

Impact of climate-resilient practices FLD on wheat crop productivity in Jhunjhunu District, Rajasthan

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Summary

The increasing variability of climatic conditions poses a significant threat to the sustainability and productivity of agricultural systems, particularly in arid and semi-arid regions such as Rajasthan, India. This study investigates the impact of climate-resilient agricultural practices on wheat crop productivity in the NICRA (National Innovations in Climate Resilient Agriculture) villages of Jhunjhunu District over the 2022-23 to 2024-2025 *Rabi* seasons. Climate-resilient practices encompassing water-saving techniques, soil health management, heat/ and stress-tolerant varieties, and integrated nutrient and pest management were systematically introduced and monitored to assess their effects on crop yield and sustainability indicators relative to conventional farming practices. Findings indicate that climate-resilient practices led to a significant improvement in wheat productivity with average yield increases ranging from 15.73% to 18.46% over traditional methods. Economic analysis revealed an increase in net returns per hectare by up to ₹9,000, primarily due to reduced input costs and enhanced yield stability. In addition to yield and economic outcomes, adoption gaps were quantified with the technology gap (17.75 q/ha), extension gap (6.74 q/ha) and technology index (26.79%) in wheat during the respective period of study. The role of the NICRA program in facilitating climate-smart interventions and enhancing community resilience in Jhunjhunu district demonstrates a viable model for replication across climate-sensitive districts.

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Introduction

Wheat (*Triticum aestivum* L.) is a major food crop in Rajasthan, but its productivity is severely impacted by climate variability, including erratic rainfall, high temperatures in early summer time/terminal heat stress, hot wind at the time of maturity and soil moisture stress. In 2011, the Government initiated a project to develop location-specific, climate-resilient agricultural practices at farmers' fields known as the NICRA (National Innovations in Climate Resilient Agriculture) project. This study aims to assess the long-term impact of these practices on wheat productivity in Jhunjhunu district, where the climate is characterized by low annual rainfall (300–500 mm) high temperatures in early summer time/terminal heat stress, hot wind at the time of maturity and high evaporation rates. Climate change poses a severe threat to wheat production in arid and semi-arid regions like Rajasthan. To mitigate these effects, climate-resilient agricultural practices were implemented under the NICRA project. This study evaluates the impact of these practices on wheat yield and sustainability over three years (2022-23, 2023-24 & 2024-25) in NICRA villages in Jhunjhunu district. The adoption of conservation agriculture techniques, stress-tolerant wheat varieties, and efficient water

management practices (sprinkler or mini-sprinkler) significantly improved productivity and resilience.

Wheat (*Triticum aestivum* L.) stands as one of the world's most essential staple crops, providing a primary source of calories and protein for more than 35% of the global population (FAO 2021). However, the increasing volatility of climate conditions presents an alarming threat to wheat productivity. From erratic rainfall patterns and rising temperatures to increased frequency of droughts and heat waves, climate change has begun to exert measurable and deleterious impacts on wheat-growing regions worldwide. In this context, the adoption of climate-resilient agricultural practices emerges not only as a necessary adaptation strategy but as a critical pathway for sustaining and improving wheat yields under changing environmental conditions (ICAR-NICRA 2023). Climate-resilient practices refer to a broad spectrum of agronomic, ecological, and technological interventions that aim to enhance the adaptive capacity of agricultural systems to climate variability and shocks. These practices often encompass conservation agriculture (including reduced or zero tillage), improved water management (such as rainwater harvesting, drip irrigation, mini-sprinkler and sprinkler irrigation), heat and drought-tolerant crop varieties, diversified cropping systems and precision nutrient management (ICAR-CSSRI, 2019).

This paper seeks to investigate the effect of climate-resilient practices on wheat crop productivity, with an emphasis on identifying which practices have the most

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significant positive impact under variable climatic conditions. This work also aims to bridge the gap between agronomic research and climate adaptation policy by highlighting the role of integrated climate-smart strategies in securing the future of wheat production in a warming world.

Materials and Methods

The study was conducted in NICRA villages (Bharu, Chakwas & Madansar) of Jhunjhunu district, Rajasthan, from the year 2022-23 to 2024-25 with the help of a farmer participatory approach. In this study, we included 25 farmers in each year from the three NICRA villages and the same number of farmers from non-NICRA villages. The region falls under the *Transitional Plain of Inland Drainage* Agro-climatic zone of Rajasthan & semi-arid zone of India, with an average annual rainfall of 350 mm, which is mostly received during monsoon (July–September). The soil was sandy loam with low organic matter content and lower water-holding capacity. Baseline data on wheat productivity, soil fertility, rainfall, and temperature patterns were recorded for the pre-intervention in every year.

The practices implemented (Table 1) included line sowing, crop residue management, micro-irrigation (Mini-sprinkler and sprinkler systems), use of climate-resilient wheat varieties RAJ-4238 and DBW 187, and site-specific nutrient management (SSNM). Additionally, real-time agro-advisories were provided

Table 1 Comparisons of different improved technology and farmer practices

S. No.	Particular	FLDs technology	Farmers Practices
1	Farming situation	Irrigated	Irrigated
2	Variety	Raj-4238 & DBW-187	Raj-3077
3	Land preparation	Ploughing and harrowing	Ploughing and harrowing
4	Sowing Method	Line sowing	Line sowing
5	Sowing time	15 Nov to 25 Nov	25 Nov to 5 Dec
6	Seed rate	100 kg	125 kg
7	Seed treatments	Seed treatment with Tebucona-zole 2 DS at 2 g/kg seed followed by Azotobacter and PSB culture	Nil
8	Fertilizer dose	120:40:40:20 kg N:P:K:Zn /ha	140:40:40 kg N:P:K:
9	Irrigation method	Mini-sprinkler & sprinkler system	Sprinkler system
10	Weed management	Sulfosulfuron 75 % + Metsulfuroun methyl 5 % WG (ready mix) 32 g a.i./ha at 30-35 DAS	2,4-D at 0.50 kg a.i./ha at 30-35 days after sowing (DAS)
11	Plant protection measure	Need based application of chloropyriphos 20 % EC to protect the crop against termite and leaf eating caterpillars	Nil

Number of Grains Spike⁻¹

Similar trends were observed in the number of grains per spike. The application of climate-resilient practices (T₁) consistently outperformed the conventional treatment (T₂) across all three years. T₁ recorded 53.61, 59.32, and 59.95 grains spike⁻¹ in 2022–23, 2023–24, and 2024–25, respectively, with a pooled mean of 58.05 grains spike⁻¹, which was higher than T₂, resulting in a pooled mean of 55.15 grains spike⁻¹. The superior grain count in T₁ could be attributed to reduced abiotic stress and improved physiological efficiency under climate-smart practices. Similar enhancements in spike fertility due to climate-resilient

using ICT tools, ensuring timely interventions in response to climatic aberrations. The treatments were included: T₁: Climate Resilient Practices & T₂: Farmers Practices. Data on wheat yield and yield attributes, harvest index (%) and benefit cost ratio was calculated.

Results and Discussion

Effect on Yield Attributes

The impact of climate-resilient practices on yield attributes of wheat, such as the number of tillers m⁻², number of grains Spike⁻¹ and test weight, was evaluated across three consecutive *Rabi* seasons (2022–23, 2023–24, and 2024–25), and the pooled data are presented in Table 2.

Number of Tillers m⁻²

The number of tillers m⁻² varied with treatment T₁, which included a comprehensive climate-resilient approach, recorded the highest number of tillers per m² across all three seasons, with values of 234.8, 291.2, and 275.6 in 2022–23, 2023–24, and 2024–25, respectively. The pooled mean for T₁ was 269.4 tillers m⁻², higher than T₂ (which followed conventional practices), which recorded a pooled mean of 251.8 tillers m⁻². These results are in agreement with those of Kumar et al. (2021), who also reported that climate-resilient management improved tillering due to better soil moisture retention and optimized nutrient availability.

agronomy have been documented by Sharma et al. (2020) and Singh et al. (2022).

Test weight (g)

The test weight, an important grain quality parameter indicative of grain density and overall seed development, was influenced by the adoption of climate-resilient agricultural practices (Table 3). Across the three *Rabi* seasons (2022–23 to 2024–25), treatment T₁, which incorporated improved climate-resilient practices, consistently recorded higher test weight values compared to the conventional practice (T₂). In the 2022–23 season, T₁ recorded a test weight of 42.14 g, which increased to 45.14 g in 2023–24 and slightly declined to 44.65 g in 2024–25. The pooled

mean for T_1 was 44.14 g, which was higher than the 42.05 g pooled mean observed under T_2 . The improved grain weight in T_1 may be attributed to better plant health, effective stress mitigation (e.g., heat and drought stress) and enhanced nutrient and moisture availability during the grain filling stage. These factors are known to influence kernel development and density positively. The results were consistent with findings reported by Yadav et al. (2021) and Choudhary et al. (2023), who demonstrated that conservation agriculture and climate-resilient interventions improve grain filling duration and seed weight in wheat.

Effect on Yield

The impact of climate-resilient agricultural practices on seed yield was assessed over three consecutive years (2022–23 to 2024–25), and the pooled data were presented in Table 3. The results revealed a consistent and slightly improvement in seed yield under climate-resilient practices (T_1) compared to conventional farmer practices (T_2). During 2022–23, the seed yield under T_1 was 41.26 q ha⁻¹, higher than T_2 (34.75 q ha⁻¹). Similar trends were observed in 2023–24 and 2024–25, where T_1 recorded yields of 48.24 q ha⁻¹ and 49.45 q ha⁻¹, respectively, as against 41.78 q ha⁻¹ and 42.20 q ha⁻¹ under T_2 . The pooled mean yield across three

years was 46.31 q ha⁻¹ under T_1 and 39.57 q ha⁻¹ under T_2 , reflecting a yield advantage of 6.74 q ha⁻¹ (approximately 17% increase) due to the adoption of climate-resilient technologies. The higher yields under T_1 may be attributed to the integrated application of practices such as drought-tolerant varieties, in-situ moisture conservation, timely sowing, improved nutrient and water management, and integrated pest and disease control, which helped mitigate the adverse effects of climate variability. This outcome is consistent with Singh et al. (2021) and Rathore et al. (2022) findings and validate the effectiveness of improved climate resilient practices increases crop production. In addition to agronomic benefits, the resilience of wheat production systems improved under variable weather conditions, such as winter temperature fluctuations. These findings reinforce the notion that integrated climate-resilient strategies have a positive effect on wheat growth and reproductive traits by mitigating environmental stresses such as terminal heat, water scarcity, and nutrient imbalances. Long-term adoption of such approaches can substantially enhance wheat productivity in arid and semi-arid regions under changing climatic conditions.

Table 2. Effect of climate-resilient practices on yield parameters of wheat crop

Particulars	Number of tiller m ⁻²				Number of grains spike ⁻¹			
	2022-23	2023-24	2024-25	Pooled	2022-23	2023-24	2024-25	Pooled
T_1	234.8	291.2	275.6	269.4	53.61	59.32	59.95	58.05
T_2	221.2	267.8	258.6	251.81	50.95	55.14	57.24	55.15

Table 3. Effect of climate resilient practices on test weight (g) and yield of wheat crop

Particulars	Test weight (g)				Seed yield (q ha ⁻¹)			
	2022-23	2023-24	2024-25	Pooled	2022-23	2023-24	2024-25	Pooled
T_1	42.14	45.14	44.65	44.14	41.26	48.24	49.45	46.31
T_2	40.72	42.75	42.32	42.05	34.75	41.78	42.20	39.57

Technology Gap

The observed technology gap defined as the difference between the potential yield and the yield obtained from demonstration plots (Table 4), was recorded as the highest during 2022-23 (21.54 q ha⁻¹) and lowest in the year 2024-25 (15.25 q ha⁻¹). However, overall average of technology gap during the study period was 17.75 q ha⁻¹. This consistent disparity underscores the potential for further refinement in demonstration practices through improved best management practices to local agroclimatic and edaphic conditions. The variation in technology gap observed may be due to dissimilarity in soil fertility, microclimate, weather condition and management practices also reported by Kumar et al. (2021). Therefore, site specific adaptation and management practices are essential to bridge this yield gap and enhance the effectiveness of technology dissemination in similar findings with Patel et al. (2021).

Extension Gap

The data (Table 4) ranged from 6.46 q ha⁻¹ to 7.25 q ha⁻¹ was obtained during the period of study with an average extension gap 6.74 q ha⁻¹, respectively. This gap indicates a critical need for intensified farmer education and outreach through effective extension activities. Patel et al., (2021) reported that enhancing the dissemination of technology through extension strategies for narrowing this gap and improving overall crop productivity.

Technology Index

An index that shows the feasibility of the disseminated technology at farmers' fields is known as technology index. The data presented in Table 4 revealed that gradually decrease in the technology index value which means more is the feasibility of the technology. The lowest value of technology index 21.03 was during 2024-25 followed by 25.47 in the year 2023-24 whereas maximum value of the technology index of 33.88 was reported in the year of 2022-23. These finding were in close conformity of Singh (2017) and Chourasiya et al. (2022).

Table 4. Effect of climate resilient practices on various indices of wheat crop

Years	No of farmers	Area (ha)	Potential yield (q/ha)	Technology gap (q/ha)	Extension Gap (q/ha)	Technology Index (%)
2022-23	30	12	62.8	21.54	6.51	33.88

2023-24	30	12	64.7	16.46	6.46	25.47
2024-25	30	12	64.7	15.25	7.25	21.03
Average	30	12	64.86	17.75	6.74	26.79

Economics

The economic viability of wheat cultivation under climate-resilient practices (Demonstration plots) and farmers' practice (FP) was assessed over three crop seasons. The data (Table 5) revealed that the adoption of climate-resilient technologies significantly improved the net returns and benefit-cost (B:C) ratio of wheat cultivation compared to conventional practices. The cost of cultivation under demonstration plots ranged between 51,200 to 53,300 ₹ ha⁻¹ across the three years, slightly higher than or comparable to the cost under farmers' practice (50,100 to 57,850 ₹ ha⁻¹). However, the gross return was consistently higher under the demonstration plots, with a pooled average of 1,16,891 ₹ ha⁻¹, compared to 99,104 ₹ ha⁻¹ under farmers' practice. This resulted in pooled net returns of

64,621 ₹ ha⁻¹ under demonstrations and 44,321 ₹ ha⁻¹ under farmers' practice. Moreover, the benefit-cost (B:C) ratio, an indicator of economic efficiency, was substantially higher in climate-resilient plots across all years. The pooled B:C ratio under demonstration was 2.21, compared to 1.81 under farmers' practice. This suggests a 22% higher return per rupee invested due to the adoption of improved practices such as drought-tolerant varieties, moisture conservation, balanced fertilization, and timely agronomic interventions. These findings corroborate earlier studies by Meena et al. (2020) and Rao et al. (2021), who emphasized that climate-resilient practices not only stabilize yields under erratic climatic conditions but also enhance the economic sustainability of smallholder farmers.

Table. 5 Effect of climate resilient practices on the economics of wheat crop

S.N.	Particulars	2022-23		2023-24		2024-25		Pooled	
		Demon	FP	Demon	FP	Demon	FP	Demon	FP
1	Cost of cultivation (₹/ha)	52310	50100	51200	56400	53300	57850	52270	54783
2	Gross return (₹/ha)	118623	99935	109736	95042	119916	102335	116891	99104
3	Net Return (₹/ha)	66314	49835	58536	38642	66616	44485	64621	44321
4	B:C ratio	2.27	1.99	2.14	1.69	2.24	1.76	2.21	1.81

Conclusion

This three-year study highlights the significant benefits of climate-resilient practices in wheat production under the NICRA project. The result revealed that climate resilient practices significantly improved the yield attributes, yield and income per hectare of farmer compared to conventional agricultural practices in all the years. These findings help to insure the farmers by adopting climate-resilient strategies can enhance wheat productivity, conserve natural resources, and ensure sustainable agriculture in Rajasthan's drought-prone regions.

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