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RESOURCE CONSERVATION THROUGH DIRECT SEEDED RICE: EVIDENCE FROM INDIAN PUNJAB

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ABSTRACT

In India, 40–45 per cent of the total acreage used for cereal crops under rice, which is the primary food crop for more than 70 per cent of the country's population. Punjab State known as the 'food bowl of India' contributed about 25 to 30 rice and 35 to 40 per cent wheat to the central pool during the last one decade. Under the prevailing conditions of free electricity supply to the farm sector and assured marketing of paddy in the state that makes paddy the most remunerative *kharif* season crop, the farmers are reluctant to move towards crop diversification. When used as an alternative to the conventional puddled transplanted rice (PTR), direct seeded rice (DSR) saves money, resources, time, and energy without sacrificing the environment. With this backdrop the present study was carried out in Punjab during 2021–2022 in Sri Mukatsar Sahib district having the highest area under the DSR. The area under DSR was 84.9 thousand hectares only forming about 3 per cent of the total area under paddy. Use of all the farm inputs was lower on DSR farms as compared to PTR farms except seed, plant protection chemicals (PPC) and micro-nutrients. DSR generated significant savings in the use of human labour (41%), machine (12.63%), fertilizers (15.06%) and irrigation water (15.90 %) in comparison to PTR. Groundwater productivity for PTR (Rs 7.33 per m^3) was also lower than for DSR (Rs 8.61 per m^3) as a result of much higher groundwater usage. In economic terms, the net returns over variable cost were higher by about 13 per cent in DSR than PTR because of lower variable costs for DSR. The cost in production of one kg grain using DSR was found to be lower by about 15 per cent than in PTR and the input energy involved in the same was Rs 7.84 MJ as compared to 8.86 MJ respectively. All this points to the fact that there is a strong need to generate more awareness of recommended DSR production practices among the farmers along with government initiatives like subsidizing the cost of DSR per acre and further research and development efforts which can help in rapid extension of area under the DSR.

Keywords: *DSR, PTR, Punjab, Production Technologies.*

INTRODUCTION

In India, 40–45% of the total acreage used for cereal crops is used for rice, which is the primary food crop for more than 70% of the country's population. It is the primary crop grown on the trans-Indo-Gangetic Plains during the wet season, including Punjab State, the most developed state in India. Known as the 'food bowl of India' Punjab contributed about 25 to 30 rice and 35 to 40 per cent wheat to the central pool during the last one decade (PAU, 2022). With rising population and food production, the use of non-renewable energy sources has risen. As a result, natural resources have been under continual stress, endangering the viability of agriculture (Basavaligaiah *et al* 2020). Hand-transplanting of paddy in puddled field conditions not only damages soil structure but also uses a lot of water and energy. For greener and more sustainable production, nonrenewable energy sources must be conserved and resources must be managed effectively in agriculture (Kumar *et al* 2019). Energy inputs used in different farming operations must be used as efficiently and effectively as possible given the current agriculture's steadily declining energy-use efficiency (Kumar *et al* 2020). Under the prevailing conditions of free electricity supply to the farm sector and assured marketing of paddy in the state that makes paddy the most remunerative kharif season crop, the farmers are reluctant to move towards crop diversification. Being a labour-saving technology, its adoption as a water-saving technique is of utmost importance for the state which is on the brink of desertification due to overuse of groundwater for paddy cultivation. When used as an alternative to the conventional puddled transplanted rice (PTR), DSR saves money, resources, time, and energy without sacrificing the environment (Jat *et al* 2022).

The DSR is yet to become an integral part of the farming ecosystem in Punjab. Considering sustainable agriculture as the keystone of Punjab's social and economic prosperity, promotion of DSR has been one of the pioneer steps in this regard in the Punjab Government's 2023-24 Budget. As a pilot project, the state government has shortlisted 16 blocks in 16 districts where water level has dropped from 21.3 to 1.5 metres since 1998 and planning to sow paddy directly on 1.5 lakh acres in these blocks during 2023-24 (TNS, 2023). With this backdrop, the present study was carried out to study the present status of adoption, resource use, and financial savings in DSR cultivation.

MATERIAL AND METHODS

The core data used for the current study, which was conducted in the Indian state of Punjab between 2021–2022, were gathered using a multi-stage random sampling approach. At the first stage, one district namely Sri Mukatsar Sahib having the highest area under the DSR technology for paddy cultivation was identified through consultation with officials of the Punjab State Department of Agriculture. Keeping in view the concentration of DSR technology, two blocks namely Gidderbaha and Mukatsar were selected at the second stage (Table 1).

Table 1. Distribution of survey sample

District	Block	Village	DSR Adopters	DSR Non-Adopters	Total
SriMukatsarSahib	Gidderbaha	Kauni	20	10	30
		Doda	20	10	30
	Mukatsar	Bhullar	20	10	30
		Thandewala	20	10	30
Grand Total			80	40	120

Using simple random sampling technique, 20 DSR adopter farmers were chosen from each selected village for the study. In order to undertake impact assessment of the DSR technology, ten DSR non-adopter farmers from the same vicinity were also taken as a control group in the analysis. Thus, the total sample for the study comprised of 120 farmers (80 adopters and 40 non-adopters).

The primary data pertaining to the two cultivation practices i.e. DSR and PTR were collected from the sample farmers for the agricultural year 2021-22 through personal interview method. The necessary data, including seed, diesel fuel, fertilizers, farm yard manure (FYM), chemicals (insecticides, fungicides, herbicides), crop yield, total labour hours (men and women hours), draught power used for various farm operations, as well as the total working hours of agri-machinery, were recorded. Data on paddy grain yield was used for the estimation of straw yield using crop to residue ratio method (Chauhan, 2012).

Pump efficiency was assumed to be 40 per cent and the groundwater draft was estimated by using the following formula (Srivastva *et al* 2014) where horse power (Hp) is the capacity of the pumps owned by the farmer in terms of :

$$\text{Groundwater Draft (litre/sec)} = \frac{\text{Hp} \times 75 \times \text{Pump efficiency}}{\text{Total head (m)}}$$

Values for the total head for calculating the groundwater was taken from an earlier study by Garg *et al* 2012. By dividing total groundwater usage by crop output, the predicted groundwater footprints for paddy (in m^3/kg) were calculated. Similar to this, ground water usage and output value (grain) were divided to measure water productivity (Rs/m^3).

To examine the changing pattern of important variables for input use pattern for DSR and PTR, t-test was applied to test the significance of difference in average value between two cultivation methods. The student t statistic applied was under:

$$t = \frac{m_1 - m_2}{S\sqrt{\frac{1}{n_1} + 1/n_2}}$$

Where,

t=calculated value for t-distribution with degree of freedom $n_1 + n_2 - 2$; m_1 and m_2 are means of the two groups i.e. DSR and PTR, respectively and S is combined standard deviation of 2 groups.

RESULTS AND DISCUSSION

In this section, a brief introduction to the present status of agriculture sector in Punjab state (Figure 1) has been given.

➢Granary of India- With only 1.53% of the total geographical area of the country, Punjab produces approximately, 19% of wheat, 11% of rice and 5% of cotton of the country

➢Contribution to central pool- 32.4 % paddy, 35.7% wheat

➢Produces about 3%, 2% and 1% paddy, wheat and cotton of the world

Figure 1. Scenario of Punjab's Agriculture Contribution towards India

PRESENT STATUS OF PUNJAB AGRICULTURE

1. Cropping pattern

In the state of Punjab, food grain farming occupies over 93 percent of the province's total arable area. The state has a high degree of specialization in the production of paddy-wheat monoculture, which is primarily attributable to the successful implementation of an agricultural pricing policy with a minimum support price. As a result, roughly 85% of the state's GCA has been occupied by paddy and wheat, with their respective areas making up about 40% and 45% of the GCA, respectively (Figure 2). Cotton stands in third in the state's cropping pattern, accounting for around 3% of the GCA, behind maize (1.47%), oilseeds (1.35%), and sugarcane (1.16%), while other crops account for less than 1% of the GCA.

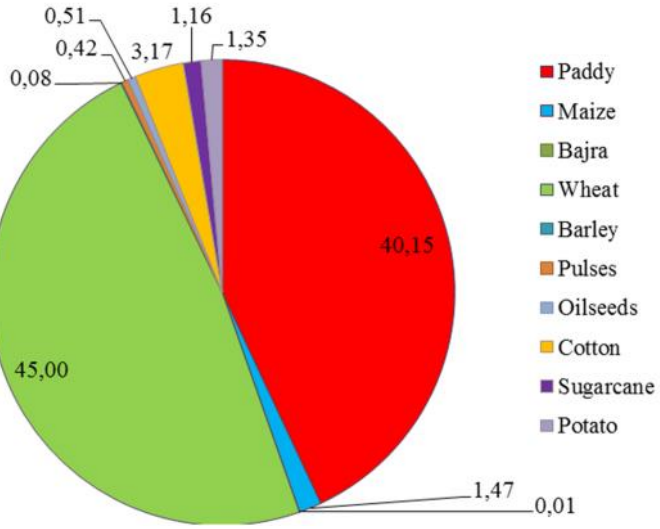

Figure 2. Area under principal crops in Punjab, 2021-22 (% to GCA)

Intensive farming has resulted in a decrease in the variety of crops grown, the loss of natural resources, an increase in energy use, subsidies for agriculture, and a drop in profitability. The Punjab state's predominant crop is the water-guzzling paddy, which is endangering the state's groundwater supplies.

2. Ground water resources

As far as groundwater level is concerned, out of 150 blocks of the state, 114 blocks are "Over-exploited (with >100% ground water extraction)", 4 blocks are "Critical" (> 90% and ≤ 100%), 15 blocks are "Semi-critical" (> 70% and ≤ 90%) and 17 blocks are in "Safe" (≤ 70%)category (Figure 3). It has been noted that over-exploited areas of the state have "NIL" net ground water availability for future irrigation expansion.

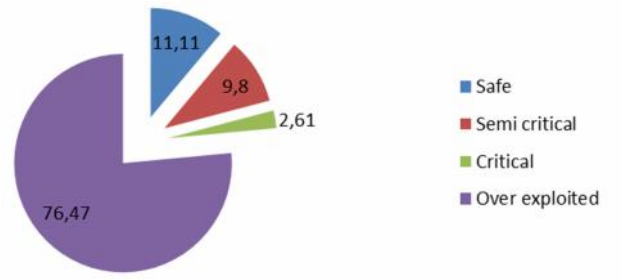

Figure 3. Distribution of blocks of Punjab according to stage of ground water extraction (% share in total)

Source: GoP, 2022

In order to prevent water logging in the near future, it is urgently necessary to replenish ground water in the over-exploited blocks and develop accessible shallow ground water in the safe blocks. Adopting strategies like Direct Seeding of Rice (DSR) may help in this circumstance by easing the strain on the state's diminishing groundwater supplies.

3. Status of adoption of DSR in Punjab

As per estimates, about 30 thousand famers have been provided with an incentive Rs1500 per acre for adopting the practice of DSR, for which Rs25 crore has been paid (Figure 4). During 2021-22, the area under DSR was 84.9 thousand hectares forming only about 3 per cent of the total area under paddy (3144.6 thousand hectare). District wise analysis of the data revealed that the highest proportion of area under DSR was under Shri Mukatsar Sahib (20.8%) and amount of subsidy availied (22.9%) while maximum of number of farmers availing the subsidy belonged to Fazilka (19.8%).

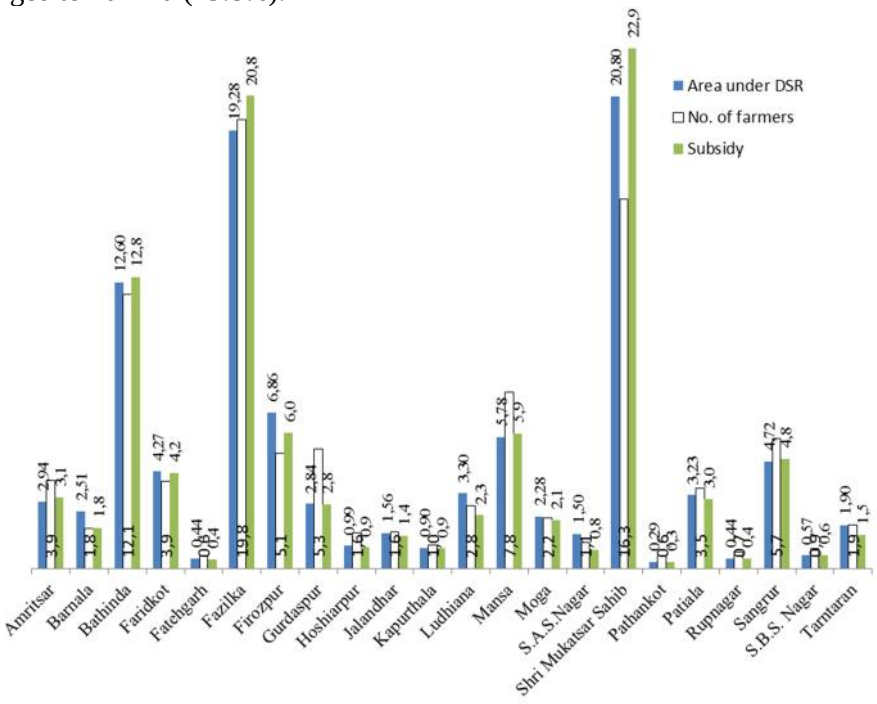

Figure 4. District wise area under DSR and subsidy provided for adoption of DSR in Punjab, 2021-22 (% shares to respective totals)

Source: Department of Agriculture and Farmers' Welfare, Government of Punjab

Thus, DSR paddy had higher adoption in the south western districts of the state. One major reason behind this is that ground water is not fit for irrigation in most of the villages in this area.

4. Input use in paddy cultivation using DSR and PTR method

The results for comparative input use pattern and output of paddy cultivation under DSR and PTR method is given in Table 2. Human labour use was found to be about 41 per cent higher for PTR (169.9 hours) than for DSR (101.03 hours) as the human labour requirements in DSR were reduced due to no need for transplanting the paddy seedlings. Machine labour use was also higher by about13 per cent for PTR (9.50 hours) than DSR (8.30 hours) and consequently about 8 per cent higher diesel use existed in PTR (46.5 litre) than DSR (42.75 litre). Compared to the average seed rate used by DSR adopters (7.89 kg), the PTR followers used only 5.30 kg of seed for sowing one acre of paddy because of self-confidence in their farming practices.

Table 2. Input use pattern from paddy cultivation using DSR and PTR in Punjab
(Per acre)

Sr. No.	**Input/Method**	**DSR**	**PTR**	**Mean difference**	**t-value**
1	Human Labour(h)	101.03	169.90	-68.87**	129.34
2	Animal Labour(h)	0.75	1.00	-0.25	0.375
3	Machine Labour(h)	8.3	9.50	-1.20**	49.03
4	Diesel (litre)#	42.75	46.50	-3.75*	18.24
5	Seed (kg)	7.89	5.30	2.59**	15.40
6	Fertilizers and micro nutrients				
A	Urea (kg)	143.80	170.62	-26.82**	71.98
B	Phosphatic (kg)	6.54	6.80	-0.26	0.480
C	Muriate of Potash (kg)	6.14	6.80	-0.66	0.821
D	Zinc (kg)	5.13	6.50	-1.37*	2.125
E	Iron Sulphate (kg)	5.82	4.60	1.22	1.351
F	Others (kg)##	3.18	2.70	0.48	1.121
G	FYM (Tonne)	5.74	5.90	-0.16	0.752
7	Plant Protection Chemicals				
A	Rodenticide (kg)	1.54	0.50	1.04**	32.48
B	Insecticide (litre and kg)	2.70	2.23	0.47	1.658
C	Weedicide (litre)	3.21	1.20	2.01**	11.26
8	Electricity for irrigation (KWh)	610.05	725.40	-115.35**	371.66
9	Total output				
A	Grain (kg)	2769.00	2801.30	-32.30	1.34
B	Straw (kg)	3738.15	3781.76	-43.61	1.37

** and * significant at one and five per cent level of significance

#use of tractor for land preparation, irrigation, transport on farm and harvester combine

##include seed treatment chemicals and growth regulators

Among different chemical fertilizers, the use of urea, phosphatic fertilisers, muriate of potash, and micro nutrients-zinc and Iron sulphate, was higher for PTR than DSR except Iron sulphate (lower for PTR by 1.22%) and seed treatment chemicals and growth regulators (by 0.48%). On the contrary, the use of PPC was much higher by the DSR adopters. Due to huge weed infestation, almost double amount of weedicide application per acre (3.21 litre) was observed for DSR than PTR (1.20 litre). Further, use of rodenticides to avoid rodent attack was three times higher side in DSR (1.54 kg) than PTR (0.50 kg). Insecticide application was also higher in DSR (2.70) than PTR (2.23) though the difference was statistically non-significant. The use of electricity for the irrigation was higher on PTR (725.40 KW) than the DSR farms (610.05 KW) by about 16 per cent because of lesser number of irrigations and water application in DSR. Output from paddy cultivation in terms of grain and straw production was estimated to be about 2801 kg and 3782 kg per acre on PTR farms, while the corresponding figures worked out to be about 2769 kg and 3738 kg per acre for DSR but this difference was statistically nonsignificant.

The analysis revealed that use of all the inputs was lower on DSR farms as compared to PTR farms except seed, plant protection chemicals (PPC) and micro-nutrients. The mean difference of major inputs such as human labour, machine labour, diesel fuel, seed rate, urea, rodenticides, weedicides, electricity differ significantly among DSR and PTR method of paddy cultivation. Besides urea, crop duration, plant protection and machine hours came out be significant factors in affecting the yield of the crop (Singh *et al*, 2021).

In terms of per cent shares, human labour use was found to be about 41 per cent higher for PTR than for DSR (Figure 5) and the DSR generated significant savings in the use of machine (12.63%), fertilizers (15.06%) and irrigation water (15.90 %) in comparison to PTR.

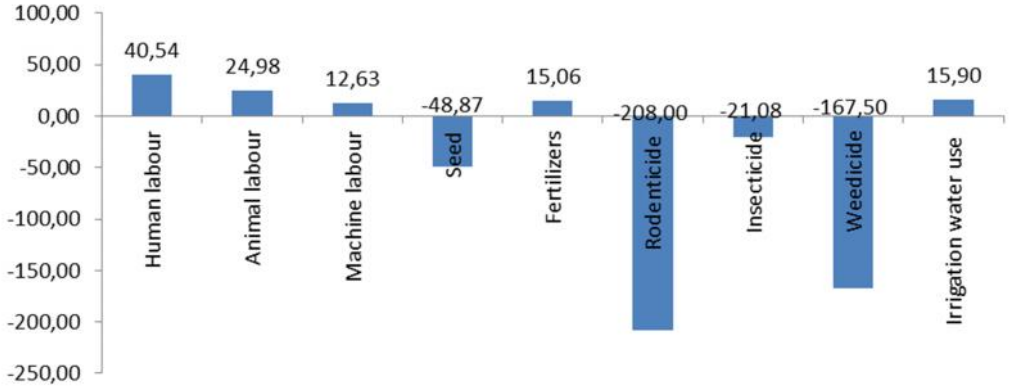

Figure 5: Extent of savings in inputs in DSR method of paddy cultivation by the respondents, 2021-22 (% change over PTR)

On the contrary, weeds infestation and rodent attacks was the major problem in DSR paddy cultivation which led to higher requirement of plant protection chemicals (i.e. rodenticides, insecticides and weedicides) along with the higher seed rate (-48.87%) than the PTR. The utilization of human labour, machine labour, and irrigation water were reduced by 13.16, 41.34, and 11.88%, respectively, in DSR as compared to the PTR technique of rice production, according to data from a previous study (Tripathi *et al* 2014).

WATER PRODUCTIVITY

The estimates of groundwater draft for paddy cultivation were estimated to the tune of about 6366 m^3 per acre on DSR as against the 7569 m^3 per acre in case of PTR method. It may be mentioned here that as per Price Policy (2015), Punjab consumes 5337 litres of water to produce a kilogram of rice (Table 3). According to our study, the average amount of groundwater needed to produce one kilogram of rice was 3448 liters, whereas the amount needed for the PTR approach was 4053 liters. As a result, DSR lowers the total amount of water used for rice farming. Groundwater productivity (Rs per m^3) for PTR (7.33) was likewise lower than for DSR (8.61) as a result of much higher groundwater usage.

Table 3. Water productivity in paddy cultivation by DSR and TPR in Punjab

Crop	**Groundwater Draft (m^3/acre)**	**Crop Yield of rice (kg/acre)**	**Groundwater foot prints (Litre/kg)**	**Crop Value (Rs./Acre)**	**Groundwater productivity(Rs./ m^3)**
DSR	6365.74	1846.00 (2769.00)	3448.40	54826.20	8.61
PTR	7569.39	1867.53 (2801.30)	4053.15	55465.74	7.33

Note: It may be mentioned here that as per Anonymous (2015), Punjab consumes 5337 litres of water to produce a kilogram of rice.
Figures in parentheses is paddy yield

Paddy, the primary crop in the state's current cropping pattern, is thereby endangering the groundwater supplies. Agriculture-related water is getting more and more limited, and the issue is likely to get worse in the coming years. The farmers may not move toward crop diversification under the current electricity pricing and paddy marketing assurances, which make it the most profitable kharif crop (Sarkar and Das 2014), but adoption of measures like DSR may help in easing the pressure on the state's diminishing groundwater resources.
In terms of important economic parameters such as yield, total variable cost, gross returns, net income Economic benefits of DSR over PTR method of paddy cultivation is presented in Table 4.

Table 4. Economic benefits of DSR paddy cultivation in Punjab (per acre)

Sr. No.	Particulars	DSR	PTR	Advantage in DSR (%)
1	Yield(kg)	2769.00	2801.30	-1.15
2	Total variable cost(Rs)	23344.06	27677.33	-15.66
3	Gross returns (Rs)	54826.20	55465.74	-1.15
4	Net returns over variable cost (Rs)	31482.14	27788.41	13.29
5	Cost of Grain production (Rs per kg)	8.43	9.88	-14.67
6	Energy (MJ per kg)	7.84	8.86	-11.50

The results revealed that the net returns over variable cost were higher by about 13 per cent in DSR (Rs 31482.14 per acre) than PTR (Rs 27788.41 per acre) because of lower variable costs involved in DSR. The cost in production of one kg grain using DSR was found to be lower (Rs 8.43 per kg) by about 15 per cent than in PTR (Rs 9.88 per kg) and the input energy involved in the same was Rs 7.84 MJ as compared to 8.86 MJ.

CONCLUSIONS

Hence, DSR is an input saving as well as cost saving technology for paddy cultivation in comparison to traditional PTR method. There is a need to generate more awareness of recommended DSR production practices among the farmers. Embracing of standard practices especially judicious use of inputs like fertilizers, underground water and plant protection chemicals will not only optimize the energy use but also will minimize the cost of cultivation. Government initiatives like subsidizing the cost of direct seeding of rice per acre can help in rapid extension of area under DSR. In this regard, Agro Service Centers in all co-operative societies need to be strengthened so that timely availability of required farm machinery/implements on custom hiring basis could be enhanced for the benefit of the small farmers. In order to combat the weed problem, further research and development efforts are required to provide acceptable agronomic techniques, cultivars, and mechanical equipment. To create high yielding rice varieties that are ideal for DSR and have desirable qualities including robust growth, weed-suppressing capacity, and resistance to micronutrient shortage, more research is required.

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