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Integrated Resource Management for Sustainable Wheat (*Triticum aestivum* L.) Production in the South-Eastern Region of Rajasthan

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Abstract

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops in India and plays a major role in ensuring food security, nutritional stability, and economic development. It is widely cultivated across different agro-climatic regions of the country and serves as a staple food for millions of people. Due to increasing population pressure and limited cultivable land, there is a growing need to enhance wheat productivity through sustainable agricultural practices. Among the various factors affecting wheat production, irrigation and nutrient management are considered the most important. Proper irrigation at critical growth stages and balanced nutrient supply are essential for achieving higher grain yield and maintaining soil fertility. Excessive use of chemical fertilizers alone may provide immediate crop response, but continuous application over a long period can negatively affect soil health, reduce microbial activity, and lower nutrient use efficiency. Therefore, integrated nutrient management, which combines chemical fertilizers with organic sources such as farmyard manure (FYM), has emerged as an effective approach for sustainable crop production. FYM improves soil structure, increases water-holding capacity, enhances soil organic carbon, and promotes better nutrient availability. Keeping these aspects in view, the present study was conducted during the Rabi season of 2025–26 at the Agricultural Instructional Farm, School of Agricultural Sciences, Career Point University, Kota, Rajasthan. The experiment was designed to evaluate the effect of different irrigation schedules and fertility source treatments on wheat growth, yield, quality, soil fertility, and economic returns. The soil of the experimental field was silty loam in texture, slightly alkaline in reaction, low in organic carbon, and medium in fertility status. The experiment consisted of four irrigation levels and four fertility source treatments arranged in a split plot design with three replications. The

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irrigation treatments included one irrigation at Crown Root Initiation (CRI) stage, two irrigations at CRI and flowering stages, three irrigations at CRI, late jointing, and milk stages, and four irrigations at CRI, tillering, flowering, and milk stages. Fertility treatments included 100 percent recommended dose of fertilizers (RDF) through chemical fertilizers, 75 percent RDF through fertilizers + 25 percent FYM, 50 percent RDF through fertilizers + 50 percent FYM, and 100 percent RDF through FYM. The results of the study revealed that higher irrigation frequency significantly improved plant height, number of tillers, dry matter accumulation, leaf area index, grain yield, straw yield, and water use efficiency. Among the irrigation treatments, four irrigations at CRI, tillering, flowering, and milk stages produced the highest growth and yield. Similarly, integrated nutrient management treatments performed better than sole application of fertilizers or FYM. The treatment receiving 75 percent RDF through fertilizers combined with 25 percent FYM recorded the highest grain yield, better nutrient uptake, improved grain quality, and maximum economic returns. Therefore, the study concluded that integrated irrigation and nutrient management is essential for sustainable wheat production and long-term soil health.

Keywords: Wheat, Irrigation Scheduling, Integrated Nutrient Management, Farmyard Manure

1. Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops in the world and serves as a staple food for a large proportion of the global population. In India, wheat occupies a prominent place in the agricultural sector and is the second most important food crop after rice. It contributes significantly to national food security, nutritional requirements, rural employment, and the overall economy. Wheat grains are rich in carbohydrates, proteins, vitamins, and minerals, making them an essential component of the daily diet of millions of people. India is one of the leading producers of wheat in the world, with major cultivation areas located in states such as Punjab, Haryana, Uttar Pradesh, Rajasthan, Madhya Pradesh, and Bihar. However, the continuous rise in population has increased the demand for wheat production. Since the availability of cultivable land is limited, enhancing productivity per unit area has become a major challenge for researchers and farmers. Sustainable intensification of wheat production is therefore essential to meet future food demands without degrading natural resources. Among the various factors affecting wheat productivity, irrigation and

nutrient management play a vital role. Wheat is highly responsive to irrigation, especially at critical growth stages such as crown root initiation, tillering, flowering, and grain filling. Inadequate water supply during these stages can lead to poor growth, reduced tiller formation, lower grain filling, and ultimately decreased yield. On the other hand, excessive irrigation may result in nutrient losses, waterlogging, and inefficient use of water resources. Therefore, proper irrigation scheduling is necessary to achieve maximum productivity and water use efficiency. Similarly, balanced nutrient management is crucial for obtaining higher wheat yields and maintaining soil fertility. Traditionally, farmers rely heavily on chemical fertilizers to increase crop production. Although the use of inorganic fertilizers provides quick nutrient availability and immediate crop response, continuous and imbalanced application may adversely affect soil structure, microbial activity, and long-term soil health. Overdependence on chemical fertilizers can also lead to nutrient imbalance, soil degradation, and declining productivity over time. Integrated nutrient management, which involves the combined use of organic and inorganic nutrient sources, has emerged as an effective strategy for sustainable wheat cultivation. Farmyard manure (FYM) is an important organic source that improves soil physical, chemical, and biological properties. It enhances soil organic matter content, improves water-holding capacity, promotes microbial activity, and increases nutrient availability. When FYM is used along with recommended doses of chemical fertilizers, it not only supplies essential nutrients but also improves nutrient use efficiency and crop performance. Thus, integrated management of irrigation and nutrients is essential for achieving higher wheat productivity, better grain quality, improved soil health, and enhanced profitability. Adoption of such sustainable practices can help farmers maintain long-term productivity while conserving soil and water resources.

2. Materials and Methods

The present investigation was carried out during the Rabi season of 2025–26 at the Agricultural Instructional Farm, School of Agricultural Sciences, Career Point University, Kota, Rajasthan. The experimental site is located in the south-eastern plain zone of Rajasthan, which is characterized by a semi-arid climate with hot summers and mild winters. The region receives most of its annual rainfall during the monsoon season, while the rabi season remains comparatively dry, making irrigation management highly important for successful wheat cultivation. Before the initiation of the experiment, representative soil samples were collected

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from the experimental field at a depth of 0–15 cm and analyzed for their physical and chemical properties. The soil of the experimental field was silty loam in texture, slightly alkaline in reaction, low in organic carbon content, and medium in available nitrogen, phosphorus, and potassium status. The field was uniform in fertility and well-drained, making it suitable for conducting the wheat experiment. The experiment was laid out in a split plot design with three replications. Irrigation levels were assigned to the main plots, while fertility source treatments were allocated to the sub-plots. This design was adopted to study the individual as well as combined effects of irrigation and nutrient management practices on the growth, yield, quality, and economics of wheat cultivation.

Four irrigation levels were included in the study. The first treatment consisted of one irrigation applied at the Crown Root Initiation (CRI) stage. The second treatment involved two irrigations, one at the CRI stage and the other at the flowering stage. The third treatment included three irrigations applied at the CRI stage, late jointing stage, and milk stage. The fourth treatment consisted of four irrigations applied at critical growth stages, namely CRI, tillering, flowering, and milk stage. These irrigation schedules were selected to assess the response of wheat to varying levels of water availability during important growth stages. Four fertility source treatments were also evaluated in the experiment. The first treatment consisted of 100 percent recommended dose of fertilizers (RDF) supplied entirely through chemical fertilizers. The second treatment included 75 percent RDF through chemical fertilizers combined with 25 percent nutrient requirement supplied through farmyard manure (FYM). The third treatment consisted of 50 percent RDF through chemical fertilizers along with 50 percent nutrient requirement supplied through FYM. The fourth treatment involved 100 percent nutrient requirement supplied entirely through FYM. The recommended dose of fertilizers for wheat was 120:60:40 kg $N:P_2O_5:K_2O$ per hectare. Nitrogen was applied through urea, phosphorus through diammonium phosphate (DAP), and potassium through muriate of potash (MOP). Farmyard manure was incorporated into the soil before sowing according to the treatment requirements. Full doses of phosphorus and potassium and half of the nitrogen dose were applied as basal application at the time of sowing, while the remaining nitrogen was top-dressed in two equal splits during crop growth. The wheat crop was sown using a suitable seed rate and recommended agronomic practices were followed throughout the crop season. Necessary intercultural operations, weed management, plant protection measures, and irrigation applications were carried out uniformly in all treatments according to the

experimental plan. Observations on growth parameters, yield attributes, grain yield, straw yield, quality parameters, soil fertility status, water use efficiency, and economics were recorded and analyzed statistically to determine the significance of treatment effects.

3. Review of Literature

Previous studies have indicated that irrigation management and integrated nutrient management play a crucial role in improving the productivity and sustainability of wheat cultivation. Wheat is highly sensitive to moisture stress, particularly during critical growth stages such as Crown Root Initiation (CRI), tillering, flowering, and milk stage. Adequate irrigation during these stages promotes better root growth, tiller formation, nutrient absorption, grain filling, and ultimately higher grain yield. Researchers have reported that an increase in irrigation frequency significantly improves plant height, number of tillers, leaf area index, dry matter accumulation, grain yield, and water use efficiency in wheat. Timely irrigation at critical stages such as CRI, tillering, flowering, and milk stage is highly important for improving wheat productivity and tiller development. Among different irrigation schedules, four irrigations applied at CRI, tillering, flowering, and milk stage have often been found to produce the highest grain and straw yields, along with better water use efficiency. Integrated nutrient management involving the combined use of farmyard manure (FYM) and inorganic fertilizers has also been widely recognized as an effective approach for maintaining soil fertility and improving crop performance. Continuous use of chemical fertilizers alone may lead to soil degradation and decline in soil organic matter, whereas the incorporation of organic manures helps improve soil structure, microbial activity, water-holding capacity, and nutrient availability. Combined use of FYM and inorganic fertilizers improves soil organic carbon, nutrient availability, grain yield, and soil fertility in wheat-based systems. A study conducted by the Indian Council of Agricultural Research in 2019 reported that integrated nutrient management significantly increased wheat yield, nutrient uptake, and soil fertility status in alluvial soils. The study found that partial substitution of chemical fertilizers with organic sources enhanced soil organic carbon and improved the availability of nitrogen, phosphorus, and potassium. Similarly, a study published in BMC Plant Biology in 2024 highlighted that optimizing irrigation, nutrient management, and organic amendments together improved wheat productivity, nutrient use efficiency, and soil health. The authors emphasized that balanced use of water and nutrients is essential for

achieving sustainable wheat production. Research carried out by the Indian Council of Agricultural Research in 2025 on pearl millet–wheat systems under saline irrigation conditions revealed that integrated nutrient management practices reduced the negative effects of saline water and improved crop growth, yield, and soil fertility. Another study by the Indian Council of Agricultural Research in 2021 on rice–wheat cropping systems reported that target yield-based integrated nutrient management improved crop productivity, nutrient use efficiency, and economic returns while maintaining soil fertility over the long term.

In 2023, the Indian Council of Agricultural Research developed integrated nutrient management recommendations for late-sown wheat and found that combined use of FYM and chemical fertilizers significantly improved plant growth, grain yield, and nutrient uptake compared to sole application of fertilizers. A meta-analysis conducted by the International Rice Research Institute in 2019 also concluded that integrated nutrient management in rice–wheat cropping systems contributes to sustainable production by improving soil health, crop yield, and nutrient balance in the Indian subcontinent. Furthermore, T. Fazily, S.K. Thakra, and A.K. Dhaka in 2021 reported that integrated nutrient management significantly improved growth parameters, yield attributes, grain yield, and straw yield of wheat. Their findings confirmed that combining organic and inorganic nutrient sources is more beneficial than using either source alone. Overall, previous research findings suggest that higher irrigation frequency and integrated nutrient management practices are essential for improving wheat growth, productivity, soil fertility, and profitability. Several researchers concluded that four irrigations at critical growth stages along with partial substitution of chemical fertilizers through FYM produced the best results in wheat cultivation.

4. Results and Discussion

The results of the experiment clearly indicated that irrigation scheduling and integrated nutrient management had a significant influence on the growth, yield, quality, and soil fertility status of wheat. Higher irrigation frequency resulted in better crop growth due to improved availability of soil moisture during critical growth stages. Adequate soil moisture enhanced nutrient absorption, photosynthetic activity, and dry matter production, which ultimately contributed to higher yield.

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Among the different irrigation levels, the application of four irrigations at CRI, tillering, flowering, and milk stages recorded the highest values of plant height, number of effective tillers per square meter, dry matter accumulation, and leaf area index. These critical growth stages are highly sensitive to water stress, and timely irrigation during these periods promoted better vegetative growth and reproductive development. In contrast, the lowest growth parameters were observed under the treatment receiving only one irrigation at the CRI stage due to limited moisture availability during later stages of crop growth. Yield attributes such as number of grains per ear head, ear length, test weight, grain yield, straw yield, and biological yield were also significantly affected by irrigation treatments. The highest grain and straw yields were recorded under the four-irrigation schedule, which may be attributed to better grain filling, improved translocation of photosynthates, and greater nutrient uptake. Adequate irrigation during flowering and milk stages particularly helped in reducing grain shriveling and improving grain size and weight. The fertility source treatments also showed a marked effect on crop performance. Treatments involving combined use of inorganic fertilizers and farmyard manure (FYM) performed better than the treatments receiving only chemical fertilizers or only FYM. The integration of organic and inorganic nutrient sources ensured balanced nutrient supply throughout the crop growth period and improved the physical, chemical, and biological properties of the soil. Among the fertility treatments, the application of 75 percent recommended dose of fertilizers through chemical fertilizers along with 25 percent nutrient requirement through FYM recorded the best performance in terms of plant growth, yield attributes, nutrient uptake, and grain quality. This treatment resulted in higher grain protein content, better test weight, and increased uptake of nitrogen, phosphorus, and potassium by the crop. The superior performance of this treatment may be due to the gradual release of nutrients from FYM and the immediate availability of nutrients from chemical fertilizers, which together improved nutrient use efficiency. Integrated nutrient management also had a positive effect on post-harvest soil fertility. The combined application of FYM and fertilizers increased soil organic carbon content and improved the availability of nitrogen, phosphorus, and potassium after harvest compared to sole application of fertilizers. This indicates that integrated nutrient management not only enhances crop productivity but also helps maintain long-term soil health and sustainability. Economic analysis of the treatments revealed that higher irrigation levels combined with integrated nutrient management practices produced greater net returns and benefit-cost ratio. The treatment receiving four irrigations along with 75 percent RDF through fertilizers and 25 percent FYM

was found to be the most profitable due to its higher grain yield and better input-use efficiency. Thus, the study demonstrated that balanced irrigation and nutrient management practices are essential for maximizing wheat productivity, profitability, and soil fertility under semi-arid conditions.

5. Conclusion

The findings of the present study clearly demonstrated that integrated resource management plays a vital role in achieving sustainable wheat production under semi-arid conditions. Proper management of irrigation and nutrient sources significantly influenced crop growth, yield attributes, grain quality, soil fertility, and economic returns. Among the different irrigation schedules, the application of four irrigations at critical growth stages, namely CRI, tillering, flowering, and milk stage, proved to be the most effective in enhancing plant height, tiller production, dry matter accumulation, grain filling, and overall grain yield. Adequate water supply during these stages ensured better nutrient uptake and efficient utilization of available resources. Similarly, integrated nutrient management practices involving a combination of organic and inorganic nutrient sources performed better than the sole application of fertilizers or farmyard manure. The treatment consisting of 75 percent recommended dose of fertilizers through chemical fertilizers along with 25 percent nutrient requirement supplied through FYM recorded the highest grain yield, improved grain quality, greater nutrient uptake, and better economic returns. This treatment also contributed to the improvement of soil organic carbon and available nitrogen, phosphorus, and potassium content after harvest. Therefore, it can be concluded that the combined use of four irrigations at critical growth stages along with integrated nutrient management using 75 percent RDF through fertilizers and 25 percent FYM is the most suitable approach for maximizing wheat productivity, improving water use efficiency, maintaining soil health, and enhancing profitability. Adoption of these practices can help farmers achieve higher and sustainable wheat yields while conserving soil and water resources for future generations.

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