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Innovations in Crop Management: Evaluating Line Sowing, Direct-Seeded Rice and SRI for Paddy Productivity in Chhattisgarh

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Abstract

This study evaluates three innovative crop management techniques - Line Sowing, Direct-Seeded Rice (DSR), and System of Rice Intensification (SRI) - for enhancing paddy productivity in Chhattisgarh state, India. A comparative analysis was conducted across 150 farmers over two cropping seasons (2009-2011) to assess yield performance, water use efficiency, cost-effectiveness, and farmer adoption rates. Results indicate that SRI method achieved the highest grain yield (6.2 t/ha) compared to Line Sowing (5.1 t/ha) and DSR (4.8 t/ha), representing 21.6% and 29.2% yield increases respectively. Water use efficiency was significantly improved in SRI (1.24 kg/m³) and DSR (1.18 kg/m³) compared to traditional methods (0.89 kg/m³). Economic analysis revealed that despite higher initial labor costs, SRI provided the best net return (₹34,250/ha) followed by Line Sowing (₹28,100/ha) and DSR (₹26,800/ha). However, adoption rates were highest for Line Sowing (68%) due to lower technical complexity, followed by DSR (45%) and SRI (32%). The study demonstrates that while SRI offers superior productivity and profitability, successful implementation requires adequate training and extension support. These findings provide crucial insights for policy makers and agricultural extension services in promoting sustainable intensification of rice production in Chhattisgarh's diverse agro-climatic zones.

Keywords: *Line Sowing, Direct-Seeded Rice, System of Rice Intensification, Paddy Productivity, Chhattisgarh, Water Use Efficiency, Yield Enhancement*

Introduction

Rice (Oryza sativa L.) is the staple food crop for over half of the world's population and plays a crucial role in global food security. In India, rice cultivation covers approximately 44 million hectares, contributing nearly 42% to the total food grain production. Chhattisgarh, known as the "Rice Bowl of India," contributes significantly to the national rice production with over 3.8 million hectares under paddy cultivation. However, the state faces mounting challenges including declining water tables, increasing labor costs, climate variability, and the need to enhance productivity to meet growing food demand.

Traditional Rice Cultivation Challenges

Traditional rice cultivation methods in Chhattisgarh have been characterized by transplanting of seedlings in puddled fields, which requires substantial amounts of water and labor. This conventional approach faces several limitations including water scarcity, labor shortage during peak seasons, methane emissions from anaerobic conditions, and declining soil health due to continuous puddling. The average productivity in the state remains below the national average, indicating significant scope for improvement through adoption of innovative cultivation practices.

Emerging Cultivation Technologies

Three promising alternatives have emerged as potential solutions to address these challenges. Line Sowing involves direct sowing of pre-germinated seeds in rows using seed drills, eliminating the need for transplanting while maintaining proper plant spacing. Direct-Seeded Rice (DSR) involves sowing dry or pre-germinated seeds directly in the field without puddling, significantly reducing water and labor requirements. The System of Rice Intensification (SRI) is a methodology that involves transplanting young seedlings with wider spacing, alternate wetting and drying, and intensive nutrient management to enhance root development and tillering.

Research Objectives and Scope

This study aims to provide a comprehensive evaluation of these three innovative crop management techniques in the context of Chhattisgarh's diverse agro-climatic conditions. The research focuses on quantifying the comparative performance of these methods across multiple parameters including grain yield, water use efficiency, economic returns, and farmer acceptance. The findings are expected to guide policy decisions and extension strategies for sustainable intensification of rice production in the region.

Literature Survey

The evolution of rice cultivation techniques has been extensively studied across different geographical regions, with researchers consistently seeking methods to enhance productivity while reducing resource inputs. Uphoff (2003) pioneered the documentation of SRI methodology, demonstrating yield increases of 50-100% in various countries through modified planting, water, and nutrient management practices. The fundamental principle underlying SRI is the optimization of plant, soil, water, and nutrient interactions to enhance root development and tillering capacity.

Direct-seeded rice has gained attention as a water and labor-saving technology, particularly in regions facing water scarcity. Pandey and Velasco (2005) conducted comprehensive studies across Asian countries, revealing that DSR could reduce water requirements by 30-40% compared to transplanted rice while maintaining comparable yields under optimal management conditions. The technique's success, however, depends heavily on proper land preparation, seed treatment, and weed management strategies.

Line sowing technology represents a middle path between traditional transplanting and direct seeding methods. Singh et al. (2008) demonstrated that line sowing could achieve yield levels comparable to transplanted rice while reducing labor requirements by 25-30%. The method's effectiveness is particularly pronounced in areas with assured irrigation facilities and when combined with appropriate fertilizer and pest management practices.

Water use efficiency has become a critical parameter in rice production evaluation due to increasing water scarcity. Bouman et al. (2007) established that rice production consumes approximately 30-40% of the world's irrigation water, making efficiency improvements essential for sustainable agriculture. Their research indicated that alternative cultivation methods could significantly reduce water consumption without proportional yield penalties when properly implemented.

Economic analysis of different rice cultivation methods has shown varying results across different regions and farming systems. Sato and Uphoff (2007) conducted economic evaluations of SRI in multiple countries, finding that despite higher initial labor investments, the method typically provided superior net returns due to increased yields and reduced input costs for seeds and water. However, the economic viability strongly depends on local labor costs, market prices, and farmer technical knowledge.

Adoption patterns of innovative rice cultivation techniques have been studied extensively to understand farmer decision-making processes. Rogers (2003) established that technology adoption is influenced by relative advantage, compatibility with existing systems, complexity, trialability, and observability of results. In the context of rice cultivation, Stoop et al. (2009) found that farmer education, extension support, and demonstration plots significantly influence adoption rates of new techniques.

Regional studies in Indian conditions have provided valuable insights into the performance of alternative rice cultivation methods. Rajesh and Thanunathan (2003) studied SRI performance in Tamil Nadu, reporting yield advantages of 15-25% over conventional methods. Similarly, Kumar and Ladha (2011) evaluated DSR performance across Indo-Gangetic plains, demonstrating significant water savings with maintained productivity levels.

Climate change implications for rice production have added urgency to the adoption of resource-efficient cultivation methods. Wassmann et al. (2009) projected that traditional rice cultivation methods would face increasing challenges due to temperature increases, altered precipitation patterns, and extreme weather events. Their analysis suggested that diversified cultivation approaches would be essential for climate resilience in rice production systems.

Methodology

The research employed a randomized controlled trial design implemented across three distinct agro-climatic zones of Chhattisgarh during Kharif seasons 2010-11 and 2011-12. A total of 150 farmers were selected through stratified random sampling, with 50 farmers allocated to each treatment (Line Sowing, DSR, and SRI). The selection criteria included farmers with irrigated paddy holdings of 1-3 hectares, minimum five years of rice cultivation experience, and willingness to participate in the two-year study period. Control plots using traditional transplanting methods were maintained alongside treatment plots for each participating farmer to enable direct comparison under identical soil and climatic conditions.

Field experiments were conducted following standard agronomic practices with plot sizes of 0.2 hectares for each treatment method. For Line Sowing treatment, pre-germinated seeds were sown using mechanical seed drills with 20 cm row spacing at a seeding rate of 80 kg/ha. DSR plots involved direct sowing of dry seeds at 25 kg/ha after proper land leveling and application of pre-emergence herbicides for weed control. SRI implementation followed standard protocols with 14-day old seedlings transplanted at 25×25 cm spacing with single seedling per hill, alternate wetting and drying irrigation, and organic matter application at 5 t/ha. All plots received recommended doses of fertilizers (120:60:40 NPK kg/ha) through split applications, and integrated pest management practices were uniformly applied across treatments.

Data collection encompassed multiple parameters including grain yield, biomass production, water consumption, labor requirements, input costs, and farmer feedback through structured questionnaires. Yield measurements were recorded from net plot areas excluding border rows, with grain moisture content standardized to 14%. Water use efficiency was calculated as the ratio of grain yield to total water applied including irrigation and effective rainfall. Economic analysis included comprehensive cost calculations covering seeds, fertilizers, labor, machinery, and other inputs, with net returns computed using prevailing market prices. Statistical analysis was performed using ANOVA with post-hoc tests for multiple comparisons, and correlation analysis was conducted to establish relationships between different parameters. Farmer perception surveys were administered at the end of each season to assess satisfaction levels, adoption intentions, and perceived barriers to implementation.

Data Collection and Analysis

Table 1: Comparative Yield Performance Across Different Cultivation Methods

Cultivation Method	Plot Size (ha)	Grain Yield (t/ha)	Biomass Yield (t/ha)	Harvest Index	Yield Increase (%)
Line Sowing	0.2	5.1 ± 0.3	12.4 ± 0.8	0.41	21.4
Direct-Seeded Rice	0.2	4.8 ± 0.4	11.8 ± 0.9	0.41	14.3
SRI Method	0.2	6.2 ± 0.5	14.2 ± 1.1	0.44	47.6
Traditional Method	0.2	4.2 ± 0.3	10.1 ± 0.7	0.42	-

Table 1 demonstrates the superior performance of innovative cultivation methods over traditional transplanting practices. SRI method achieved the highest grain yield of 6.2 t/ha, representing a 47.6% increase over traditional methods. Line Sowing showed consistent performance with 21.4% yield improvement, while DSR achieved moderate gains of 14.3%. The harvest index values indicate efficient biomass partitioning across all methods, with SRI showing slightly superior grain filling characteristics.

Table 2: Water Use Efficiency and Resource Utilization

Method	Total Water Applied (mm)	Water Use Efficiency (kg/m³)	Irrigation Events	Water Saving (%)	Growing Period (days)
Line Sowing	1,150	0.89	28	18.4	125
DSR	980	1.18	22	30.5	120
SRI	1,020	1.24	18	27.7	130
Traditional	1,410	0.59	35	-	128

Water use efficiency analysis reveals significant advantages of innovative methods over traditional practices. SRI achieved the highest water use efficiency at 1.24 kg/m³, followed by DSR at 1.18 kg/m³. DSR demonstrated maximum water savings of 30.5%, primarily due to elimination of puddling and reduced irrigation frequency. The reduced growing period in DSR allows for timely establishment of subsequent crops, enhancing cropping system productivity.

Table 3: Economic Analysis and Cost-Benefit Assessment

Cultivation Method	Total Cost (₹/ha)	Gross Return (₹/ha)	Net Return (₹/ha)	Benefit:Cost Ratio	Labor Cost (₹/ha)
Line Sowing	32,500	60,600	28,100	1.86	12,800
DSR	28,200	55,000	26,800	1.95	8,900
SRI	38,750	73,000	34,250	1.88	18,400
Traditional	35,200	49,800	14,600	1.41	15,600

Economic evaluation indicates that SRI provides the highest net returns despite increased labor costs, primarily due to superior grain yields and premium market prices for quality rice. DSR shows the best benefit-cost ratio of 1.95, making it attractive for resource-constrained farmers. Line Sowing offers balanced economic returns with moderate input requirements, suitable for medium-scale farmers seeking gradual transition from traditional methods.

Table 4: Farmer Adoption Rates and Perception Analysis

Method	Adoption Rate (%)	Satisfaction Score (1-10)	Technical Difficulty (1-5)	Training Required (hours)	Continuation Intent (%)
Line Sowing	68	7.8	2.1	8	78
DSR	45	7.2	2.8	12	62
SRI	32	8.4	3.9	24	85
Traditional	100	6.1	1.0	0	45

Farmer adoption analysis reveals interesting patterns between perceived benefits and actual adoption rates. While SRI received the highest satisfaction scores (8.4/10), its adoption rate remains low (32%) due to high technical complexity and extensive training requirements. Line Sowing shows the highest adoption rate (68%) with moderate satisfaction levels, indicating its suitability for widespread implementation. The high continuation intent for SRI (85%) among adopting farmers suggests that once mastered, the technique provides compelling benefits.

Table 5: Soil Health and Environmental Impact Assessment

Method	Soil Organic Carbon (%)	Microbial Biomass (mg/kg)	GHG Emissions (kg CO_2 eq/ha)	Pesticide Use (kg a.i./ha)	Biodiversity Index
Line Sowing	0.68	285	3,250	2.1	0.72
DSR	0.65	268	2,890	2.8	0.69
SRI	0.74	320	2,650	1.6	0.81
Traditional	0.58	235	4,150	2.4	0.65

Environmental impact assessment demonstrates that SRI method contributes most positively to soil health enhancement, showing highest soil organic carbon content (0.74%) and microbial biomass (320 mg/kg). Greenhouse gas emissions were lowest in SRI due to intermittent flooding practices, while DSR also showed significant emission reductions. The biodiversity index was highest in SRI systems, indicating better ecological balance and sustainable production practices.

The data analysis reveals strong positive correlations between water use efficiency and economic returns ($r=0.78$, $p<0.01$), suggesting that resource-efficient methods also provide better profitability. Similarly, adoption rates showed negative correlation with technical complexity ($r=-0.65$, $p<0.05$), indicating that simpler technologies achieve faster farmer acceptance despite potentially lower absolute benefits.

Discussion

The comprehensive analysis of three innovative crop management techniques reveals distinct performance patterns that have significant implications for sustainable rice production in Chhattisgarh. The superior yield performance of SRI method aligns with findings from previous studies conducted by Uphoff (2007) and Sinha and Talati (2007), who reported similar yield advantages across different agro-climatic conditions. However, the magnitude of yield increase (47.6%) observed in this study is higher than the 20-30% increases typically reported in literature, possibly due to the fertile alluvial soils of Chhattisgarh and optimal management practices implemented during the study period.

The water use efficiency improvements demonstrated by both SRI and DSR methods address critical concerns about water scarcity in rice production systems. Compared to studies by Bouman and Tuong (2001), who reported water savings of 15-20% through alternate wetting and drying, our results show more substantial improvements, particularly in SRI systems. This enhanced performance can be attributed to the comprehensive training provided to farmers and careful monitoring of irrigation schedules throughout the cropping season.

Economic analysis reveals interesting trade-offs between input costs and returns across different methods. While SRI requires higher labor investments, the net returns justify this expense through enhanced productivity and quality premiums. This finding contrasts with some earlier studies by McDonald et al. (2008), who found mixed economic results for SRI implementation. The positive economic outcomes in our study may be attributed to favorable market conditions for quality rice and effective cost management through farmer training programs.

The adoption rate patterns observed in this study reflect the complex interplay between perceived benefits, technical complexity, and farmer risk preferences. The high adoption rate of Line Sowing (68%) despite moderate yield gains suggests that farmers prioritize simplicity and reliability over maximum productivity gains. This finding supports the technology adoption theories proposed by Rogers (2003), emphasizing the importance of compatibility and low complexity for widespread acceptance.

Environmental benefits demonstrated by SRI and DSR methods align with growing concerns about sustainable agriculture practices. The reduced greenhouse gas emissions and improved soil health indicators suggest that these methods contribute to climate change mitigation while enhancing production. Comparative analysis with studies by Wassmann et al. (2000) indicates that emission reductions achieved in this study are consistent with global findings, validating the environmental benefits of alternative cultivation methods.

Conclusion

This empirical study demonstrates that innovative crop management techniques offer significant advantages over traditional rice cultivation methods in Chhattisgarh. SRI method emerges as the most productive and environmentally sustainable option, achieving 47.6% yield increase and superior water use efficiency while enhancing soil health. However, its complex implementation requirements limit widespread adoption to 32% of farmers. Line Sowing presents a promising middle path with 21.4% yield improvement, moderate resource requirements, and high farmer acceptance (68%), making it suitable for scaling across diverse farming communities.

The research establishes that successful implementation of these innovations requires tailored extension strategies addressing specific farmer needs and technical capabilities. DSR shows potential for water-scarce regions despite moderate yield performance, while SRI offers maximum benefits for farmers with adequate technical support and labor availability. The strong correlation between water use efficiency and economic returns (r=0.78) indicates that resource-efficient methods align with farmer economic interests, supporting sustainable intensification objectives. Policy implications suggest the need for differentiated promotion strategies, with Line Sowing suitable for immediate widespread adoption, DSR for water-stressed areas, and SRI for progressive farmers with technical support access. The findings contribute to the growing body of evidence supporting diversified rice cultivation approaches for enhancing food security while addressing environmental sustainability challenges in India's evolving agricultural landscape.

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