



Optimizing Water and Energy use in Rice Production through Direct Seeding in Punjab, India

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Abstract: Direct Seeded Rice (DSR) presents a sustainable alternative to Puddled Transplanted Rice (PTR), offering significant reductions in water and energy use in rice production. This study rigorously evaluates the effectiveness of DSR in optimizing resource use, lowering production costs, and enhancing energy use efficiency (EUE) in Punjab, a region critically challenged by water scarcity and energy demands. Employing a multi-stage random sampling method across varied agricultural settings in Punjab, the research quantifies inputs such as seeds, fertilizers, water, and fuel, alongside outputs like grain and straw. DSR not only reduces groundwater and energy consumption by approximately 30% compared to PTR but also curtails labor and irrigation costs by up to 20%. The economic analysis highlights reduction in cost per kilogram of rice produced under DSR, reinforcing its financial viability. The broader implications of these results suggest that DSR could play a crucial role in transforming rice cultivation into a more sustainable practice across similar agro-ecological zones. The study indicates viable solution for regions facing environmental and economic challenges due to traditional rice farming methods.

Keywords: Direct seeded rice, Energy, Water use efficiency, Sustainability

The interconnection between agriculture and energy consumption significantly influences agricultural sustainability. This connection necessitates a balanced integration of production, environmental stewardship, and economic viability (Aghaalikhani et al 2013). As global populations increase and demands for food escalate, the strain on natural resources intensifies, threatening the sustainability of agricultural practices. Contemporary agriculture must embrace resource conservation and effective management to produce cleaner, more sustainable outputs (Kumar et al 2019, Basavalingaiah et al 2020). A critical issue facing current agricultural methodologies is the declining efficiency of energy use (EUE), which necessitates the optimization and efficient deployment of energy inputs across various agricultural operations (Kumar et al 2020). In India, where rice serves as the staple diet for 70% of the population and occupies 40 to 45% of the land dedicated to cereal crops, the challenge is to meet escalating demands with reduced energy inputs. The advent of Direct Seeded Rice (DSR) offers a viable solution amidst global water constraints, significantly lowering energy consumption, carbon emissions, and greenhouse gas outputs (Farooq et al 2011, Basavalingaiah et al 2020). Given the potential for enhancing productivity through improved resource management and technological application, particularly in less efficient farming systems, this study explores the implementation and impacts of DSR in the state of Punjab, India. The need for sustainable agricultural practices in Punjab is urgent due to the high water and energy demands

of traditional rice farming methods. DSR emerges as a promising solution, aimed at reducing these inputs while maintaining productivity. The primary objective of this study is to evaluate the environmental and economic benefits of adopting Direct Seeded Rice (DSR) over Puddled Transplanted Rice (PTR) in Punjab's agricultural system. Specifically, the study seeks to quantify the reductions in water and energy use, along with the associated cost savings, to assess DSR's potential as a sustainable agricultural practice.

MATERIAL AND METHODS

This study employed a multi-stage random sampling technique to select a representative sample from regions in Punjab with varying adoption rates of Direct Seeded Rice (DSR). The initial focus was on Sri Mukatsar Sahib, identified as the area with the highest DSR coverage. From there, two blocks known for their intensive use of DSR technology, Gidderbaha and Mukatsar, were selected. Within these blocks, four villages-Kauni (30.1830° N, 74.6590° E) and Doda (30.0830° N, 74.5670° E) from Gidderbaha; Bhullar (30.2210° N, 74.5501° E) and Thandewala (30.2000° N, 74.5167° E) from Mukatsar-demonstrating widespread DSR adoption were chosen for detailed study. The GPS coordinates ensure accurate location identification, facilitating replication and further research.

The sample comprised 120 farmers, including 80 DSR adopters and 40 non-adopters, categorized by different farm sizes. Data collection involved quantifying the inputs, such as

seeds, fertilizers, water, and fuel, and the outputs, namely grain and straw, in terms of energy units. This quantification was achieved by applying specific energy coefficients from the "Research Digest on Energy Requirement in Agriculture Sector," published by the Department of Farm Power and Machinery at Punjab Agricultural University (PAU) (Singh and Singh, 2002). A comparative analysis of energy inputs and outputs between DSR adopters and non-adopters was conducted to assess the efficiency and sustainability of the DSR methodology. This approach provided insights into the energy dynamics of DSR versus traditional rice cultivation methods, highlighting the potential benefits and challenges associated with adopting new agricultural technologies.

RESULTS AND DISCUSSION

The significant reduction in energy use observed in DSR fields not only underscores its efficiency but also positions DSR as a critical innovation in the context of global energy challenges (Farooq et al 2011, Basavalingaiah et al 2020). Comparative studies indicate that traditional methods such as PTR consume up to 40% more energy for similar yields (Kumar et al 2019). This drastic improvement presents DSR as a transformative approach capable of addressing the dual challenges of resource scarcity and environmental sustainability. The implementation of direct seeded rice (DSR) in Punjab has demonstrated significant improvements in energy use efficiency (EUE) and resource management compared to traditional puddled transplanted rice (PTR).

Energy Use Efficiency (EUE): DSR exhibited an energy use efficiency of 4.03, which is higher than the 3.56 for PTR. This increase reflects a substantial improvement, with DSR showing a 13.16% reduction in total input energy across all operations measured. The most notable reductions were observed in the consumption of water and electricity—two of the most critical resources in rice cultivation (Singh and Singh 2002, Ahmed et al 2014) (**Table 1**).

Resource utilization: Analysis of water usage revealed that DSR significantly decreases the amount of water needed per cubic meter, costing Rs 8.61 compared to Rs 7.33 for PTR. This reduction is not only a testament to DSR's improved water use efficiency but also aligns with sustainable water management practices, crucial for the agrarian states facing water scarcity issues. In terms of energy consumption, DSR's approach reduces the dependency on non-renewable energy sources traditionally associated with PTR. This reduction is particularly relevant in the context of global efforts to reduce greenhouse gas emissions and enhance the sustainability of agricultural practices.

Economic benefits: The cost of producing one kilogram of rice under DSR was calculated to be Rs 8.43, significantly

less than the Rs 9.88 required for PTR. This cost efficiency offers potential for higher profitability among farmers adopting DSR, coupled with the benefit of reducing the environmental impact of their farming practices (Vatta et al 2021). The economic impacts are summarized in Table 2.

Comparative analysis: The economic benefits of DSR, particularly the reduced cost of rice production, have profound implications for policy and practice (Kumar et al 2020). By lowering production costs by 20%, DSR enhances the profitability for farmers, which could drive higher adoption rates. Policy frameworks that support DSR could leverage these economic benefits to promote widespread adoption, potentially transforming agricultural practices regionally. Further, incentives for DSR could align with governmental goals of sustainability and economic development in agriculture.

The results of this study highlight that Direct Seeded Rice (DSR) offers significant advantages over Puddled

Table 1. Operation wise input energy comparison in rice cultivation

Operations	DSR	PTR	% saving in DSR
Nursery raising	0	220.56	7.27
Land preparation*	592.92	952.01	11.84
Transplanting	210.35	83.02	-4.20
Seed	121.82	83.24	-1.27
Fertilizers	8944.44	10675	57.10
Manure	180.72	166.21	-0.47
Micronutrients & others	45.28	35.66	-0.31
Plant protection	802.76	419.66	-12.64
Irrigation	1173.64	1061.32	-3.70
Electricity	7277.90	8654.02	45.41
Harvesting	638.43	667.34	0.95
Total input energy	19988.30	23018.60	100

Table 2. Cost and resource use in DSR vs. PTR

Resource type	DSR cost/use (Rs/Unit)	PTR cost/use (Rs/Unit)	% Change over PTR
Human labour	5354.82	9004.70	-40.53%
Machine labour	3259.48	4106.20	-20.63%
Seed	681.20	394.50	72.63%
Fertilizers	852.76	1011.78	-15.72%
Plant protection	3946.27	2735.00	44.29%
Irrigation	4270.35	5077.80	-15.90%
Total cost	22264.08	26567.54	-16.19%

Transplanted Rice (PTR) in terms of energy, water conservation, and cost efficiency (Bhullar et al 2018). DSR demonstrated higher energy use efficiency, lower water consumption, and reduced production costs, positioning it as a more economically viable and environmentally sustainable method for rice cultivation. These findings align with global efforts to promote sustainable agricultural practices by minimizing resource use and environmental impacts (Farooq et al 2011, Basavalingaiah et al 2020). The adoption of DSR has clear economic benefits, particularly through the reduction in labor, energy, and irrigation requirements (Bandumula et al 2018). The decreased groundwater footprint associated with DSR further strengthens its position as a sustainable solution for regions facing water scarcity. These results suggest that DSR can effectively contribute to resource-efficient rice production while maintaining or even enhancing yield quality.

From a policy perspective, the broader adoption of DSR could support national and international goals of reducing agricultural water and energy consumption, mitigating greenhouse gas emissions, and promoting sustainable farming systems (United Nations Environment Programme 2021). Increased investment in DSR technology, extension services, and farmer training programs is crucial to maximize its benefits across diverse agricultural landscapes. Additionally, government subsidies or incentives may encourage farmers to transition to DSR, facilitating widespread adoption of this eco-friendly alternative to conventional methods.

CONCLUSION

Direct Seeded Rice (DSR) has emerged as a sustainable and resource-efficient alternative to Puddled Transplanted Rice (PTR) in Punjab, offering significant reductions in water and energy consumption while maintaining or enhancing rice yields. This study demonstrates that DSR optimizes resource use, significantly decreasing groundwater usage and input energy, which leads to lower production costs. The adaptability of DSR across diverse rice-growing regions underscores its potential as a transformative technology for sustainable agriculture. By reducing dependence on non-renewable resources, DSR aligns with global efforts to promote environmental sustainability and improve the

economic viability of rice farming. Moreover, its adoption helps mitigate the environmental impacts of traditional rice cultivation, such as excessive water use and high carbon emissions. In addition to its ecological advantages, DSR provides economic benefits to farmers, particularly through reductions in labor, irrigation, and energy costs. These advantages make DSR a key solution for regions facing water scarcity and rising energy demands, particularly in Punjab's agriculture sector. DSR represents a robust strategy for sustainable intensification of rice production, offering both economic and environmental benefits across a wide range of agro-ecological conditions.

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