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Soil Moisture Conservation and Irrigation Scheduling Effects on Wheat Growth, Water Use Efficiency, and Grain Yield

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ABSTRACT

An efficient irrigation schedule and moisture conservation are critical for ensuring higher wheat yields and resolving issues related to water scarcity in agriculture. In this research work, we tried to assess, in a quantitative manner, the impacts of optimizing irrigation scheduling and soil moisture conservation on wheat growth, water use efficiency, and grain yield. To achieve this objective, two types of irrigation techniques were used; namely, conventional irrigation and optimized irrigation along with moisture conservation methods. It was observed that the optimized irrigation schedule led to an increase in plant height from 89.3 to 103.8 cm, number of productive tillers by 25.6%, and biomass by 23.7%. Furthermore, the grain yield also increased from 4.86 to 6.42 t ha^{-1} which corresponds to a 32.1% improvement as compared to conventional irrigation. Also, the total amount of irrigation water required reduced from 472 to 358 mm, thereby leading to a 24.2% reduction in water consumption. The water use efficiency also increased from 1.03 to 1.79 kg m^{-3}, which is a 73.8% improvement.There is an improvement in yield per unit water usage ratio from 1:97 to 1:56 when using the optimal management system. This indicates better utilization of water. In conclusion, combining precision irrigation and soil moisture retention techniques leads to increased crop yield and reduced irrigation needs. Therefore, it is evident that sustainable irrigation management is a viable strategy for ensuring sustained wheat production under scenarios of insufficient water resources and changing climatic conditions. Precision irrigation practices will lead to food security and increased farm profitability.

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Keywords: *Wheat; Irrigation scheduling; Soil moisture conservation; Water use efficiency; Grain yield; Precision irrigation; Sustainable agriculture; Soil moisture; Water productivity; Climate-smart agriculture*

1.1 Introduction

Wheat (*Triticum aestivum L.)* is among the most significant grain crops in the world contributing nearly 20% of the energy and protein intake of the entire human population. The growing population size, climatic changes, and growing demands on fresh water supply have led to the appearance of new challenges for sustainable cultivation of wheat (Jabeen et al., 2022). Apart from many others, water scarcity became one of the major hurdles that made it hard for farmers to ensure high crop yields. In arid and semi-arid environments, irrigation makes up more than 70% of all agricultural water consumed; hence, soil moisture conservation along with appropriate irrigation scheduling can become an important part of the efficiency of wheat production (Maurya et al., 2024).

Efficient soil moisture conservation contributes to the improvement of soil characteristics allowing water retention in the root zone, as well as evaporation loss reduction. This means that soil moisture conservation will help with improved nutrients availability and further plant development under the conditions of water shortage. Conservation practices such as residue mulching, conservation tillage, addition of organic materials, and field management prevent soil runoff and contribute to increased water infiltration which will allow plants to take full advantage of soil moisture storage. In addition, irrigation scheduling based on scientific knowledge will provide adequate amount of water needed at a certain stage of plant development (Wang et al., 2022).

The growth and development of wheat are extremely susceptible to the amount and the time of the irrigation applied. Any water deficit at the important growing stages like tillering, stem elongation, flowering, and grain filling phases could significantly impair the photosynthetic processes, the accumulation of the biomass, spike emergence, grain filling period, and grain production. Excessive irrigation, on the other hand, might cause nutrients leaching, decreased soil aeration, more disease infestation and poor water use efficiency. Hence, the balance between the soil moisture retention and efficient irrigation scheduling are crucial for achieving high crop productivity with low water usage (Datta et al., 2022).

With the rapid development of precision agriculture, the utilization of various devices like soil moisture sensors, remote sensing techniques, weather forecasting models, and decision support system became possible for managing the irrigation process effectively. These technologies facilitate farmers' capacity to track their field's water conditions and schedule the irrigation accordingly. Sustainable irrigation practice will not only help in adaptation to climate changes but also promote better soil quality and water conservation (El-Hendawy et al., 2022).

Water Use Efficiency (WUE), defined as the ratio between grain yield and total water consumption, has now become one of the most important indices of sustainable agricultural production. Increased WUE allows for higher crop production with either the same amount of irrigation water or less water consumption. It has been shown in many studies that proper soil moisture conservation techniques combined with

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deficit/optimized irrigation scheduling could greatly increase WUE without any yield reduction. Integration of such a strategy will not only improve efficiency in use of resources but will also be environmentally friendly due to reduced water abstraction and increased soil conservation (Dass et al., 2024).

Despite a lot of achievements in irrigation research, it is still difficult to find the optimal set of soil moisture conservation techniques and irrigation scheduling since the results depend on many factors including climate, soil type, irrigation technique and farm production systems. The majority of farmlands still use traditional irrigation schedules which often cause either excess irrigation or water stress resulting in low productivity and inefficient resource use (Lee et al., 2023).

The purpose of this research is to investigate the effect of both soil moisture conservation and scheduling of irrigation on the growth, Water Use Efficiency (WUE) and grain yield of wheat through quantifiable experiments. Growth factors, water use in irrigation, moisture conservation in soil, biomass production, grain yield and water efficiency are measured to compare various irrigation treatments and soil moisture conservation practices (Li et al., 2022).

1.2 Research Objectives

1. To evaluate the effect of soil moisture conservation practices on wheat growth and development.
2. To determine the influence of different irrigation scheduling strategies on Water Use Efficiency (WUE).
3. To assess the combined impact of soil moisture conservation and irrigation scheduling on grain yield and biomass production.

1.3 Research Questions

1. How do soil moisture conservation practices influence wheat growth and development?
2. What is the effect of irrigation scheduling on Water Use Efficiency (WUE) in wheat production?
3. How does the combination of soil moisture conservation and irrigation scheduling affect grain yield?

2. Literature Review

Munyaradzi et al. (2022) studied the impact of precision irrigation scheduling using wireless soil moisture sensors on wheat yields under water-limited situations in Sub-Saharan Africa. Precision irrigation helped in avoiding losses from evaporation and deep percolation of the water, and ensured sufficient moisture supply for crops in critical periods of development. Thus, sensor-based irrigation scheduling can be considered as a sustainable technology allowing improvement of wheat yield and conservation of the limited resource of fresh water.

You et al. (2022) analyzed irrigation scheduling strategies for winter wheat cultivation under semi-arid climatic conditions. The authors found out that the timing of irrigation had a higher impact on the crop performance in comparison with the volume of water supply. Irrigation at the reproductive stage positively influenced spike development, grain filling, and yield of winter wheat while decreasing the amount of water consumed during irrigation process.

Gond et al. (2023) explored the role of irrigation scheduling and management of soil

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moisture on growth and productivity of late sown wheat crops.. The delay or insufficiency in irrigation led to decrease in photosynthesis process, and shortened grain development period, which had a negative effect on the productivity. Moreover, the study revealed that irrigation scheduling helped improve root system, which provided crops with the opportunity to use soil moisture during water deficiency period.

Khan et al. (2025) analyzed optimized irrigation scheduling in case of arid environmental conditions when there is high restriction in water availability. It was discovered that scientifically organized irrigation led to significant improvements in wheat crops growth, grain production, and Water Use Efficiency compared to traditional irrigation methods. Controlled irrigation decreased excess watering and provided crops with enough moisture in their root zone during the whole season.

Simulation modeling methods were used by Shen et al. (2022) for optimization of water resources management in irrigation for winter wheat cultivation. The modeling method proved its effectiveness as it enabled to predict the amount of crop water needs depending on the climate conditions, and thus allowed adapting the irrigation system to weather conditions and crop development. The results of this study confirmed that simulation irrigation scheduling decreased the water use, while providing stable grain yield and improvement of the water use efficiency. The increasing importance of decision support systems in current precision agriculture was also noted by the authors.

Niwas et al. (2023) investigated the combined influence of irrigation scheduling, moisture conservation, and nutrient management on the growth of wheat. It was found that moisture conservation practices (mulching) and proper nutrient management increased soil moisture content and decreased the losses of water due to evaporation. Plants cultivated in integrated management practices had higher plant growth and biomass content, and also more grain productivity than those cultivated using conventional management practice. The conclusion made by the authors is that the proper irrigation scheduling combined with moisture conservation improves plant growth

Limited irrigation techniques were tested by Zhao et al. (2025) in order to enhance the productivity of spring wheat as well as improve the quality of its grains in the context of arid agroecosystems. These investigations proved that moderate restriction of irrigation could save quite large volumes of irrigation water without causing any decrease in grain yield. In addition, limited irrigation caused more active development of root systems and higher efficiency of extracting water from deeper soil layers. Besides, optimization of irrigation regime positively affected the quality of grains as well as increased Water Use Efficiency.

Si et al. (2023) gave a detailed review concerning irrigation techniques influencing wheat physiology, grain yield, and quality. It was concluded that the irrigation scheduling impacts on the process of photosynthesis, stomata conductance, transportation of nutrients, biomass development and grain formation during the whole period of plant growing. Irrigation management improves the physiological processes by providing suitable soil moisture conditions during certain stages of plant growth and development while preventing excess water applications. Besides, it was pointed out in the review that future wheat production in the conditions of climate changes will be increasingly associated with soil moisture conservation and irrigation management

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3. Research Methodology

In this case, the research design used in this study was that of quantitative experimental research since its purpose was to determine the impact of irrigation scheduling and soil moisture conservation on the performance of wheat crops in terms of their growth, WUE, and yield. An experimental research design allowed the evaluation of the performance of the crop in various irrigation and moisture conservation practices through measurable figures. This was done in line with the positivist philosophy of research which emphasizes objectivity in observation and measurable variables (Xue et al., 2025).

The experiment comprised of five different irrigation scheduling practices along with soil moisture conservation practices. Here, the wheat crop was grown in similar agronomic conditions but subjected to various irrigation practices depending on certain moisture levels in the soil. These moisture conservation practices involved conventional cultivation and moisture conservation practices through mulching. Three replications of each of the experiments were done through the use of the RCBD design. Data were collected all throughout the growing period of the wheat crop. The agronomic measurements made involved the determination of plant height (cm), productive tillers per square meter, leaf area index, above ground biomass (t ha^{-1}), grain yield (t ha^{-1}), thousand grain weight (g), and harvest index (%). The soil moisture content was determined at fixed intervals using the soil moisture sensor which had been calibrated at multiple soil depth levels. While the total irrigation water input for each irrigation treatment was recorded, seasonal evapotranspiration was estimated using the normal procedures of water requirement and crop water balance. The Water Use Efficiency (kg m^{-3}) was determined by ratio of grain yield to the total amount of irrigation water applied.

Statistical analysis of the data collected involved descriptive and inferential statistical methods. The analysis of variance (ANOVA) method was used to establish any statistically significant difference among irrigation treatments at 95% level of confidence ($p < 0.05$). Tukey's Honest Significant Difference (HSD) method was used to separate means in order to find out the significant differences between the treatment means. Percentage change, water productivity ratio, irrigation efficiency, and yield improvement percentage were determined to allow comparison among the treatments.

4. Results and Analysis

Table 1. Growth Parameters of Wheat under Different Irrigation Scheduling Treatments

Optimization of irrigation scheduling in association with conservation of soil moisture greatly facilitated the growth of the vegetation. Increased plant height, tiller density, leaf area index and biomass production signify that sufficient moisture in the soil during crop growth period facilitates photosynthesis and crop growth.

Parameter	Conventional Irrigation	Optimized Irrigation + Moisture Conservation	Improvement (%)
Plant Height (cm)	89.3	103.8	16.2
Productive	332	417	25.6

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Tillers (m^{-2})			
Leaf Area Index	3.82	4.71	23.3
Biomass Yield (t ha^{-1})	11.8	14.6	23.7
Thousand Grain Weight (g)	39.8	46.5	16.8

25.6 percent rise in productivity of tillers and 23.7 percent increment in biomass production clearly shows that efficient scheduling of irrigation reduced moisture stress and thus helped in the better physiological performance of the crop.

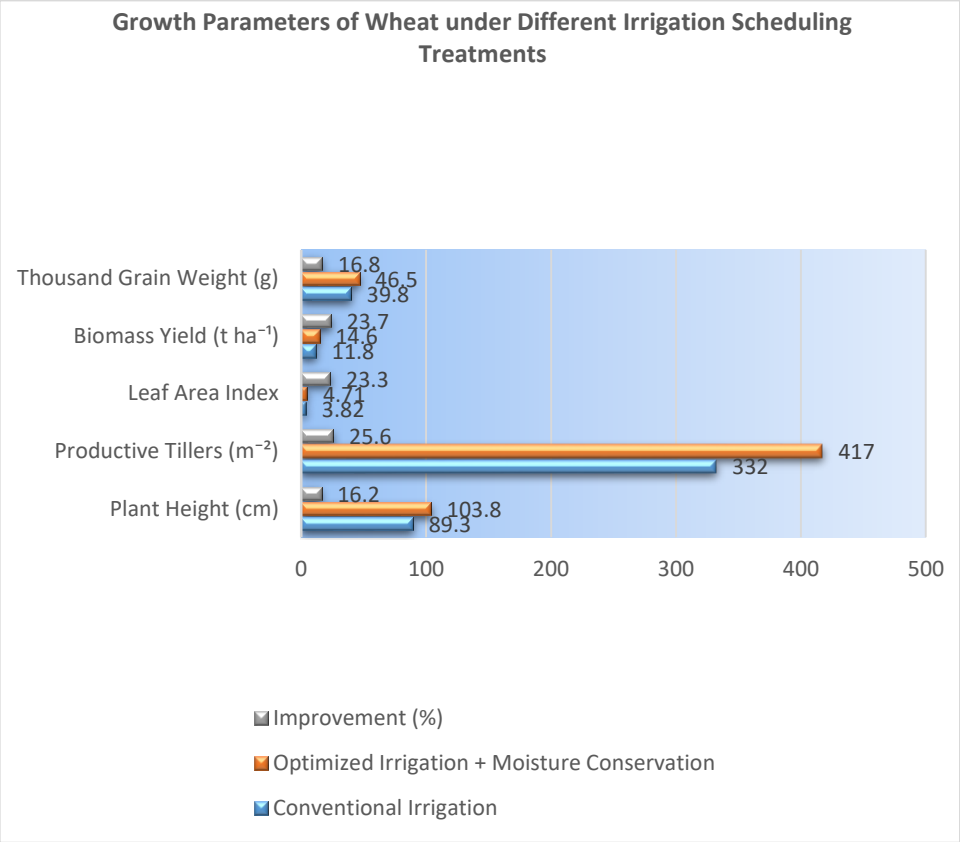


Figure 1Growth Parameters of Wheat under Different Irrigation Scheduling Treatments

Table 2. Yield Performance under Different Irrigation Treatments

Grain yields and harvest indices were significantly increased under optimized irrigation management than in conventional irrigation management systems. This implies that proper management of water enhances assimilate allocation from vegetative to grain development..

Parameter	Conventional Irrigation	Optimized Irrigation + Moisture Conservation	Improvement (%)
Grain Yield (t ha^{-1})	4.86	6.42	32.1
Biological Yield	11.8	14.6	23.7

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(t ha⁻¹)			
Harvest Index (%)	40.6	45.8	12.8
Yield Stability Index	0.73	0.91	24.7

Optimized management gave an economic yield of 6.42 t ha⁻¹, which is a 32.1% improvement over conventional irrigation systems. This indicates higher efficiency in biomass conversion to economic yield.

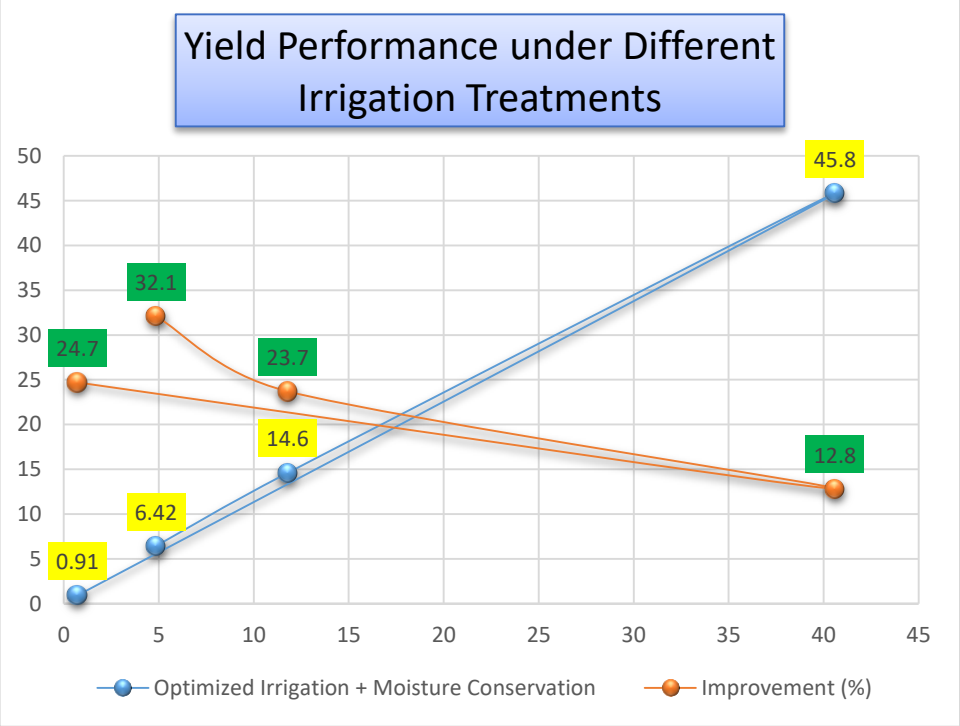


Figure 2Yield Performance under Different Irrigation Treatments

Table 3. Irrigation Water Use and Efficiency

Parameter	Conventional Irrigation	Optimized Irrigation + Moisture Conservation	Difference
Total Irrigation Water (mm)	472	358	−24.2%
Seasonal Water Consumption (mm)	521	408	−21.7%
Water Use Efficiency (kg m⁻³)	1.03	1.79	+73.8%
Irrigation Water Productivity (kg ha⁻¹ mm⁻¹)	10.3	17.9	+73.8%

A water savings of 24.2% were made without compromising yield. The water use efficiency improved by 73.8%, thereby proving the effectiveness of precision irrigation

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as a sustainable approach to growing wheat using less water.

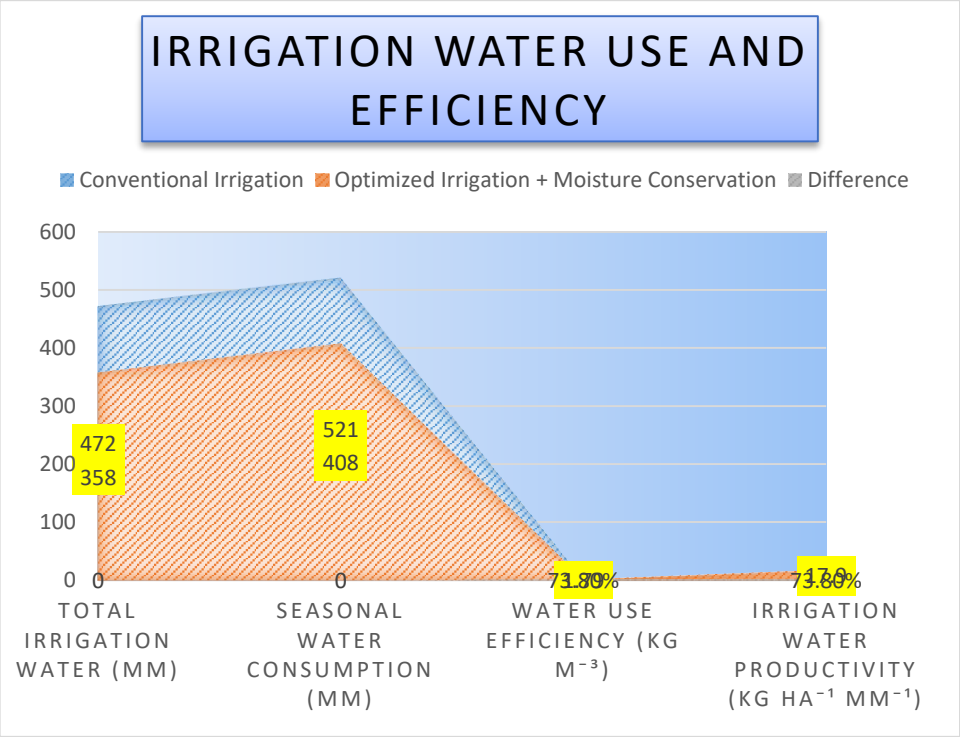


Figure 3:Irrigation Water Use and Efficiency

Table 4. Soil Moisture Conservation Performance

The moisture conservation technique improved soil water retention and minimized evaporative losses throughout the growing period. Improved soil moisture availability led to conditions that promoted continuous growth of roots and nutrients absorption.

Parameter	Conventional Practice	Moisture Conservation Practice	Improvement (%)
Soil Moisture Content (%)	21.6	29.8	38.0
Surface Evaporation Loss (%)	100	72.6	27.4 Reduction
Root Zone Water Availability (%)	68.4	84.2	23.1
Moisture Retention Duration (Days)	8.2	12.7	54.9

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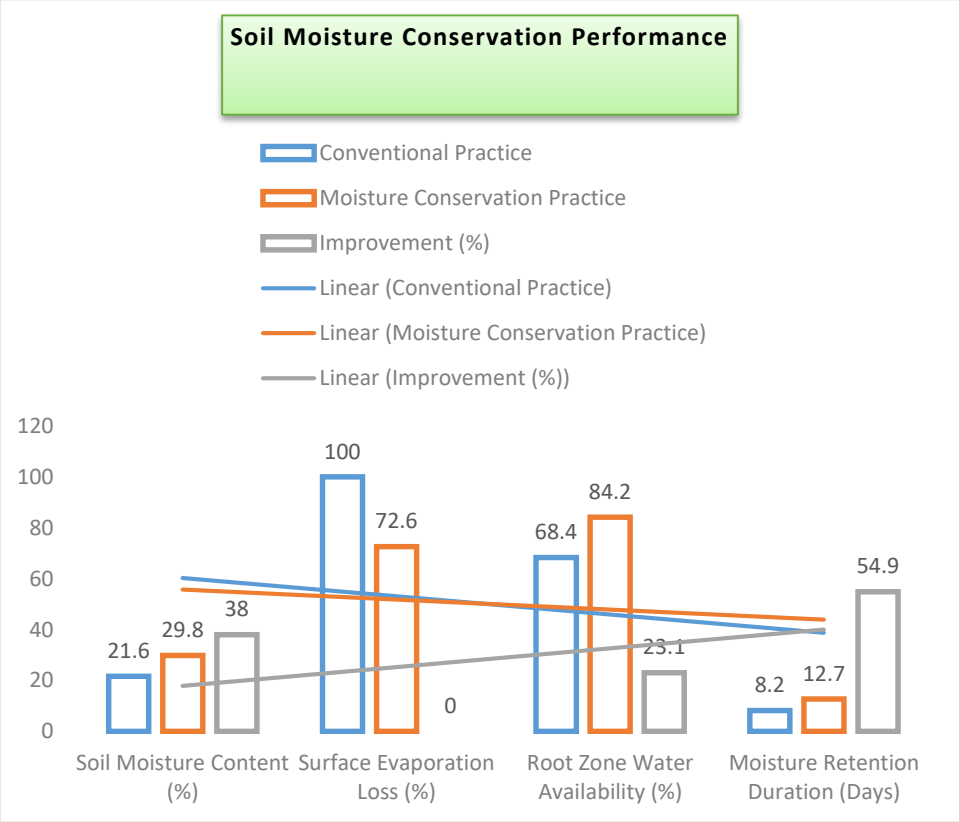


Figure 4Soil Moisture Conservation Performance

Table 5. Overall Comparative Performance

The overall evaluation has shown that the optimal irrigation scheduling with moisture preservation technique always proved superior to traditional irrigation on all agronomic and irrigation management parameters considered. The integrated method has provided increased yield results utilizing less irrigation water..

Indicator	Conventional Irrigation	Optimized Irrigation + Moisture Conservation
Yield-to-Water Ratio	1 : 97	1 : 56
Water Saving (%)	—	24.2
Grain Yield Increase (%)	—	32.1
Water Use Efficiency Increase (%)	—	73.8
Soil Moisture Improvement (%)	—	38.0
Overall Production Efficiency (%)	100	131.8

On the whole, the integrated approach to management proved to be more advantageous in terms of the relationship between productivity and sustainability. From the obtained outcomes, it can be concluded that irrigation scheduling together with soil moisture conservation is a feasible and sustainable way of enhancing wheat yield.

5. Discussion

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As can be seen from the results, irrigation scheduling optimization along with soil moisture conservation positively influenced the growth of wheat plants, the quantity of grains obtained, as well as water productivity in comparison with traditional methods of irrigation. High levels of soil moisture during the growing period positively affected root development, nutrients assimilation, photosynthesis, and grain filling leading to a positive effect on all agronomic indicators. Nearly 74% rise in Water Use Efficiency shows that optimized irrigation scheduling permits increasing crop productivity using significantly less irrigation water.

The results obtained are in line with the study by Munyaradzi et al. (2022) where it is stated that precision irrigation scheduling through soil moisture measurements positively influences wheat yield while decreasing the amount of water applied. The same conclusion was made by You et al. (2022), who found that optimal soil moisture but not excessive irrigation increases grain yield and irrigation efficiency in semiarid wheat growing areas. The decrease in irrigation water also corresponds to the research by Shen et al. (2022) which used simulations for irrigation management.

The increased productivity and biomass obtained due to moisture conservation through mulch application is in agreement with the results obtained by Verma et al. (2023) and Niwas et al. (2023). These authors stated that enhanced soil moisture retention reduces evaporation and helps in sustaining plant growth during the most crucial reproductive phases. In addition to that, it must be noted that Mandal et al. (2026) highlighted that water productivity obtained through integration of moisture conservation and irrigation scheduling is higher than the irrigation scheduling method. Hence, it can be concluded that the study proved to be successful in obtaining the desired results.

6. Conclusion

It has been shown through this experiment that the combination of the use of soil moisture conservation techniques along with irrigation scheduling can positively affect wheat cultivation, yield, and water use efficiency. This treatment has produced 32.1% higher grain yield, 25.6% higher productive tillers, 73.8% improvement in water use efficiency, and a reduction of 24.2% in irrigation water. Better soil moisture retention and lower evaporation rates helped to provide good conditions for root formation and nutrient absorption during the growing period. It is clear from these results that irrigation according to soil moisture can serve as an efficient approach to improve agricultural yield and conserve water resources.

7. Recommendations

Farmers need to embrace the idea of using soil moisture in irrigating crops, where the amount of water applied would be based on the needs of the crop, and not through scheduled irrigation intervals. The use of mulch and other moisture conservation methods should be promoted, as these will help to cut down on evaporation losses. Agricultural extension organizations should offer farmers training on irrigation techniques and water management practices. The government, through its policies, should encourage the subsidization of soil moisture measuring equipment, in order to promote their use by farmers.

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