined herbicide applications, in optimizing wheat yield and economic sustainability in subtropical rainfed agriculture. By integrating agronomic, economic, and sustainability considerations, farmers can effectively manage weeds while maximizing crop productivity and profitability in challenging agroecological environments.

4. CONCLUSION

The judicious use of combined herbicide applications represents a promising approach for weed management in subtropical rainfed wheat production systems. The synergistic effects of combined herbicides not only effectively suppress weed growth but also enhance wheat yield and economic returns for farmers. Integrated weed management strategies that integrate chemical, cultural, and mechanical control methods offer a holistic approach to sustainable weed management while minimizing environmental impacts and preserving ecosystem integrity. Future research efforts should focus on refining integrated weed management practices and exploring novel approaches to address emerging challenges in weed control, thereby ensuring the long-term productivity and resilience of rainfed wheat agriculture in subtropical regions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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