

ENERGY USE EFFICIENCY OF DIRECT SEEDING OF RICE IN PUNJAB

Thesis

**Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
for the degree of**

**MASTER OF SCIENCE
in
AGRICULTURAL ECONOMICS
(Minor Subject: Statistics)**

By

**GURPREET SINGH
(L-2020-BS-262-M)**

**Department of Economics and Sociology
College of Basic Sciences and Humanities
© PUNJAB AGRICULTURAL UNIVERSITY
LUDHIANA-141004**

2022

CERTIFICATE-I

This is to certify that the thesis entitled “**Energy use efficiency of direct seeding of rice in Punjab**” submitted for the degree of **Master of Science** in the subject of **Agricultural Economics** (Minor subject: **Statistics**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Gurpreet Singh (L-2020-BS-262-M)** under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

(Dr. Sangeet Ranguwal)
Major Advisor
Agricultural Economist
Deptt. of Economics and Sociology
Punjab Agricultural University,
Ludhiana-141 004.

CERTIFICATE – II

This is to certify that the thesis entitled, “**Energy use efficiency of direct seeding of rice in Punjab**” submitted by **Mr. Gurpreet Singh** (Admn. No. **L-2020-BS-262-M**) to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **M.Sc.** in the subject of **Agricultural Economics** (Minor subject: **Statistics**) has been approved by the Student’s Advisory Committee along with Head of the Department and External Examiner after an oral examination on the same.

(Dr. Sangeet Ranguwal)
Major Advisor

(Dr. Maan Singh Toor)
External Examiner
Professor of Economics (Retd.)
114-15, Rajouri Garden
Barewal Road, Ludhiana

(Dr. Kamal Vatta)
Professor and Head
Department of Economics and Sociology

(Dr. Sandeep Bains)
Dean, Postgraduate Studies

ACKNOWLEDGEMENT

Foremost of all, I express my sincere gratitude to the “AKAL PURKH” for his benign blessing hand and bestowing a healthy and creative environment throughout my carrier.

Words are compendious in expressing my profound indebtedness to my major advisor **Dr. Sangeet Ranguwal, Agricultural Economist, Deptt. of Economics and Sociology**, who is objective and humanitarian in principles, for her scholarly guidance in shaping the dissertation in this form. Her ability, perseverance, parental inspiration, constant encouragement, invaluable suggestions and administrative help sustained my efforts for completion of this work in time. I consider myself fortunate.

In recognition to the support and help extended by my advisory committee members namely **Dr. Jatinder Sachdeva (Senior Agricultural Economist), Dr. Mohammed Javed (Professor Statistics), Dr. Sanjay Walia (Dean PG Nominee)**, and. I am grateful to them for their able guidance, kind suggestions during the course of investigation.

My vocabulary utterly fails in expressing my profound gratitude to my supportive and loving family; my father **S. Gurmeet Singh**, my mother **Smt. Sukhjeet Kaur**, uncle **S. Daljit Singh** and aunt **Smt. Sukhpreet Kaur** whose unconditional love and sacrifice can never be forgotten and brother **S. Manpreet Singh, Mehakdeep** and sister **Bhawan & Ritu** whose ever willing help has a great role in my life endeavors.

A word of appreciation will not compensate for the ever willing help and cooperation by my seniors **Sukhdeep Singh, Baljit Singh, Gagandeep Singh, Harwinder Singh and Arshdeep Singh**. A special thanks to all my seniors for their support and for the memorable moments during my degree programme.

Cheerful acknowledgements are expressed to galaxy of my friends – **Maninder, Anmolveer, Amrit, Gurpinder, Amanjot, Simarjot, Sukhdeep, Paramveer, Prabhjoban, Yashi, Annu, Aval, Rajjit, Harbir, Chetan** and all my classmate for their help and good wishes.

I am thankful to the **librarian** and **Mr. Tarwinder Singh**, Clerk, Department of Economics and Sociology for their cooperation and timely help at the hours of need.

Mr. Deepak Kumar and **Mr. Beer Bahadur** (Ekta Computer Centre, Opp. P.A.U. Gate No.3, Ludhiana) deserve special thanks for bringing out this manuscript in its presentable form.

Cordial thanks to all kith and kins who helped me one way or the other. All may note mentioned but none is forgotten. Needless to say, errors and omissions if any are mine.

Place :

(Gurpreet Singh)

Date:

Title of the Thesis : Energy use efficiency of direct seeding of rice in Punjab
 Name of the Student : Gurpreet Singh
 and Admission No. (L-2020-BS-262-M)
 Major Subject : Agricultural Economics
 Minor Subject : Statistics
 Name and Designation : Dr. Sangeet Ranguwal
 of Major Advisor Agricultural Economics
 Degree to be awarded : M.Sc.
 Year of award of Degree : 2022
 Total Pages in Thesis : 66 + Appendix (iii) + VITA
 Name of University : Punjab Agricultural University, Ludhiana-141004, Punjab, India.

ABSTRACT

The present study was undertaken to examine and compare the resource and energy use pattern between the direct seeded rice (DSR) and conventional puddled transplanted rice (PTR) in Sri Mukatsar district of Punjab. Primary data were collected from 120 farmers (80 DSR adopters and 40 non adopters) selected using multi-stage random sampling technique through personal interview method during the agricultural year 2021-22. The input use for DSR showed an increasing trend with the farm size except for animal labour and non-significant (NS) differences existed among the different farm categories. Similarly, output for DSR had a rising trend with the farm size. In terms of energy use, NS differences were observed among farm categories for all input energies except human labour. Both input and output energy in DSR were lesser on DSR farms (21708.61 and 87431 MJ/acre) as compared to PTR farms (24816.79 and 88451 MJ/acre) but the net energy gain for DSR (65722.57 MJ/acre) was higher than the PTR (63634.26 MJ/acre). Chemical fertilizers were the dominant source of energy contributing about 41 to 42 per cent of the total input energy (with maximum share being from nitrogenous fertilisers) in DSR and PTR respectively. Electricity consumption for irrigation use also consumed a noteworthy share of 33 to 35 per cent share for DSR and PTR respectively followed by diesel fuel (11-10%). Plant protection chemical (PPC) contributed to as high as about 4 per cent of energy use in DSR as compared to only 2 per cent share in PTR. Higher EUE of 4.03 was observed in DSR than PTR (3.56). Marginal farm category was relatively more energy efficient (4.1) as compared to small (4.07) and large farms (3.92). High energy intensity of 8.86 MJ/kg with a low energy productivity index of 0.11 kg/MJ for PTR in comparison to DSR indicated that there is room for improving energy productivity of rice crop in the traditional PTR. The TVC was significantly lower by about 16 per cent in DSR (Rs 23344.06 per acre) than PTR (Rs 27677.33 per acre) and the major share belonged to human labour i.e about 23 per cent for DSR and about 33 per cent for PTR. Machine labour followed by electricity used for irrigation accounted for about 20 per cent and 18 per cent share respectively share in TVC for both the methods. The money spent on PPC was higher by about 7 per cent in DSR (16.9%) than PTR (9.88%) and the share of seed cost was observed to be almost double for DSR (2.92%) than the PTR (1.43%). DSR method generated significant savings in the physical terms in use of machine (12.63%), fertilizers (15.06%) and irrigation water (15.90 %) in comparison to PTR. In value terms, DSR reduced the cost of human labour, machine labour, fertilizers, electricity for irrigation by 40.53, 15.10, 7.63, 15.90 per cent resp. over the PTR though it enhanced the cost of seed and PPC by 72.67 and 44.29 per cent. With marginally lower yield in DSR (2769 kg per acre) than PTR (2801.3 kg per acre), the net ROVC were higher by about 13 per cent in DSR (Rs 31482.14 per acre) than PTR (Rs 27788.41 per acre) because of lower VC 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). Results of binomial regression analysis indicated that among 7 statistically significant factors affecting adoption of the DSR, one per cent rise in the availability of direct seeding implements, extension contacts and DSR trainings increased the adoption level by 33, 23 and 20 per cent respectively while with increase in age it declined by 2 per cent. High transplanting cost for human labour, expert advice and non availability of required implement were the major hurdles in adopting DSR by the adopters while easily available of labour for transplanting paddy, lack of technical knowledge, diffidence in adopting DSR and non-availability of required implements were the major reasons of non adoption. Study suggested the need to generate more awareness of recommended DSR production practices; capacity building by educating/training; timely availability of required farm implements on custom hiring basis; auxiliary research and development efforts for large scale adoption of the DSR.

Keywords: Benefits, DSR, Efficiency, Farm category, Input use

 Signature of Major Advisor

 Signature of the Student

ਖੋਜ ਦਾ ਸਿਰਲੇਖ	: ਪੰਜਾਬ ਵਿੱਚ ਝੋਨੇ ਦੀ ਸਿੱਧੀ ਬਿਜਾਈ ਲਈ ਊਰਜਾ ਦੀ ਵਰਤੋਂ ਦੀ ਕੁਸ਼ਲਤਾ
ਵਿਦਿਆਰਥੀ ਦਾ ਨਾਂ	: ਗੁਰਪ੍ਰੀਤ ਸਿੰਘ
ਅਤੇ ਦਾਖਲਾ ਨੰਬਰ	: (ਐੱਲ-2020-ਬੀਐੱਸ-262-ਐੱਮ)
ਪ੍ਰਮੁੱਖ ਵਿਸ਼ਾ	: ਖੇਤੀਬਾੜੀ ਅਰਥ-ਸ਼ਾਸਤਰ
ਸਹਿਯੋਗੀ ਵਿਸ਼ਾ	: ਆਂਕੜਾ ਵਿਗਿਆਨ
ਮੁੱਖ ਸਲਾਹਕਾਰ ਦਾ ਨਾਮ	: ਡਾ. ਸੰਗੀਤ ਰੰਗੂਵਾਲ
ਅਤੇ ਅਹੁਦਾ	: ਖੇਤੀਬਾੜੀ ਅਰਥ ਸ਼ਾਸਤਰੀ
ਡਿਗਰੀ	: ਐਮ.ਐਸ.ਸੀ.
ਡਿਗਰੀ ਮਿਲਣ ਦਾ ਸਾਲ	: 2022
ਖੋਜ ਪੱਤਰ ਵਿੱਚ ਕੁੱਲ ਪੰਨੇ	: 66 + ਅੰਤਿਕਾਵਾਂ (iii) + ਵੀਟਾ
ਯੂਨੀਵਰਸਿਟੀ ਦਾ ਨਾਮ	: ਪੰਜਾਬ ਖੇਤੀਬਾੜੀ ਯੂਨੀਵਰਸਿਟੀ, ਲੁਧਿਆਣਾ-141 004, ਪੰਜਾਬ, ਭਾਰਤ

ਸਾਰ ਅੰਸ਼

ਮੌਜੂਦਾ ਖੋਜ ਵਿੱਚ ਪੰਜਾਬ ਦੇ ਸ੍ਰੀ ਮੁਕਤਸਰ ਸਾਹਿਬ ਜ਼ਿਲ੍ਹੇ ਵਿੱਚ ਸਿੱਧੀ ਬੀਜੇ ਝੋਨੇ (DSR) ਅਤੇ ਰਿਵਾਇਤੀ ਕੱਦੂ ਵਿਧੀ ਨਾਲ ਬੀਜੇ ਝੋਨੇ (PTR) ਦਰਮਿਆਨ ਸਰੋਤ ਅਤੇ ਊਰਜਾ ਵਰਤੋਂ ਦੀ ਸੰਚਰਨਾ ਦਾ ਮੁਲਾਂਕਣ ਅਤੇ ਤੁਲਨਾਤਮਕ ਅਧਿਐਨ ਕੀਤਾ ਗਿਆ। ਸੰਨ 2021-22 ਦੌਰਾਨ ਨਿੱਜੀ ਤੌਰ 'ਤੇ ਮਿਲ ਕੇ ਬਹੁ-ਪੜਾਵੀਂ ਰੈਂਡਮ ਸੈਂਪਲਿੰਗ ਵਿਧੀ ਰਾਹੀਂ ਕੁੱਲ 120 ਕਿਸਾਨਾਂ (80 ਸਿੱਧੀ ਬਿਜਾਈ ਅਪਨਾਉਣ ਵਾਲੇ ਅਤੇ 40 ਸਿੱਧੀ ਬਿਜਾਈ ਨਾ ਅਪਨਾਉਣ ਵਾਲੇ) ਤੋਂ ਮੁੱਢਲੇ ਆਂਕੜੇ ਇਕੱਠੇ ਕੀਤੇ ਗਏ। DSR ਲਈ ਇੰਨਪੁਟ ਯੂਜ਼ ਤੋਂ ਪਤਾ ਚੱਲਿਆ ਕਿ ਪਸ਼ੂ ਲੇਬਰ ਤੋਂ ਇਲਾਵਾ ਖੇਤ ਦੇ ਅਕਾਰ ਨਾਲ ਇਸ ਦਾ ਵਾਧੇ ਦਾ ਰੁਝਾਨ ਵੇਖਿਆ ਗਿਆ ਅਤੇ ਵੱਖ-ਵੱਖ ਖੇਤ ਸ਼੍ਰੇਣੀਆਂ ਵਿੱਚ ਗੈਰ-ਅਰਥਪੂਰਨ ਵਿਭਿੰਨਤਾ ਦੇਖੀ ਗਈ। ਇਸੇ ਤਰ੍ਹਾਂ, ਖੇਤ ਦੇ ਆਕਾਰ ਨਾਲ DSR ਲਈ ਆਉਟ-ਪੁਟ ਵਿੱਚ ਵਾਧਾ ਹੋਇਆ। ਊਰਜਾ ਵਰਤੋਂ ਦੀ ਗੱਲ ਕਰੀਏ ਤਾਂ, ਮਨੁੱਖੀ ਮਜ਼ਦੂਰੀ ਤੋਂ ਇਲਾਵਾ ਬਾਕੀ ਸਾਰੀਆਂ ਇੰਨਪੁਟ ਊਰਜਾਵਾਂ ਲਈ ਖੇਤ ਆਕਾਰ ਦੀਆਂ ਵੱਖ-ਵੱਖ ਸ਼੍ਰੇਣੀਆਂ ਦਰਮਿਆਨ ਗੈਰ-ਅਰਥਪੂਰਨ ਵਿਭਿੰਨਤਾ ਦਰਜ ਕੀਤੀ ਗਈ। PTR ਫਾਰਮਾਂ (24816.79 ਅਤੇ 88451 MJ/acre) ਦੇ ਮੁਕਾਬਲੇ DSR ਫਾਰਮਾਂ (21708.61 ਅਤੇ 87431 MJ/acre) ਉੱਪਰ DSR ਵਿੱਚ ਇੰਨਪੁਟ ਅਤੇ ਆਉਟ-ਪੁਟ ਊਰਜਾ ਘੱਟ ਸੀ ਪਰ PTR (65722.57 MJ/acre) ਦੇ ਮੁਕਾਬਲੇ DSR (63634.26 MJ/acre) ਲਈ ਸ਼ੁੱਧ ਊਰਜਾ ਜ਼ਿਆਦਾ ਸੀ। ਰਸਾਇਣਕ ਖਾਦਾਂ, ਊਰਜਾ ਦੇ ਮੁੱਖ ਸਰੋਤ ਸਨ ਜਿਹਨਾਂ ਦੀ DSR ਅਤੇ PTR ਵਿੱਚ ਕੁੱਲ ਇੰਨਪੁਟ ਊਰਜਾ (ਜ਼ਿਆਦਾ ਹਿੱਸੇਦਾਰੀ ਨਾਈਟ੍ਰੋਜਨ ਵਾਲੀਆਂ ਖਾਦਾਂ ਵਿੱਚ) ਦੀ ਹਿੱਸੇਦਾਰ ਕ੍ਰਮਵਾਰ 41 ਤੋਂ 42 ਪ੍ਰਤੀਸ਼ਤ ਹਿੱਸਾ ਸੀ। ਸਿੱਚਾਈ ਲਈ ਬਿਜਲੀ ਦੀ ਖਪਤ ਨੇ ਵੀ DSR ਅਤੇ PTR ਲਈ ਕ੍ਰਮਵਾਰ 33 ਤੋਂ 35 ਪ੍ਰਤੀਸ਼ਤ ਹਿੱਸੇਦਾਰ ਦਰਸਾਈ ਅਤੇ ਇਸ ਉੱਪਰੰਤ ਡੀਜ਼ਲ ਦੀ 11-10% ਦੀ ਹਿੱਸੇਦਾਰੀ ਵੇਖੀ ਗਈ। PTR ਦੇ ਮੁਕਾਬਲੇ DSR ਵਿੱਚ PPC ਵਧੇਰੇ ਸੀ, DSR ਵਿੱਚ ਇਸਦੀ ਕੁੱਲ ਹਿੱਸੇਦਾਰੀ 4 ਪ੍ਰਤੀਸ਼ਤ ਅਤੇ PTR ਵਿੱਚ 2 ਪ੍ਰਤੀਸ਼ਤ ਦਰਜ ਕੀਤੀ ਗਈ। PTR (3.56) ਦੇ ਮੁਕਾਬਲੇ DSR ਵਿੱਚ ਵਧੇਰੇ EUE (4.03) ਦਰਜ ਕੀਤੀ ਗਈ। ਖੇਤ ਦੇ ਅਕਾਰ ਦੇ ਲਿਹਾਜ਼ ਨਾਲ ਛੋਟੇ (4.07) ਅਤੇ ਵੱਡੀਆਂ (3.92) ਸ਼੍ਰੇਣੀਆਂ ਦੇ ਮੁਕਾਬਲੇ ਸਿਮਾਂਤ (4.10) ਖੇਤ ਸ਼੍ਰੇਣੀ ਵਿੱਚ ਊਰਜਾ ਦੀ ਸੁਚੱਜੀ ਵਰਤੋਂ ਹੋਈ। DSR ਦੇ ਮੁਕਾਬਲੇ PTR ਲਈ 8.66 MJ/kg ਦੀ ਉੱਚ ਊਰਜਾ ਤੀਬਰਤਾ ਅਤੇ 0.11 kg/MJ ਊਰਜਾ ਉਤਪਾਦਕਤਾ ਸੁਚਕਾਕ ਤੋਂ ਇਹ ਸੰਕੇਤ ਮਿਲਿਆ ਕਿ ਰਿਵਾਇਤੀ PTR ਵਿਧੀ ਵਿੱਚ ਝੋਨੇ ਦੀ ਊਰਜਾ ਉਤਪਾਦਕਤਾ ਵਿੱਚ ਸੁਧਾਰ ਲਿਆਉਣ ਦੀ ਗੁੰਜਾਇਸ਼ ਹੈ। PTR (Rs 27677.33/acre) ਦੇ ਮੁਕਾਬਲੇ DSR (Rs 23344.06/acre) ਵਿੱਚ TVC ਅਰਥਪੂਰਨ ਤੌਰ 'ਤੇ 16 ਪ੍ਰਤੀਸ਼ਤ ਤੱਕ ਘੱਟ ਸੀ ਅਤੇ ਪ੍ਰਮੁੱਖ ਹਿੱਸਾ ਮਨੁੱਖੀ ਮਜ਼ਦੂਰੀ ਨਾਲ ਸਬੰਧਤ ਸੀ ਜੋਕਿ DSR ਲਈ 23 ਪ੍ਰਤੀਸ਼ਤ ਅਤੇ PTR ਲਈ 33 ਪ੍ਰਤੀਸ਼ਤ ਸੀ। ਬਿਜਾਈ ਦੀਆਂ ਦੋਨਾਂ ਵਿਧੀਆਂ ਲਈ TVC ਵਿੱਚ ਮਸ਼ੀਨੀ ਲੇਬਰ ਅਤੇ ਇਸ ਉੱਪਰੰਤ ਸਿੱਚਾਈ ਲਈ ਬਿਜਲੀ ਦੀ ਵਰਤੋਂ ਉੱਪਰ ਆਉਣ ਵਾਲਾ ਹਿੱਸਾ ਕ੍ਰਮਵਾਰ 20 ਅਤੇ 18 ਪ੍ਰਤੀਸ਼ਤ ਸੀ। PTR (9.88%) ਦੇ ਮੁਕਾਬਲੇ DSR (16.90%) ਵਿੱਚ PPC ਉੱਪਰ ਆਉਣ ਵਾਲਾ ਖਰਚਾ ਲਗਭਗ 7 ਪ੍ਰਤੀਸ਼ਤ ਵਧੇਰੇ ਸੀ ਅਤੇ DSR (2.92) ਵਿੱਚ ਬੀਜ ਉੱਪਰ ਆਉਣ ਵਾਲਾ ਖਰਚਾ ਵੀ PTR (1.43%) ਤੋਂ ਲਗਭਗ ਦੁਗਣਾ ਸੀ। PTR ਦੇ ਮੁਕਾਬਲੇ DSR ਨਾਲ ਮਸ਼ੀਨੀ (12.63%), ਖਾਦਾਂ (15.06%) ਅਤੇ ਸਿੱਚਾਈ ਲਈ ਪਾਣੀ (15.90%) ਦੀ ਵਰਤੋਂ ਦੇ ਲਿਹਾਜ਼ ਨਾਲ ਭੌਤਿਕ ਰੂਪ ਵਿੱਚ ਮਹੱਤਵਪੂਰਨ ਬੱਚਤ ਹੋਈ। ਪੈਸੇ ਦੇ ਲਿਹਾਜ਼ ਨਾਲ, PTR ਦੇ ਮੁਕਾਬਲੇ DSR ਨਾਲ ਮਨੁੱਖੀ ਮਜ਼ਦੂਰੀ, ਮਸ਼ੀਨੀ ਖਰਚੇ, ਖਾਦਾਂ, ਸਿੱਚਾਈ ਉੱਪਰ ਬਿਜਲੀ ਦੀ ਲਾਗਤ ਉੱਪਰ ਆਉਣ ਵਾਲੇ ਖਰਚੇ ਵਿੱਚ ਕ੍ਰਮਵਾਰ 40.53, 15.10, 9.96, 15.90 ਪ੍ਰਤੀਸ਼ਤ ਦੀ ਕਮੀ ਆਈ ਹਾਲਾਂਕਿ ਇਸ ਨਾਲ ਬੀਜ ਅਤੇ PPC ਉੱਪਰ ਆਉਣ ਵਾਲੀ ਲਾਗਤ ਵਿੱਚ ਕ੍ਰਮਵਾਰ 72.67 ਅਤੇ 44.29 ਪ੍ਰਤੀਸ਼ਤ ਦਾ ਵਾਧਾ ਹੋਇਆ। DSR ਵਿੱਚ ਘੱਟ ਪਰਵਿਰਤਨਸ਼ੀਲ ਲਾਗਤਾਂ ਹੋਣ ਕਾਰਨ, PTR (2801.3 kg per acre) ਦੇ ਮੁਕਾਬਲੇ DSR (2769 kg per acre) ਵਿੱਚ ਥੋੜ੍ਹਾ ਘੱਟ ਝਾੜ, PTR (Rs 27788.41 per acre) ਦੇ ਮੁਕਾਬਲੇ DSR (Rs 31482.14 per acre) ਵਿੱਚ ਕੁੱਲ ਪਰਵਿਰਤਨਸ਼ੀਲ ਲਾਗਤਾਂ ਲਗਭਗ 13 ਪ੍ਰਤੀਸ਼ਤ ਵਧੇਰੇ ਸੀ। PTR (Rs 9.88 per kg) ਦੇ ਮੁਕਾਬਲੇ DSR (Rs 8.43 per kg) ਵਿੱਚ ਇੱਕ ਕਿੱਲੋ ਦਾਣਿਆਂ ਦੇ ਉਤਪਾਦਨ ਉੱਪਰ ਲਗਭਗ 15 ਪ੍ਰਤੀਸ਼ਤ ਘੱਟ ਲਾਗਤ ਆਈ। ਬਾਈਐਨੋਮੀਅਲ ਪ੍ਰਤੀਗਮਨ ਵਿਸ਼ਲੇਸ਼ਣ ਦੇ ਨਤੀਜਿਆਂ ਤੋਂ ਪਤਾ ਚੱਲਿਆ ਕਿ DSR ਅਪਨਾਉਣ ਦੀ ਦਰ ਨੂੰ ਪ੍ਰਭਾਵਿਤ ਕਰਨ ਵਾਲੇ 7 ਅਰਥਪੂਰਨ ਕਾਰਕਾਂ ਵਿੱਚੋਂ, ਸਿੱਧੀ ਬਿਜਾਈ ਦੇ ਸੰਦਾਂ ਦੀ ਉਪਲਬਧਤਾ, ਪਸਾਰ ਸੰਪਰਕਾਂ ਅਤੇ DSR ਸਿੱਖਲਾਈ ਵਿੱਚ ਇੱਕ ਪ੍ਰਤੀਸ਼ਤ ਵਾਧੇ ਨੇ ਇਸਨੂੰ ਅਪਨਾਉਣ ਦੀ ਦਰ ਵਿੱਚ ਕ੍ਰਮਵਾਰ 33, 23 ਅਤੇ 20 ਪ੍ਰਤੀਸ਼ਤ ਵਾਧਾ ਕੀਤਾ ਜਦੋਂਕਿ ਉਮਰ ਦੇ ਵਧਣ ਨਾਲ ਇਸਦੇ ਅਪਨਾਉਣ ਦੀ ਦਰ ਵਿੱਚ 2 ਪ੍ਰਤੀਸ਼ਤ ਦੀ ਕਮੀ ਆਈ। ਮਨੁੱਖੀ ਮਜ਼ਦੂਰੀ, ਮਾਹਿਰਾਂ ਦੀ ਸਲਾਹ ਅਤੇ ਲੋੜੀਂਦੇ ਸੰਦਾਂ ਦੀ ਉਪਲਬਧਤਾ ਨਾ ਹੋਣਾ, DSR ਨੂੰ ਅਪਨਾਉਣ ਵਿੱਚ ਆਉਣ ਵਾਲੀਆਂ ਮੁੱਖ ਰੁਕਾਵਟਾਂ ਸਨ ਜਦੋਂਕਿ ਪਨੀਰੀ ਰਾਹੀਂ ਝੋਨੇ ਦੀ ਲੁਆਈ ਦੀ ਮਜ਼ਦੂਰਾਂ ਦਾ ਅਰਾਮ ਨਾਲ ਮਿਲਣਾ, ਤਕਨੀਕੀ ਜਾਣਕਾਰੀ ਦੀ ਕਮੀ, DSR ਨੂੰ ਅਪਨਾਉਣ ਵਿੱਚ ਮਤਭੇਦ ਅਤੇ ਲੋੜੀਂਦੇ ਸੰਦਾਂ ਦੀ ਉਪਲਬਧਤਾ ਨਾ ਹੋਣਾ ਇਸਨੂੰ ਨਾ ਅਪਨਾਉਣ ਦੇ ਮੁੱਖ ਕਾਰਨ ਸਨ। ਅਧਿਐਨ ਦੇ ਨਤੀਜਿਆਂ ਦੇ ਅਧਾਰ 'ਤੇ DSR ਉਤਪਾਦਨ ਅਭਿਆਸਾਂ ਬਾਰੇ ਵਧੇਰੇ ਜਾਗਰੂਕਤਾ; ਸਿੱਖਿਆ/ਸਿਖਲਾਈਆਂ ਦੁਆਰਾ ਸਮਰੱਥਾ ਵਿਕਾਸ; ਕਸਟਮ ਹਾਈਰਿੰਗ ਆਧਾਰ 'ਤੇ ਲੋੜੀਂਦੇ ਖੇਤੀ ਸੰਦਾਂ ਦੀ ਸਮੇਂ ਸਿਰ ਉਪਲਬਧਤਾ; ਸਹਾਇਕ ਖੋਜ ਅਤੇ DSR ਨੂੰ ਵੱਡੇ ਪੱਧਰ 'ਤੇ ਅਪਨਾਉਣ ਲਈ ਯਤਨ ਕਰਨ ਦੀ ਸਿਫਾਰਿਸ਼ ਕੀਤੀ ਜਾਂਦੀ ਹੈ।

ਮੁੱਖ ਸ਼ਬਦ: ਲਾਭ, ਝੋਨੇ ਦੀ ਸਿੱਧੀ ਬਿਜਾਈ, ਸਮਰੱਥਾ, ਖੇਤ ਦਾ ਆਕਾਰ, ਇੰਨਪੁਟ ਵਰਤੋਂ

CONTENTS

CHAPTER	TOPIC	PAGE NO.
I	INTRODUCTION	1-3
II	REVIEW OF LITERATURE	4-15
III	MATERIAL METHODS	16-24
IV	RESULTS AND DISCUSSION	25-54
V	SUMMARY	55-61
	REFERENCES	62-66
	APPENDIX	i-iii

LIST OF TABLES

TABLE NO.	TOPIC	PAGE NO.
3.1	Sampling design	16
3.2	Energy coefficients used in energy calculation for paddy cultivation	18
3.3	Different variables used in binary logistic regression model in the study	23
4.1.1	Age wise distribution of the respondents in Punjab, 2021-22	26
4.1.2	Distribution of the respondents according to literacy status, 2021-22	27
4.1.3	Distribution of respondents according to family size, 2021-22	27
4.1.4	Distribution of the respondents according to the farming experience, 2021-2	28
4.1.5	Source of agricultural information among adopters and non-adopters	29
4.1.6	Number of farmers attending training/camp of direct seeded rice (DSR)	30
4.1.7	Distribution of the respondents according to participation in trainings related to DSR, 2021-22	30
4.2.1	Size of operational holding of selected farmers in Punjab, 2021-22	31
4.2.2	Cropping Pattern followed by selected farmers in Punjab, 2021-22	32
4.2.3	Distribution of sample households according to source of irrigation	33
4.2.4	Distribution of sample households on the basis of variety of paddy	33
4.2.5	Details of plough back area by the respondents in Punjab, 2021-22	34
4.2.6	Reasons of ploughing back of DSR by the respondents	35
4.3.1	Input use pattern and output in paddy cultivation by DSR method among different farm size categories, 2021-22	36
4.3.2	Input use pattern and output from paddy cultivation using DSR and PTR method by the respondents, 2021-22	38
4.4.1	Energy consumption pattern in paddy cultivation by DSR method among different farm size categories, 2021-22	40
4.4.2	Energy consumption pattern in paddy cultivation by DSR and TPR method by the respondents, 2021-22	42
4.5	Cost of different inputs used in paddy cultivation by DSR and PTR method of cultivation in Punjab, 2021-22	45
4.6	Energy pattern in paddy cultivation on the selected farms in Punjab, 2021-22	47
4.6.1	Extent of savings in physical use of different inputs in DSR method of paddy cultivation by the respondents, 2021-22	48
4.6.2	Water productivity in paddy cultivation by DSR and TPR method of	49

TABLE NO.	TOPIC	PAGE NO.
	cultivation, 2021-22	
4.7	Extent of saving in value terms in DSR and PTR methods of paddy cultivation by the respondents, 2021-22	50
4.7.1	Economic benefits of DSR paddy cultivation, 2021-22	50
4.8	Adoption of agronomic practices by the respondents using DSR	52
4.9	Results of binomial regression and marginal effects for different factors influencing the adoption of DSR by the respondents, 2021-22	53
4.10.1	Perceptions regarding adopting DSR method of cultivating paddy by the respondents, 2021-22	54
4.10.2	Perceptions for not adoption of DSR by the respondents, 2021-22	54

LIST OF FIGURES

FIGURE NO.	TOPIC	PAGE NO.
1	Source of input energy in paddy cultivation by DSR and PTR	43
2	Cost of different inputs used in paddy cultivation by DSR and PTR method	46

CHAPTER I

INTRODUCTION

The entire process of human growth depends on energy. It has been found to be the most beneficial agricultural input in all of its forms i.e. mechanical (from machines, human labour, animal draft), chemical (fertilizer, pesticides, herbicides), electrical, heat, etc. (Pimentel *et al* 1992). Agriculture and energy consumption have a strong relationship, and further agricultural sustainability is dependent on a balance of production, environmental, and economic factors. Energy is a necessary input for agriculture, which essentially converts energy into products that improve food security, add value, and advance rural economies (FAO 2000). Agriculture consumes a significant amount of locally accessible non-commercial energy sources, such as manure and animal energy, as well as commercial energy both directly and indirectly in the form of expensive seed, diesel, electricity, fertiliser, plant protection chemicals, irrigation water, machinery, etc., all of which are soon likely to run out (Alam *et al* 2005; Iqbal 2007). 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). In this regard, efficient use of energy by the agriculture sector seems as one of the conditions for sustainable agriculture because it not only allows financial savings and preservation of fossil resources but also reduces air pollution (Pervanchon *et al* 2002). For cleaner and more sustainable output, agriculture is rapidly realising the benefits of resource conservation and effective resource management (Kumar *et al* 2019). Increased energy inputs and improvements to the quality of the energy have been crucial to the advancement of all technologies, including those related to agricultural output. The major concern is to enhance the energy efficiency either through raising the agricultural output with the existing level of energy input or to reduce the level of energy use without affecting the current output level.

Energy budgets for agricultural production may be used as the foundation for lifecycle analyses of goods that incorporate agriculture as well as a first step in identifying crop production techniques that would benefit from greater efficiency (Piringer 2006). Unlike economic analysis, energy analysis provides indirect information on the usage of energy and is unaffected by artificial price fluctuations in agricultural commodities. Energy management in agricultural systems includes energy conservation as a key component. To decrease energy losses and/or improve the efficiency of each energy input, the energy audit should be focused on specific areas of the system (Nassiri and Singh 2009). Therefore, energy analysis becomes the basis for sound management and policy decisions for conservation and efficient management of scarce resources for improved agricultural production. A balance sheet of the overall energy input and output might help to increase energy usage efficiency while

requiring less EUE energy input and help to ensure the long-term viability of the production system.

From an economic and environmental perspective, it is crucial to use the right source and mix of energy input while producing crops. A thorough analysis of the local situation, available energy sources, skills, and needs is necessary to evaluate alternative forms of energy with lower production costs and increased agricultural productivity because the pattern of energy use varies depending on the energy sources available in a given region and the farmers' financial capacity. Therefore, energy analysis is necessary for efficient management of scarce resources for enhancing the agricultural productivity. It helps to identify production practices that are economical and effective along with other benefits like determination of the energy invested in each stage of the production process to categorize the steps that require least energy. The current agriculture's steadily declining energy-use efficiency is a major concern that prompting the optimal and efficient use of energy inputs used in diverse agricultural activities (Kumar *et al* 2020). Therefore, energy analysis becomes the basis for sound management and policy decisions for conservation and efficient management of scarce natural resources for improved agricultural production.

Moreover, 70% of Indians use rice as their primary food source, and it takes up between 40% and 45% of all the land in India used for cereal crops. It is the main crop during rainy season in trans-Indo-Gangetic Plains, including Punjab. The growing demand of rice has to be met by producing more rice with less agricultural input energy usages. Further, paddy is mostly cultivated by hand-transplanting in puddled field conditions (wet cultivation) in the country. Puddling damages soil structure and uses a lot of water and energy. During the past ten years, the Indian economy has seen a significant transition as farm labour has been migrating throughout this time to industries with better pay and working conditions which led to a sharp rise in farm labourer pay, which affected the profitability of the rice production (Bhullar *et al* 2018). Further, the search for alternative management techniques to improve water productivity in rice cultivation is motivated by the impending water crisis and the water-intensive nature of rice farming. When the future of rice production is in jeopardy due to worldwide water constraint, direct seeded rice (DSR) presents a desirable alternative (Farooq *et al* 2011). Due of its minimal input demand, direct seeded rice (DSR) is a potential replacement for conventional puddled transplanted rice (PTR). There is an urgent need to switch from the traditional PTR to DSR because DSR tends to reduce water consumption, labour requirements, and helps to maintain the soil structure in the situation of fast-paced ground water depletion (Bandumula *et al* 2018). Due to the puddling process, surface evaporation, and percolation, which leads in significant energy expenditure for irrigating the rice plants, substantial volumes of water loss in the PTR are anticipated (Begum *et al* 2006). DSR as a conservation tillage practice also helps in reducing the energy consumption, carbon

input and greenhouse gas (GHG) emission in comparison to PTR method (Basavalingaiah *et al* 2020).

Punjab, comprising only 1.54 per cent of the total geographical area of the country is the most progressive state of India. With 3.1 million hectares of land under rice, it has significant contribution towards the food security of the nation. Punjab state known as the ‘food bowl of India’. It 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 the passage of time, Punjab farmers started using more and more of commercial energy and became highly energy intensive. In the state, farmers' reliance on groundwater to irrigate paddy together with the supply of electricity and irrigation at concessions has fostered inefficient resource use, altered the inter-temporal resource allocation, and led to ecological imbalance. The state has a significant growth in the number of power operated tube wells due to the increased availability of electric power and the policy of its subsidised or tariff-free provision for agriculture, which has led to an overuse of groundwater resources. There is an urgent need to switch from the PTR to DSR. According to a study, if water is available and labour costs are low, transplanting is preferred; if labour costs are high and water is scarce, DSR is preferred (Kaur and Singh 2017). Energy inputs for crop production on farms must be provided in a variety of ways and to varied degrees, and even within the same set of agricultural activities, energy consumption varies from farmer to farmer (Halim *et al* 1999). For farms with lower efficiency levels, there is also enough room to increase production via good management and allocation of the available resources and technologies (Samarpitha *et al* 2016). Keeping all this in mind, the present study entitled “Energy use efficiency of direct seeding of rice in Punjab”, was conducted with the following objectives;

1. To compare the resource-use pattern of direct seeded rice (DSR) to conventional puddled transplanted rice (PTR)
2. To measure the energy use efficiency of paddy cultivation for direct seeded rice and conventional puddled transplanted rice;
3. To study the different factors affecting the energy use efficiency of direct seeded rice Technology.

CHAPTER II

REVIEW OF LITERATURE

A few research studies are available on energy use efficiency for paddy crop grown by the farmers in Punjab (Kumar, 2017; Singh *et al* 2019). But there is dearth of comparative studies regarding the energy use pattern in growing paddy by Direct Seeded Rice (DSR) and puddled transplanted rice (PTR) Technology. The review has been categorized into three different sub-heads which are given below:

2.1 To compare the resource-use pattern of direct seeded rice (DSR) to conventional puddled transplanted rice (PTR)

Freedman (1980) highlighted the modifications of traditional rice production practices in the developing world. By calculating the ratio of food energy output to cultural energy input, traditional, transitional (labour-intensive), green revolution (capital-intensive) and experimental (intermediate) techniques of rice cultivation were compared. The inputs of human and animal labour, equipment needs, and auxiliary inputs of fertilizers, pesticides, herbicides, and irrigation were estimated for diverse agricultural processes along with input use for each step of the cultivation process, including sowing, land preparation, harvesting, and threshing. There was higher energy output of food produced as compared to the cultural energy consumed for the production by all techniques of producing rice. To compare the amount of energy needed to create a certain amount of rice with the actual amount needed, comparative efficiencies were also computed for each production process and it was found that in comparison to the experimental technique (33.6) and the Green Revolution method (21.0), the transitional approach (48.0) was considered to be the most successful adaptation of the conventional method.

Khan *et al* (2009) studied the pattern of energy consumption and the connection between energy inputs and rice output in Pakistan's Dera Ismail Khan District. The data analyzed in this study were cross-sectional data obtained from farmers through personal interviews. A stratified sampling method was used to choose the sample farms. The findings showed that on Bullock Operated Farms (BOF), rice output was 5,756 kWh and 3.23 tonnes per hectare, whereas, on Tractor Operated Farms, it was 11,162 kWh and 4.12 tonnes per hectare (TOF). Due to the extensive usage of animate energy in land preparation operations, animate energy consumption on BOF was higher than on TOF. BOF's output-to-input ratio (6.32) was greater than the TOF's (4.16). Although the yield and subsequent crop values and net return were greater on TOF than on BOF, the cost of production was still cheaper on BOF than TOF. It was determined that higher energy consumption at the farm level boosted rice output, allowing farmers with higher production costs to receive better returns on their crops.

Tripathi *et al* (2014) in a study on economic evaluation of direct seeded and

transplanted methods of rice production in Haryana stated that DSR was the fast-growing alternative due to labour shortage and increasing cost of production. The study revealed that the use of human labour, machine labour, and irrigation water were saved by 13.16, 41.34, and 11.88 per cent, respectively, in DSR as compared to the transplanted method of rice production and the expenditure incurred on the machine, irrigation and human labour was substantially lower by 41.34, 22.45 and 6.62 per cent, respectively, in direct-seeded rice as against transplanted method. The study examined that farmers' main motive for a shift to DSR was to overcome the shortage of human labour and machine power (tractor) during the peak period of transplanting. The study supported that DSR technology could be a viable alternative to overcome the problems of the rising cost of cultivation, labour, and water shortages for sustainable rice production if the problems of seed drill availability and weed infestation were addressed to accelerate wider adoption of DSR technology.

Kumar *et al* (2015) in a study on productivity and economics of DSR highlighted labour and cost savings of 97 per cent and 80 per cent in DSR as compared to manual Puddled Transplanted Rice in sowing/transplanting. The yield of manual PTR was significantly higher (10-12%) than DSR during both the years of study. It was examined that DSR consumed 12-17 per cent less water as compared to PTR rice during 2011, whereas, it consumed 5-9 per cent more water as compared to puddled transplanted rice during 2012 and when compared to manual puddled transplanted rice, a labour-saving of 7-8 per cent (overall) was observed in DSR during both the years. The study revealed that the B: C ratio was highest in DSR in zero till condition (1.74) as compared to manual PTR (1.62). It was also revealed that the conventional practice of puddled transplanting could be replaced with zero till DSR to save water and labour.

Kumar and Batra (2017) in a research study on economic and constraint analysis of rice cultivation by DSR Technology in Karnal district of Haryana observed that total costs in rice production amounted to Rs 96631.41/hectare (Ha) and the gross return was found to be Rs 98452.50/Ha. The net returns were observed to be Rs 1821.09/Ha in comparison to conventional rice production, as against Rs 2509.91/Ha. Among various constraints in the production of rice with DSR technology, major ones were higher weed infestation, lack of suitable varieties for DSR, comparative lower yield than rice produced by the conventional transplanted method, lack of technical guidance about the technology, and higher cost of weedicides. The study concluded that DSR technology was better than the transplanted method of rice cultivation due to lesser irrigation and human labour requirements per unit area and was found to be more profitable in terms of net returns per hectare. The study supported that DSR could be an alternative to conventional transplanted rice without much compromise for the yield.

Yuan and Peng (2017) studied the input-output energy of rice production in different

crop management practices in Wuxue County (23 m above sea level), Hubei Province, China during the middle growing season in 2014 and 2015. Energy security and the long-term sustainability of rice production depended on reducing energy inputs and improving energy use efficiency (EUE). 54 per cent of China's total rice output and rice-cultivated land was in Central China. An input-output energy analysis was used to estimate the energy input and EUE in farmers' practices (FP) and simplified and reduced-input practices (SRIP) to carry out these analyses. The findings revealed that rice grain yield in FP and SRIP was 9171.3 and 8449.9 kg per ha, respectively and that the energy input and output, were 34544.4 and 25441.5 MJ per ha, 266744.9 and 234393.0 MJ per ha respectively. EUE and energy productivity were much greater in SRIP than FP by 19.0 and 24.8 per cent, respectively. Lower specific energy in SRIP (3.01 MJ per kg) compared to FP (3.76 MJ per kg) suggested that less energy was required to produce one unit of grain in SRIP. This study showed that SRIP implementation might greatly boost EUE by lowering energy usage. More inventive agronomic techniques will be needed in rice cultivation in the future with lower energy input to increase yield and energy output.

Sidana *et al* (2020) in a study on comparative economics of direct seeded rice technology and transplanted rice highlighted the changing pattern of labour use in resource conservation technologies in Punjab agriculture. It was revealed that the adoption of DSR resulted in labour and water saving to the extent of 56.06 per cent and 31.81 per cent respectively as compared to the conventional method of paddy transplanting. The study supported the promotion of DSR as a strategy to enhance the profitability of farmers and also as a water-saving technology in the face of depleting water resources for agriculture in general and rice in particular.

2.2 To measure the energy use efficiency of paddy cultivation for direct seeded rice and conventional puddled transplanted rice

According to a study of Thailand's wetland rice systems, Gajasen (1995) highlighted that the conventional methods relied heavily on deposits of organic silt left over after floods, which constituted 49% of the systems' total energy input for transplanting and that of 48% for direct seeding. The direct sowing approach had a total grain output to input ratio of 2.7, whereas for the transplanting it was 4.5. Currently, industrial-based inputs made up 23 per cent of the overall input for the transplanting system and account for 69 per cent of the entire input for direct seeding. Energy efficiency has decreased as a result of rising input intensity and rising energy yields per unit area. A blatant example of decreasing returns is the ratio of total grain production to total input, which has fallen to 1.2 for the transplanting system and 0.3 for the direct sowing approach.

Gevao *et al* (2005) studied the direct and indirect energy consumption of field operations in the lowland rice production system of Malaysia". The study revealed that the

highest average operational energy consumption for tillage was 1747.33 MJ ha⁻¹ which accounted for about 48.6% of the total operational energy consumption (3595.87 MJ ha⁻¹), followed by harvesting (1171.44 MJ ha⁻¹, 32.6 %) and planting (562.91 MJ ha⁻¹, 15.7%). It was noted that applying fertilizer and pesticides did not significantly increase operational energy usage. The results indicate that fuel accounted for the majority of direct energy consumption (22.2%) and that fertilizer had the largest indirect energy consumption (7721.03 MJ ha⁻¹) (63.2 per cent). Human Labour, pesticides, seeds, and indirect energy for machinery use had marginal importance, contributing only 0.2, 0.6, 6.8, and 6.9 per cent respectively to the total energy consumption (12225.97 MJ ha⁻¹). It was also considered that one of the key aspects of mechanization was the indirect energy involved with the use of agricultural machines.

Bautista and Minowa (2010) conducted the study “Analysis of the Energy for Different Rice Production Systems in the Philippines” to measure and evaluate the energy of various Philippine rice growing systems using life cycle assessment (LCA). Human labor, machinery, animals, seeds, irrigation, fuel, fertilizer, and pesticides were different types of energy inputs. Energy outputs consisted of rice yield and husk. Nitrogen, fuel, and seeds made for around 80 per cent of the total energy inputs in all farming systems. Labour was the main source of energy for the production of rice. The study found that the usage of inputs including fertilizers, high-yielding rice varieties, pesticides, and farm technology increased the total energy input of rice production. These innovations were responsible to shorten the cultivation cycle and raised the prospect of greater yields but, it also raised overall production costs, which led to a worsen output-to-input ratio than the conventional method. The output-to-input ratio of the man/animal energy system was higher than that of the man/machine system. It was concluded that the most effective method for productive rice farming is direct sowing, along with mechanized operations and channel irrigation.

Khan *et al* (2010) studied and examines the energy consumption, energy input-output relationship, and benefit-cost ratio of wheat, rice, and barley crop production systems in Coleambally Irrigation Areas (CIA) and Murrumbidgee Irrigation Area (MIA) of New South Wales, Australia. The values of all energy inputs and output were converted to an energy form. Results revealed that chemical fertilizer consumed 47, 43, and 29 per cent of the total energy inputs on wheat, rice, and barley growing farms, respectively. Wheat, rice and barley consumed 3028, 6699 and 2175 kWh ha⁻¹ respectively. Similarly in water usage, wheat utilized 2852, rice 17754, and barley 856 m³ha⁻¹. The average energy output of wheat was 27874, rice 44885, and barley obtained 17865 kWh ha⁻¹. Wheat was the most energy-efficient crop compared to rice and barley, whereas barley achieved the highest water productivity. The cost of production on the wheat crop was A\$ 323, rice A\$ 896 and barley was A\$ 246 ha⁻¹. Rice growers obtained the highest return of A\$ 2088, as compared to these wheat and barley

growers, with A\$ 589 and 370 ha⁻¹. Therefore, the benefit-cost ratio was the highest on rice farms (3.33) as compared to wheat (2.82) and Barley (2.50).

Pishgar-Komleh *et al* (2011) carried out a study on energy requirement and the energy input-output relationship of rice production in the Guilan province of Iran. Using face-to-face questionnaire approach by 105 farmers. It showed that rice cultivation used 39333 MJ of total energy per ha, with fuel accounted for 46% of the total energy usage, followed by chemical fertilizer (36%) and seed (8%), and biocide (6%). The corresponding figures were 49 per cent, 51 per cent, 11 per cent, and 89 per cent, respectively, for direct, indirect, renewable, and non-renewable energy. The results showed that the energy productivity and energy consumption efficiency were 1.53 and 0.09 kg per MJ, respectively. The Cobb-Douglas production function was used to create the econometric model, and the findings demonstrated that fuel and machinery energy inputs greatly influenced the yield. According to the findings of the sensitivity analysis of the energy inputs, fuel had the highest Marginal Physical Productivity value (0.93), followed by equipment (0.23), biocide (0.17), and seed (0.15). It was further concluded that the total cost of production was \$3156 per hectare. The benefit-cost ratio was determined as 1.29 and the gross and net returns were 1642 and 940 dollars per hectare, respectively. Generally speaking, larger farms (those covering more than 1 hectare) had better management and performed better in terms of energy usage and economic output.

Agha Ali Khani *et al* (2013) conducted a case study in Mazandaran province, Iran for energy use patterns in rice production which was grown under both the traditional system (TS) and mechanized system (MS) in the year 2007-08. The cultivars of rice commonly grown in Iran were listed in three groups: native, high yield cultivars, and hybrid cultivars. It was concluded that on an average diesel fuel had the highest share within the total energy inputs, followed by chemical fertilizer in rice production in both TS and MS. Energy use efficiency was calculated as 1.72 in TS and 1.63 in MS. Total energy consumption in rice production were 71,092.26 MJ ha⁻¹ (TS) and 79,460.33 MJ/ha (MS). In general, there were no significant changes regarding the human labour and chemicals in both the systems.

Eskandari and Attar (2015) in a study on energy comparison of two rice cultivation systems i.e. DSR and transplanting cultivation system in Iran analyzed that the energy input of the two systems was significantly different in the use of diesel fuel, pesticide, electricity, irrigation, human labour, and total energy. Herbicide usage was higher in the direct seeding system than in the transplanting system, but other energy inputs (fuel, electricity, irrigation, and human labour) were found to be higher in the transplanting system and the energy output of the transplanting system was higher than that of the DSR. The study supported the adoption of a direct seeding rice cultivation system for it was more effective in reducing energy consumption along with appropriate management of inputs leading to increased

efficiency of the system. The study further suggested that farmers should be taught to reduce unnecessary energy consumption along with measures like an increase in farmers' knowledge about non-chemical weeds control; essential monitoring by agricultural experts for the use of machinery, fertilizers and other inputs by the farmers.

Kumar (2017) in a study on energy input use and its efficiency in Punjab indicated that the share of commercial energy inputs had increased from 64.66 per cent in 1970-71 to 94.21 per cent in 2012-13 and the energy consumption per hectare also increased by 558.09 per cent during this period. Among different inputs, fertilizers and agro-chemicals ranked first with the contribution of 43.03 per cent to the total energy pool during 2012-13. The, per hectare use of both commercial and non commercial energy use was more in paddy as compared to wheat. The use of commercial energy in wheat and both commercial and non commercial energy use in paddy was found to decrease while moving from a lower level to a higher level of efficiency. It was projected that there would be increase in the use of energy of 1.34 and 1.24 times during the period 2011-12 to 2031-32 in the direct commercial and non-commercial energy. The study found that a 20 per cent decrease in area under rice cultivation could reduce the energy needs to a great extent thus indicating a strong need to shift from present wheat-paddy cropping systems to a less energy-intensive cropping system.

Manohar *et al* (2017) in a study related to the economic comparison of direct seeded rice (DSR) and transplanted rice cultivation in the Tungabhadra Project command area of Karnataka analyzed the socio-economic profile of farmers, comparative cost of cultivation, cost of production, and cost and return structure of paddy and concluded that due to the continuous depletion of the water resources, increasing fuel charges and labour scarcity, there was an urgent need to popularize the DSR technology to conserve resources like water, fuel, and labour and to enhance the profitability of rice farmers. The study emphasized further research to develop high-yielding rice varieties with desirable traits, viz., vigorous growth, weeds suppressing ability, germinating ability under moisture stress, tolerance to micronutrient deficiency suitable for DSR under different agro-climatic conditions.

Soni *et al* (2018) conducted a study on energy use and efficiency in Paddy rice–Wheat (PW) and Paddy rice–Potato (PP) for middle-Indo Gangetic plains in India. The PW system was more energy efficient with an EUE of 6.87 ± 1.7 compared to 3.61 ± 0.58 for the PP system. Higher Energy Efficiency Ratio (EERM) (3.94 ± 1.30) and Specific Energy (4.39 ± 2.06) (SE) were reported for the PW system, compared to 2.62 ± 0.47 and 2.15 ± 0.35 respectively for the PP system. Fertilizer use accounted for the highest input energy consumption in both systems, accounting for 58% and 51% of the energy consumed in PW and PP systems respectively, followed by fuel, seeds, and electricity. The net income from the PP system (2295.7 ± 457.4 USD ha⁻¹yr⁻¹) was higher than that from the PW system (1555.4 ± 856.6 USD ha⁻¹ yr⁻¹). The higher return of the PP system was attributed to higher yield and

better market price for the potato produce. There were no significant differences reported for various energy and economic parameters within different farm sizes in the PP system. However, for the PW system, small farms were energy efficient while larger farms were economically efficient.

Elsoragaby *et al* (2019) carried out an analysis of energy use pattern and Green House Gases emission pattern of rice production in Malaysia considering the transplanting and broadcast seeding methods. It was noticed that both the compared fields using broadcasting techniques, fields using transplanting techniques had a mean total lower energy input (8.72 %), higher average machinery energy (6.25 %), lower seed energy (55.06 %) and higher output energy (23.01%). Fuel was the second-highest contributor after fertilizer, which supplied 62 per cent of the energy inputs in both transplanting and broadcasting methods. In the fields using the transplanting technique, the shares of direct and indirect energy were 19 and 81 per cent, respectively, while the corresponding figures in the fields using the broadcasting approach, were 17 and 83 per cent. While the proportion of renewable and non-renewable energy was 7 per cent and 93 per cent, respectively, in the fields using the transplanting technique, and 14 per cent and 86 per cent, respectively, in the fields using the broadcasting methodology. In both the methods, the harvesting process had the highest mechanization index level (0.99). The fertilisation and sowing procedures, however, had the least level of automation. The mean energy ratio for transplanting was 35.68% higher than for broadcasting (8.1 and 5.97). In the two cultivation techniques, fertilizer accounted for 44 per cent and 42 per cent, respectively of the total GHG emissions with the highest composition of nitrogen. Regression analysis revealed that human, magnesium, and seed energy had a substantial influence on raising the yield of transplanted rice while human, magnesium, and nitrogen energy had a substantial influence on increasing the production of rice planted using broadcast seeding in Malaysia.

Singh *et al* (2019) in a study for South-Western Punjab observed that on average, the energy input of $52.4 \pm 1.3 \text{ GJ ha}^{-1}$ produced total energy output of $259 \pm 4.7 \text{ GJ ha}^{-1}$, with energy productivity of 0.16 kg MJ^{-1} . The results further revealed that rice cultivation was energy efficient with an energy ratio of 5.0 ± 0.12 and a net energy gain of $206 \pm 4.5 \text{ GJ ha}^{-1}$. It was concluded that input energy for irrigation water and chemical fertilizers were the major energy syncs in rice cultivation and the distribution of human energy in rice cultivation revealed that field preparation and seedling transplanting were the major human energy chunk (86.2%), while human energy in fertilizer application, weed control, pest control measures, and crop harvesting comprised 13.8% of total human energy ($263 \pm 13 \text{ MJ ha}^{-1}$). The overwhelming significance of irrigation water, chemical fertilizers, and electricity consumption in determining the energy input in rice cultivation underpinned the opportunities for energy saving. Which together consumed more than 80 per cent of input energy in rice

cultivation. The study highlighted the scope of saving energy from electricity consumption and irrigation water use in rice cultivation. The study also highlighted the need to strengthen the extension efforts for the adoption of efficient water and nutrient management technologies.

Basavalingaiah *et al* (2020) in a comparative study for Puddled Transplanted Rice and DSR systems of Karnataka, observed excessive use of non-renewable energy inputs in case of PTR (92.4%) in comparison to that of DSR (60.3%) methods. The higher energy use efficiency (7.3), energy productivity (0.3 kg MJ⁻¹), and energy profitability (6.3) were mainly attributed to the large decrease in energy inputs under DSR. The study evaluated the energy consumption pattern and carbon sustainability of the PTR and DSR method in farmers' fields. It was highlighted the indiscriminate use of nitrogen fertilizers and irrigation water (39% of energy input) in the PTR method of rice cultivation. The mean energy input and output estimated for PTR were 35605 MJ/ha and 155776 MJ/ha and for DSR were 7823 and 53227 MJ/ha, respectively. The consumption of non-renewable energy was higher in PTR (92.4%) in comparison to the DSR system (60.3%). The study revealed the importance of the DSR method as a conservation tillage practice in reducing energy consumption, carbon input, and GHG emission in comparison to the PTR method.

Kosemani and Bamgboye (2020) conducted an energy input-output assessment for the crop production process in Nigeria. Efficient energy use helped to achieve an environmentally, economically, and socially viable crop production system. The average energy input for rice production in small, medium, and large farms were 14813, 14543, and 14067 MJ/ha, respectively, while the average yields obtainable were 6695, 7060, and 7364 kg/ha, respectively. Energy input in fertilizer application was the highest with 73.80, 75.11, and 76.90 per cent of the total energy input in a small, medium, and large farm, respectively. The net energy values were 82733, 88321, and 93226 MJ/ha, respectively. Energy ratios in small, medium, and large farms were 6.58, 7.07, and 7.62, respectively. Large farms had better energy efficiency due to better management of energy resources. It was reported that minimizing input energy through an increased level of mechanization would boost rice production in Nigeria.

Saber *et al* (2020) assessed exergo environmental aspects across different paddy production systems, including conventional (CS), low external input (LEI), and organic systems (OS) in Iran. Climate change, increasing energy demand, and fossil fuel constraints led to many plights regarding sustainable food and agricultural production. Primary data were collected from 213 paddy producers. Environmental life cycle damages were assessed by IMPACT 2002_h based on 1 ton of paddy yield as the functional unit and it was revealed that diesel fuel followed by nitrogen contributed most towards resource damage category of CS and LEI, while most values of OS belonged to diesel fuel followed by electricity. On-Farm

emissions claimed almost the largest share among the other impacts categories in the surveyed systems. The cumulative exergy demand (CExD) analysis indicated that non-renewable fossil fuel was the main energy consumer. In this regard, diesel fuel was the most substantial part of energy forms for all three systems reducing the total CExD. The economic analysis showed that the lowest LCC was associated with OS; accordingly, the highest net profit belonged to OS, followed by CS. Overall, it was further concluded that the advantage of the OS scenario was evident for long-term management and planning in different environmental-exergy-economic indices of production systems.

Yadav *et al* (2020) highlighted that no-till and mulching enhanced EUE and reduced the carbon footprint of a direct seeded upland rice production system. The triple threat of the energy and environmental crises, depleting natural resource bases, and diminishing farm profitability endangered the sustainability of existing agricultural production systems that are the main determinants of food security and human survival and stressed on the necessity to switch from "unsustainable production methods" to "cleaner production systems". To analyze the energy budget, CF, and economics of NT combined with bio-mulching for a cleaner upland rice production system, the current experiment was carried out for four consecutive years (2012–15). The experiment used four bio-mulches: rice straw mulch (RSM), gliricidiasepium mulch (GLM), cowpea (*Vigna unguiculata*) brown manuring mulch (BMM), and no mulch (NM) as a control. The two tillage procedures conventional tillage (CT) and no-till (NT) were used in the main plots and it was concluded that the adoption of NT increased EUE and the benefit-cost ratio compared to CT while reducing energy consumption by 48.50 per cent, specific energy by 49.63 per cent, CF by 16.48 per cent, and cultivation cost by 35 per cent. Additionally, it was shown that mulching, particularly the BMM, increased net returns, economic productivity, and the benefit-to-cost ratio compared to NM. According to the results, NT with BMM was an ecologically friendly production technique that may improve EUE while lowering the CF of direct-seeded upland rice farming in the Eastern Himalayas and other eco-regions across the world.

Ranguwal and Singh (2022) in a study analysed energy use patter and its efficiency in Paddy cultivation in Indian Punjab and stated that one of the requirements for sustainable agricultural output was the effective use of energy resources in agriculture. The energy-intensive rice production was to be blamed for a number of environmental issues in Punjab. The amount of energy used to cultivate paddy was 47014.69 MJ/ha, and the average energy usage was inversely correlated with farm size. Chemical fertilisers were the main source of energy (42%) and were followed by the use of power for irrigation (36.05%), machine energy (18%), diesel fuel (17%), human labour (1.36%), and FYM (1.11%). While the use of human and animal labour, seeds, and FYM varied adversely with farm size, the use of chemical, mechanical, and electrical energy varied favourably with farm size. The estimated net energy

gain per hectare was 0.175 million MJ. There was opportunity for improvement in energy productivity, as seen by the high Energy Intensity of 6.77 MJ/kg and the poor energy productivity index of 0.148 kg/MJ. Small farmers had the greatest Energy Use Efficiency (4.98). The usage of non-renewable energy and commercial energy was found to be extremely high, which might have long-term negative effects on the ecosystem and environment.

2.3 To study the different factors affecting the energy use efficiency of direct seeded rice Technology

Kaur and Kaur (2017) in a study on reasons for adoption and non-adoption of direct seeded rice in Punjab enlisted that a respondents adopted direct seeded rice for a variety of reasons, including the ability to save on labour costs, water use, and financial gain. Since direct seeding produced greater outcomes than transplanting, all of the respondents began the practice of direct seeding rice. Using random sampling technique, 15 farmers for DSR and 15 for transplanting were chosen from each village in each district. The findings showed that 98.67% of the respondents began DSR because it reduced the cost of transplanting and saved time spent on paddy nurseries. While 96% of respondents expressed interest in DSR and embraced the DSR technique, 97.33 per cent of respondents wanted to save water and cut labour costs. Respondents also wanted a simple process that didn't require any wriggling. 90% of those surveyed claimed that there was a high risk to the crop if DSR was not used. While 89.33% cited lack of access to DSR drills, 88% failure of direct seeded crops to germinate, and increased weedicide usage as reasons for non-adoption.

Kaur and Singh (2017) in a study on direct seeded rice: prospects, problems/ constraints and researchable issues in India highlighted different issues, such as a declining water table, a labour shortage during peak seasons, and worsening soil health, need the use of alternate establishment techniques to maintain both natural resource and rice yield. Due to its minimal input requirements, direct seeded rice (DSR), was becoming more and more common. It had some benefits, including reduced labour requirements, water requirements, early crop maturity, low production costs, improved soil physical conditions for succeeding crops, reduced methane emission, and greater options for being the best fit in various cropping systems. Comparative yields in DSR could be obtained by adopting various cultural practices viz., selection of suitable cultivars, proper sowing time, optimum seed rate, proper weed and water management. It was also stated that soil problems related to rice and following crops could be solved with direct seeding. There were several constraints associated with shift from PTR to DSR, such as high weed infestation, evolution of weedy rice, increase in soil borne pathogens (nematodes), nutrient disorders, poor crop establishment, lodging, incidence of blast, brown leaf spot etc. By overcoming these constraints DSR could prove to be a very promising, technically and economically feasible alternative to PTR.

Bandumula *et al* (2018) in a study of Punjab highlighted the aggregate effects at farm

level, economic effects, and other social impacts on the adoption of DSR in Punjab. It was revealed that the adoption of DSR on an average had reduced the cost of cultivation by about 29 per cent with the amount of Rs 14,615/- per hectare over the transplanting method. The study stated that these reduced costs were mainly due to the reduction in labour required for crop establishment with direct seeding. The study supported the promotion of DSR as a strategy to enhance the profitability of farmers and also as a water-saving technology in the face of depleting water resources for agriculture in general and rice in particular.

Bhullar *et al* (2018) conducted a study on Agronomic and Economic Impacts of Direct Seeded Rice in Punjab in 2013 and observed that farmers in the Indian Punjab region were pushed to develop an alternative to resource-intensive puddled transplanted rice because of a lack of labour, rising labour prices, and a diminishing ground water table (PTR). A thorough questionnaire was used in 2013 to conduct an effect analysis of this new technology among the farmers who had implemented DSR between 2009 and 2012 in 21 villages across three districts (Bathinda, Faridkot, Sri Muktsar Sahib) were selected. During the period more farmers embraced DSR; at this period, 11% of these farmers had entirely switched to DSR. In comparison to basmati rice, coarse rice saw a greater adoption rate, and farmers with medium and large landholdings exhibited the highest levels of adoption. DSR reduced costs by 14 person-days/ha and 18 to 20%. As compared to PTR, irrigation water. As opposed to PTR, DSR initially featured a 2 to 5% yield penalty. However, the yield penalty was over come within one to two years as farmers gained understanding of DSR, particularly in sowing and weed management strategies. Greater net returns were achieved because the productivity of the subsequent wheat crop was 5% higher when it was sequenced with DSR than with PTR. The overall net returns from the DSR Wheat system were INR 5050 to 8100/ha more than the PTR Wheat system. The survey findings agreed with the outcomes of experiments.

Singh and Grover (2018) examined in a study of Adoption and Impact Assessment of Direct Seeded Rice Technology in Sri Muktsar Sahib district of Punjab input use, cost effectiveness, and suggested measures for addressing the sustainability issues at farm level. Basmati DSR and non-basmati DSR input usage patterns showed savings of 56.27 and 51.23 per cent in human labour, respectively. Human labour was saved by 56.27 and 51.23 per cent, respectively. The study recommended simplifying the subsidies and enhancing the role of extension services in order to hasten the adoption of DSR. Given the high cost of seed drilling, custom hiring should be promoted through cooperative organisations and co-farmers.

Kamboj *et al* (2022) in a study on adoption status of direct seeded rice technology by the farmers of Punjab. The purpose of the study was to determined the adoption of DSR's practice. Primary data were collected from 210 randomly chosen farmers from three districts covering various agro-climatic zones of Punjab, through personal interviews method. According to the study, a small percentage of farmers had adopted DSR on 49.20 per cent of

the paddy-growing owned land. A little higher percentage of the chosen farmers had switched to the Tar-Wattar new DSR approach from the dry soil method. Only 18.52% of respondents had used the initial irrigation as advised by the Tar-Wattar method, whereas the majority (67.59%) had done so before the 21-day mark. 26.67% of farmers had chosen the best variety, PR126, and had followed the time of sowing. Fertilizers including zinc, iron, and sulphur had been used by fewer farmers to address micronutrient deficits. Although the average yield of other kinds and PR 126 were found to be very similar, adopter farmers saw larger net returns since DSR cultivation was less expensive than transplanted rice.

CHAPTER III

MATERIALS AND METHODS

This chapter presents the broad methodological framework of the present study by including place of work, period of study, data sources and statistical tools employed. The discussion is concentrated under different sub-heads as under;

3.1 Selection of study area/respondents

3.2 Collection of data

3.3 Analysis of data

3.1 Selection of study area/respondents

Locale of the study

The present study has been undertaken in the Punjab state during the agricultural year 2021-22 in order to meet the stated objectives.

Selection of districts, blocks and villages

Multi-stage random sampling technique was followed for the selection of the study sample. One district namely Sri Mukatsar Sahib having highest area under the DSR technology for paddy cultivation was identified through consultation with officials of the Punjab State Department of Agriculture at the first stage. Keeping in view the concentration of DSR technology, two blocks namely Gidderbaha and Mukatsar were selected at the second stage (Table 3.1). From each block, two villages with widespread adoption of DSR were selected at the third stage. From block Gidderbaha, Kauni and Doda villages were selected and from block Mukatsar, Bhullar and Thandewala villages were chosen for the study.

Table3.1: Sampling design

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) spreading over different farm size groups based on operational

holding i.e. small (5 acre or less), medium (5 to 15 acres) and large (more than 15 acres).

3.2 Collection of data

Construction of interview schedule

Keeping in mind the objectives of the study, a well-designed interview schedule was prepared for the collection of data from the respondents. Before data collection, pre-testing of the schedule was done among respondents in the Bhullar village of Sri Mukatsar Sahib district. The questions which were difficult to respond were simplified. Certain questions which emerged during the course of pre-testing and considered important were also included in the final schedule.

Data collection

The primary data pertaining to the two cultivation practices i.e. direct seeded rice (DSR) and puddled transplanted rice (PTR) were collected from the sample farmers for the agricultural year 2021-22 through personal interview method. The data on general information about the respondents i.e. age, education, farming experience, family size, operational holding, cropping pattern, sources of agricultural information, trainings related to DSR attended, adoption of practices recommended by Punjab Agricultural University (PAU), along with factors affecting DSR adoption, reasons for ploughing back of DSR area and farmers' perceptions regarding adoption and non-adoption of the DSR were obtained from them. Requisite information relevant to various inputs used in paddy cultivation such as seed, diesel fuel (consumed for various farm operations viz. seed bed preparation, inter-culture operations, harvesting, transport on farm etc.), fertilizers, farm yard manure (FYM), chemicals (insecticides, fungicides, herbicides), crop yield, total working hours of labour (men and women hours) as well as draught power used for different farm operations along with 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).

3.3 Analysis of data

A. Estimation of input energy expenditure

The data on inputs used in paddy cultivation and output (grain and straw) were converted to energy units using embodied energy equivalents for each input and output energy type, and expressed in Mega Joules (MJ) using specific energy coefficients taken from the Research Digest on Energy Requirement in Agriculture Sector, Department of Farm Power and Machinery, PAU (Singh and Singh, 2002) as shown in Table 3.2. Energy used in various field operations were calculated from time taken (h) by agri-machinery, human labour and animal labour; in terms of volume (litres) for diesel fuel and liquid plant protection chemicals (PPC); in terms of weight (kg) for seeds, fertilizers and granular PPCs and FYM.

Table 3.2: Energy coefficients used in energy calculation for paddy cultivation

Sr. No.	Energy source	Energy coefficient (MJ/unit)
1	Human labour (h)	
	Adult man	1.96
	Adult woman	1.57
2	Animal labour (h)	14.05
3	Fertilizer (kg)	
	N	60.6
	P ₂ O ₅	11.1
	K ₂ O	6.7
4	Farmyard manure (FYM) in kg	0.3
5	Chemicals (kg)	
	Granular chemicals (kg)	120
	Liquid chemicals (litre)	102
6	Machinery (h)	62.7
7	Diesel (litre)	56.31
8	Seed/Grain (kg)	14.57
9	Straw (kg)	12.5
10	Electricity (KWh)	11.93

Source: Singh and Singh, 2002

The information on capacity of the pumps owned by the farmer in terms of horse power (Hp) was collected from the respondents. Pump efficiency was assumed to be 40 per cent and the groundwater draft was estimated by using the following formula (Srivastva *et al* 2014);

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

Values for the total head for calculating the groundwater was taken from an earlier study by Garg *et al* 2012. The groundwater footprints for paddy (in m³/kg) were estimated by dividing total groundwater use with the crop yield. Similarly, water productivity (Rs/m³) was estimated by dividing value of output (grain) with the ground water use.

Calculation of energy from different inputs used in paddy cultivation

1. Human Energy

The human energy involved in paddy cultivation was calculated using the number of

workers (man and woman) involved in the operation per unit area, time spent (hours) in performing the operations and multiplying them by the energy conversion coefficient. The general expression used to calculate the human labour energy as an integral part of the total energy input is given in equation 1 (Elsoragaby *et al*2019).

$$HE = \frac{n * H * Ic}{A} \text{ --- (1)}$$

Where HE is human energy (MJ/acre), n is the number of workers (man and woman) engaged in the operation, H is the time spent in performing the operations (h), Ic is the energy conversion coefficient of the human worker (MJ/h) and A is the area under paddy cultivation (acres).

2. Animal Labour

The animal labour energy used as input in the farm field was calculated using the equation 2 i.e. with help of number of draught animals engaged in the operation, time spent in performing the operations (H), animal labour energy coefficient (Ic).

$$AE = \frac{n * H * Ic}{A} \text{ --- (2)}$$

3. Chemical Fertilizers Energy

The energy embodied in chemical fertilizers used was estimated based on the quantity of fertilizer used per unit area (kg/acre). The percentage of the basic elements of fertilizers composition i.e. nitrogen (N), phosphorus (P₂O₅) and potassium (K₂O) were multiplied by the respective energy conversion coefficient for the compound chemical fertilizer used. The general expression used to calculate the energy of fertilizer as an integral part of the total energy input for crop production is given in equation 3 (Muazu *et al* 2015).

$$FTE = \frac{FTq * \sum_{i=1}^n FTi * FTci}{A} \text{ --- (3)}$$

Where FTE is the input energy from the chemical fertilizer (MJ/acre), FTq is the fertilizer quantity used (kg), FT_i is the percentage composition of the ith element (N, P₂O₅ and K₂O), FT_{ci} is the energy conversion coefficient of the ith fertilizer element (MJ/kg) and A is the paddy area (acres).

4. Farmyard manure (FYM)

Energy derived from the FYM applied in the fields as input before sowing was figured out with the help of quantity used per unit area and the respective energy conversion coefficient for the FYM.

$$FYME = \frac{Fq * Fc}{A} \text{ --- (4)}$$

Where FYME is the input energy from Farmyard manure (MJ/acre), Fq is the FYM quantity used (kg), F_c is the energy conversion coefficient for the FYM and A is the cultivated area covered (acre).

5. Plant protection Chemicals (PPC)

The energy embodied in the PPC used was estimated by multiplying the quantity of chemical used per unit area with the respective energy conversion coefficient for the chemical. The general expression used for calculation is given in equation 5 (Muazu *et al* 2014).

$$CE = \frac{Pq * Pc}{A} \text{-----(5)}$$

Where CE is the energy of PP chemical (MJ/acre), Pq is the chemical quantity used (kg/litre), Pc is the energy conversion coefficient of the PPC (MJ/kg) and A is the cultivated area covered (acre).

6. Agri-Machinery

The input energy used in engaging agri-machinery was computed from the total weight, useful life, energy coefficient and time of operation. The conversion coefficients used to compute energy values for different agri-machinery were 87.63 MJ/kg for combine harvester and 93.61MJ/kg for tractor (Canakci *et al* 2005). Economic life of agri- machinery stated in the American Society of Agricultural and Biological Engineers (ASABE) standards were used in the estimation of agri-machinery energy expenditures. Data regarding average weights of different agri-machinery was collected and used to compute energy inputs from agri-machinery per unit area as explained in the following equation 6 (Singh *et al* 2019)

$$ME = \frac{W}{L*A} * C * T \text{----- (6)}$$

Where ME is agri-machinery input energy (MJ/acre), C is conversion factor for the machinery (MJ/kg), W is weight of machinery (kg), L is the useful life of the machinery (h), T is the working time (h) and A is the area under paddy (acres).

7. Fuel

Fuel energy per unit area is a function of quantity of fuel consumed by the machinery used to power engines in performing the various operations in paddy cultivation system multiplied by an energy conversion factor for the fuel. The general expression used to calculate the energy of the fuel as an integral part of the total energy input for paddy cultivation was calculated using the following equation 7 (Muazu *et al* 2014).

$$FE = \frac{f con * f c}{A} \text{-----(7)}$$

Where FE is the fuel input energy (MJ/acre), *f con* is quantity of the fuel consumed (litres), *fc* is the energy conversion coefficient of the fuel (MJ/litre) and A is the area under paddy cultivation (acres).

8. Seed

The energy embodied in the seeds used for paddy cultivation was estimated by multiplying the quantity of seed used per unit area with the energy conversion coefficient as

shown in equation 8 (Elsoragaby *et al* 2019).

$$SE = \frac{Sq * Sc}{A} \text{ --- (8)}$$

Where SE is the energy of paddy seed (MJ/acre), Sq is the seed quantity used (kg), Sc is the energy conversion coefficient of the seed and A is the cultivated area covered (acres).

9. Straw

Similarly, the energy embodied in the straw obtained from paddy production (STE) was estimated by multiplying the quantity of straw used per unit area with the energy conversion coefficient as shown in equation 9.

$$STE = \frac{STq * STc}{A} \text{ --- (9)}$$

Where STE is the energy of paddy straw (MJ/acre), STq is the seed quantity used (kg), STc is the energy conversion coefficient of the straw and A is the cultivated area covered (acres).

10. Total Energy Input

Further total input energy used in paddy cultivation per acre in both the cultivation systems (DSR and PTR) was determined as the summation of energy from all the inputs used (equation 10).

$$TEI = HE + AE + FTE + FYME + CE + ME + FE + SE + STE \text{ --- (10)}$$

Where TEI is the total energy input (MJ/acre) and HE, AE, FTE, FYME,CE,ME,FE,SE and STE was calculated using all the above mentioned 9 equations.

B. Energy Indices

Agriculture is not only a consumer of energy but also producer of energy in the form of energy output. To compare how efficiently paddy crop converts input energy into output energy following ratios were carried out (equations 11 to 14):

Energy Use Efficiency (EUE)

The energy use efficiency indicates how much energy was produced per unit of energy utilized, and it was determined as the ratio of output energy to input energy (Mobtaker *et al* 2010).

$$\text{Energy use efficiency} = \frac{\text{Energy output (MJ/acre)}}{\text{Energy input (MJ/acre)}} \text{ --- (11)}$$

Specific Energy or Energy Intensity

Specific energy indicates the amount of input energy used to produce a unit of crop yield (grain) and is determined as the ratio of total energy input to crop yield (Mobtaker *et al* 2010).

$$\text{Specific energy} = \frac{\text{Energy input (MJ/acre)}}{\text{Yield (kg /acre)}} \text{ --- (12)}$$

Net Energy

The net energy is defined as the difference between energy output and the total energy input. It was obtained by subtracting input energy from output energy.

$$\text{Net energy gain (MJ/acre)} = \text{Energy output (MJ/acre)} - \text{Energy input (MJ/acre)} \quad (13)$$

Energy Productivity

The energy productivity provides quantitative data on how much crop is obtained per unit of input energy. It was determined as the ratio of yield (kg/acre) to input energy (MJ/acre) (Mobtaker *et al* 2010).

$$\text{Energy productivity kg/MJ} = \frac{\text{Yield (kg/acre)}}{\text{Energy input MJ/acre}} \quad (14)$$

In order to achieve the stipulated objectives of the study, the data was analysed by using suitable statistical/econometric techniques. The data collected were presented in tabular form to facilitate easy comparison. Simple statistical tools like averages, ratios and percentages were computed to interpret the results properly. Average mean scores were calculated to study the constraints faced by the respondents in adopting the DSR technology.

Statistical tools used

Binary Logistic Regression Model

To study the factors affecting the adoption behavior of direct seeding of rice, the logit model was selected. The dependent binary variable for the logit model was $Y_i = 1$, if farmer i had adopted the direct seeded rice technology and 0, otherwise.

The probability of adoption (P) for a given set of values of variables can be expressed in the form of given logit model

$$\ln\left(\frac{P}{1-P}\right) = \beta_0 + \sum_{i=1}^n \beta_i X_i + \varepsilon$$

Where β_i s are logit coefficients for the n variables X_i s, β_0 is intercept and ε is the error term. In both types of variables sign of coefficient reveals the direction of change. The set of regressors, comprising personal and other variables influencing DSR technology adoption, used in the model are listed in the Table 3.3.2 given below.

Table 3.3 Different variables used in binary logistic regression model in the study

Dependent Variable	Description
Adoption Status (Y)	1 if the farmer adopts Direct Seeded Rice Technology: 0 otherwise
Independent Variables (X)	
Age	Age of respondent (Years)
Education	Educational Level of respondent (level)
Tractor HP	Capacity of the tractor in Horse power (HP)
Implements required for direct seeding of rice	Availability of implements (Yes/No)
Trainings related to DSR	Trainings attended by respondent (Yes/No)
Farm Size	Farm size of the respondents (acres)
Extension contacts	Extension contacts of Respondents (Number)
Source of irrigation	Particular Source of irrigation (Canal or Tubewell or Both)

The model used to analyze the factors affecting the adoption of direct seeding of rice technology thus became:

$$Y_i = \beta_0 + \beta_1 (\text{Age}_N) + \beta_2 (\text{Edu}_N) + \beta_3 (\text{Tractorhpcode}) + \beta_4 (\text{Implements}) + \beta_5 (\text{TrainingDSR}) + \beta_6 (\text{Farmsizecode}) + \beta_7 (\text{Extensioncontacts}) + \beta_8 (\text{Irrigation Source}) + \epsilon_i$$

Student's t-test

It is one of the most popular statistical techniques used to test whether mean difference between two groups is statistically significant. Null hypothesis states that both means are statistically equal, whereas alternative hypothesis states that both the means are statistically different. To examine the changing pattern of important variables for input use and energy consumption 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:

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

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.

Analysis of Variance (ANOVA)

It is statistical technique used to compare the means between three or more groups at same time to determine whether a relationship exists between them.

One-way ANOVA

The One-way ANOVA is extension of independent samples *t* test (In independent samples *t* test used to compare the means between two independent groups, whereas in one-way ANOVA, means are compared among three or more independent groups). In them test, one continuous dependent variable and one categorical independent variable are there. The test statistic for an ANOVA is denoted as *F*. In our study, one-way ANOVA was used to compare means for the three farm categories of DSR adoption.

Concepts used in the study:

DSR-adopters: In the study, this term refers to the respondent farmers who followed direct seeding of rice on more than 50 per cent of the paddy area cultivated.

DSR non-adopters: This term is used for the farmers who were following conventional puddle transplanting method of paddy cultivation only.

Variable cost (Rs)-It includes cost incurred on different inputs like seeds, chemical fertilizers, FYM, plant protection chemicals, labour (human and animal), plant protection chemicals, machinery charges or rents, electricity, expenses incurred on diesel fuel etc.

Hired human labour charges – labour wages paid to the labour hired as reported by the respondents. It may be mentioned here that for family labour used, imputed value of family labour use based on per hour actual wages paid to hired labour was used.

Irrigation charges -Though electricity for farm irrigation is provided free , average electricity charges of Rs 7 per unit was considered for the study. To calculate the cost for using a diesel engine and generator for irrigation, the following formula was used =

$$\text{Duration of use of diesel engine/generator(hours)} \times \text{Average diesel consumption (litre/h)} \times \text{Price of diesel (Rs./litre)}$$

Interest on variable cost- the interest on working capital was computed at the prevailing interest rate of nine per cent per annum and it was considered for six months period only since loan was short duration (crop loan) in nature.

Gross Returns- The returns from the main product (grain) were calculated by multiplying the price of main-product (Rs per quintals) by yield (Quintals per acre).

Returns over variable cost (ROVC) - It was calculated as difference between the gross returns and total variable cost

$$\text{Returns over variable cost} = \text{Gross returns} - \text{total variable cost}$$

CHAPTER-IV

RESULTS AND DISCUSSION

The continuous cultivation of paddy crop in the Punjab state disturbed the ecological balance of the environment. The concept of crop diversification is one of the alternative solutions for diverting the area from paddy to other less water consuming crops. But assured irrigation along with guaranteed marketing to some extent encourages the farmers towards paddy cultivation as a major *kharif* crop. The problem of ground water depletion has arisen due to continuous cultivation of water-guzzling paddy crop and is of major concern to the Punjab state. An alternative solution to the traditional puddled transplanted rice (PTR) is Direct Seeding of Rice (DSR) which is not only cost, input, energy and time saving but is also environment friendly (Jat *et al* 2022). Keeping this in view, the present study was carried out. This chapter highlights the results of the study which emerged after the analysis and interpretation of the data. The results have been presented under different sub sections for better understanding. Along with analytical view of the results, explanation for agreement or disagreements and references have been added at suitable places for authentication of the results presented in different sections. The results and discussion has been presented in the following order: -

- 4.1 Socio-personal profile of the respondent farmers. (includes age, education, family size, organization participation, farming experience, DSR trainings attended and source of agricultural information)
- 4.2 Land use pattern of sample farmers. (farm size, cropping pattern, initial and final DSR area, after ploughback, source of irrigation)
- 4.3 Comparative resource use and output pattern (farm category wise; DSR vs PTR)
- 4.4 Energy use pattern (farm category wise; DSR vs PTR)
- 4.5 Energy indices-Energy Use Efficiency, Direct/Indirect Energy, Renewable Energy, Net Energy (DSR vs PTR)
- 4.6 Comparative economic analysis of paddy cultivation (DSR vs PTR)
- 4.7 Savings of different inputs (physical and value terms; water use and productivity).
- 4.8 Adoption of recommended practices by PAU in DSR Cultivation.
- 4.9 Factors influencing adoption of DSR by the respondents.
- 4.10 Constraints/Perceptions regarding adoption and non-adoption of DSR.

4.1 Socio-personal profile of the respondent farmers

The socio-personal characteristics of the respondents such as age, family composition, level of education, farming experience etc. influences the decision-making and is thus considered as an important parameter of the agricultural production process. An overview of the socio-personal profile of the sampled farmers has been addressed in this

section under the following headings.

4.1.1 Age-wise distribution

The family member who is in charge of making critical decisions about family and income generation is referred to as the head of the household. Analysis of the data indicated that majority of household heads i.e., 55 (45.83%) were in the age group of 41-50 years, followed by 29 (24.17%) in the age category of 51-60 years Table (4.1.1). Further 23 respondents (19%) belonged to the age group 31-40 years. The proportion of relatively young (up to 30 years) and old (> 60 years) respondents in the total sample formed only 6.67 and 4.17 per cent of the sample, respectively i.e., most of the respondents in the total sample were in the age of productive age group.

The age-wise distribution of adopters and non-adopters of DSR indicated that the proportion of respondents falling in the age group of 41-50 years was the maximum i.e. about 49 per cent and 40 per cent respectively. Further those in age 51-60 years was about 26 and 20 per cent DSR adopters and non-adopters respectively. On the contrary, the per cent share of respondents in age group of more than 60 years was much higher for DSR non-adopters (7.5%) than the adopters (2.5%).

Table 4.1.1: Age wise distribution of the respondents in Punjab, 2021-22

Particulars	DSR-adopters		DSR non-adopters		Overall	
	Number	Per cent	Number	Per cent	Number	Per cent
Up to 30	5	6.25	3	7.50	8	6.67
31 – 40	13	16.25	10	25.00	23	19.17
41 -50	39	48.75	16	40.00	55	45.83
51 – 60	21	26.25	8	20.00	29	24.17
More than 60	2	2.50	3	7.50	5	4.17
Total	80	100.00	40	100.00	120	100.00

Thus, it can be inferred that the decision-making control for adoption of DSR technology in the research area declined with the age.

4.1.2 Literacy status of the sample respondents

The education level improves the learning skills which ultimately enhance the technical skill among farmers. The literacy status of the heads of the sampled households is listed in Table 4.1.2. It was found that about one-fourth i.e. 25 per cent of the respondents attained education up to secondary level. Like-wise, about 22 per cent of the respondents were educated up to primary level, another about 18 per cent were matriculates, about 16 per cent respondents studied up to middle level only. Only eight respondents (6.67%) had

achieved bachelor degree or higher. About 13 per cent of the total respondents were having no formal education i.e. they couldn't read and write.

Table 4.1.2: Distribution of the respondents according to literacy status, 2021-22

Education level	DSR-adopters		DSR non-adopters		Overall	
	Number	Per cent	Number	Per cent	Number	Per cent
Illiterate	9	11.25	6	15.00	15	12.50
Up to primary	17	21.25	9	22.50	26	21.67
Up to middle	13	16.25	6	15.00	19	15.83
Up to matric	14	17.50	8	20.00	22	18.33
Up to senior secondary	20	25.00	10	25.00	30	25.00
Graduation and above	7	8.75	1	2.50	8	6.67
Total	80	100.00	40	100.00	120	100.00

It is evident from the data that the literacy level of the DSR adopters was better than that of the non-adopters. The proportion of respondents having education up to graduation and above for DSR adopters was about 9 per cent in comparison to the non-adopters (2.50%). On the contrary, the proportion of illiterate respondents was higher among non-adopters (15.00%) as compared to adopters (11.25%) though the number of the respondents having education up to primary, middle, matric and secondary level differed marginally for the adopters and the non-adopters.

4.1.3 Family size

The size of the family is a crucial element in determining the family labour force on the farm. More than half of the respondents i.e. 55.83 per cent had medium sized families i.e. with five to seven members (Table 4.1.3).

Table 4.1.3: Distribution of respondents according to family size, 2021-22

Family Size (No of members)	DSR-adopters		DSR non-adopters		Overall	
	Number	Per cent	Number	Per cent	Number	Per cent
Up to 4	25	31.25	13	32.50	38	31.67
5 to 7	44	55.00	23	57.50	67	55.83
More than 7	11	13.75	4	10.00	15	12.50
Total	80	100.00	40	100.00	120	100.00

Hence, majority of the sample households had family with 5-7 members.

About 32 per cent of the respondents' families constituted of up to four members only, while remaining about 13 per cent had family of more than seven members. Almost

similar trend was observed in case of both the DSR adopters and the non-adopters. The proportion of sample respondents having family members up to 4, 5-7 and more than 7 were be 31.25, 55.00 and 13.75 per cent in case of adopters, while the corresponding figures were 32.50, 57.50 and 10.00 per cent in case of non-adopters, respectively.

4.1.4 Farming exposure

Farming exposure refers to the actual farm experience of the farmers. The distribution of sample farmers according to farm experience is given in Table 4.1.4. The highest number of the respondents (59), i.e. 49.17 per cent had farming experience of 21 to 30 years. Further, about 24 per cent had farm experience of more than 30 years followed by another 16 per cent farmers having farm experience between 11-20 years, while remaining about 11 per cent were having up to 10 years farming experience only. Hence, most of the respondent farming had sufficient farming exposure in terms of farming experience.

Table 4.1.4: Distribution of the respondents according to the farming experience, 2021-

22

Farming Experience (years)	DSR-adopters		DSR non-adopters		Overall	
	Number	Per cent	Number	Per cent	Number	Per cent
Up to 10	10	12.50	3	7.50	13	10.83
11to 20	9	11.25	10	25.00	19	15.83
21 to 30	43	53.75	16	40.00	59	49.17
More than 30	18	22.50	11	27.50	29	24.17
Total	80	100.00	40	100.00	120	100.00

The proportion of farmers having faming experience between 21-30 years was higher i.e. 53.75 per cent for the DSR adopters as compared to non-adopters (40.00 %). The proportion of sample farmers having farm experience up to 10 years, 11-20 years and more than 30 years worked out as 12.50, 11.25 and 22.50 per cent in case of adopters as against 7.50, 25.00 and 27.50 per cent in the case of non-adopters, respectively.

4.1.5 Extension contacts

Farmers who wish to keep abreast of new agricultural technology have access to multiple sources of information. The exposure of farmers in terms of new developments in agriculture sector could be very helpful in adopting new techniques and methods in the existing farming system like DSR. The approach of farmers to different sources for acquiring agricultural information has been studied in this section. It is evident from Table 4.1.5 that the adopters mostly followed institutional sources (such as State Department of Agriculture and Farmers Welfare (SDA), Krishi Vigyan Kendra (KVK) and Punjab Agricultural University

(PAU)) for acquiring agricultural information as against the non-adopters who were mostly dependent on their fellow farmers, neighbours and other sources like commission agents, private dealers and co-operative society. Maximum adopters i.e. about 31, 20 and 13 per cent approached the SDA, KVK and PAU for the agriculture related knowledge as against only about 8, and 5 each of the non-adopters, respectively. Majority DSR non-adopters i.e. 52.50 per cent relied on their relatives and friends against 28.75 per cent of the adopters for acquiring information related to agriculture. Like-wise, the proportion of sample farmers approaching neighbours, and commission agents was higher among non-adopters as compared to adopters.

Table 4.1.5: Source of agricultural information among adopters and non-adopters

(Multiple response)

Source	DSR-adopters		Non-adopters		Overall	
	Number	Per cent	Number	Per cent	Number	Per cent
State Department of Agriculture and Farmers Welfare	25	31.25	3	7.50	28	23.33
Krishi Vigyan Kendra (KVK)	16	20.00	2	5.00	18	15.00
Punjab Agricultural University (PAU)	10	12.50	2	5.00	12	10.00
Relative and Friends	23	28.75	21	52.50	44	36.67
Neighbours	15	18.75	9	22.50	24	20.00
Others (commission agents, private dealers, co-operative society)	23	28.75	26	65.00	49	40.83

Note: Percentages have been calculated from respective totals under each category

The analysis revealed that the access of adopters to instructional sources for acquiring agriculture knowledge was higher among DSR adopters as compared to non-institutional sources. In a similar study for Punjab, it was observed that the PAU/KVK/SDA was the primary source of agricultural information for DSR adopters in paddy (Vatta *et al* 2021).

4.1.6 Trainings related to DSR

Capacity building of farmers on account of direct seeded rice is an important determinant of adoption of DSR. Only five of the DSR non-adopter farmers (12.50%) had attended training or camp in the context of DSR, whereas in case of adopters, the proportion of farmers attending trainings related to DSR was about 21 per cent (Table 4.1.6). The intensity of DSR training among non-adopters was very low as compared to DSR adopters.

Table 4.1.6: Number of farmers attending training/camp of direct seeded rice (DSR)

Particulars	DSR-adopters		Non-adopters		Overall	
	Number	Per cent	Number	Per cent	Number	Per cent
Yes	17	21.25	5	12.50	22	18.33
No	63	78.75	35	87.50	98	81.67
Total	80	100.00	40	100.00	120	100.00

Hence, there is need for more extension in terms of trainings/camps to increase the adoption of DSR in the Punjab state.

4.1.7 Distribution of sample households according to source of DSR training

Trainings related to DSR is an important component for promoting DSR. The study revealed that the selected respondents were mainly acquiring the trainings related to DSR from three institutional agencies namely SDA, KVK and PAU as shown in Table 4.1.7 about 77 per cent respondents got trained after attending camps organized by the SDA, another 32 per cent followed KVKs and only four per cent came to PAU, Ludhiana to attend the trainings.

Table 4.1.7: Distribution of the respondents according to participation in trainings related to DSR, 2021-22

Trainer/Category	DSR-adopters*		DSR non-adopters		Overall*	
	Number	Per cent	Number	Per cent	Number	Per cent
State Department of Agriculture and Farmers Welfare	14	82.35	3	60.0	17	77.27
Krishi Vigyan Kendra (KVK)	5	29.41	2	40.0	7	31.82
Punjab Agricultural University (PAU)	1	5.88	-	-	1	4.55
Total	17	100.0	5	100.0	22	100.0

*Multiple response

Note: Percentages have been calculated from respective totals under each category

Among DSR adopters, again SDA was the most preferred by about 82 per cent of the DSR trainees followed by 29 per cent following KVKs and PAU (5.88%). Among five trainees (non-adopters of DSR) who got trained for DSR, again the most preferred source of training was the SDA (60.0%) followed by KVK (40%).

4.2 Land use pattern of sample farmers

Operational efficiency of a farm also depends upon the farm size which in turn increases the output of the farm in terms of farm production. In this regard, the land holding

pattern and season-wise cropping pattern of small, medium, and large farmers in the South-Western Punjab has been discussed in this section.

4.2.1 Farm size

Table 4.2.1 shows the size of operational land holdings of the sampled farmers. Farmers were categorised into three groups based on their operating holdings: small (5 acres or less), medium (5 to 15 acres), and large (15 acres or more). The average operational size of sample farms in the selected area was 19.13 acres and area owned and leased-in by the sample farmers was 16.19 and 3.74 acres on an average, which constituted about 81 and 19 per cent to the total operational area.

Table 4.2.1: Size of operational holding of selected farmers in Punjab, 2021-22

(Acres per farm)

Particulars	DSR-adopters		DSR non-adopters		Overall	
	Area	Per cent	Area	Per cent	Area	Per cent
Owned Land	17.38	81.87	13.79	79.62	16.19	81.21
Leased in land	3.85	18.13	3.53	20.38	3.74	18.79
Leased out land	-	-	-	-	-	-
Area operated	21.23	100.00	17.32	100.00	19.93	100.00

It was also observed that the average size of operational area was higher in case of DSR adopters (21.23 acres) as compared to non-adopters (17.32 acres). Of the total operational holding, the share of area owned and leased-in worked out to be 81.87 and 18.13 per cent in case of adopters, while the corresponding figures were 79.62 and 20.38 per cent in case of non-adopters.

4.2.2 Cropping pattern

The area under different crops being cultivated by the adopters and non-adopters in different crop seasons is given in Table 4.2.2. During Kharif season, paddy was the main crop occupying about 85 per cent of the total operational area followed by basmati (7.06%), cotton (4.59%), sugarcane (0.85%) and fodder (3.04%). During Rabi season, wheat only occupied about 96 per cent of the operational land followed by sugarcane (0.85%), other crops such as rapeseed and mustard and vegetables (0.3%) and fodder (2.86%).

For adopters, during the Kharif season, paddy occupied about 83 per cent of the gross cropped area (GCA) followed by basmati (6.46%), cotton (6.42%), sugarcane (1.18%) and fodder (2.6%). For DSR non-adopters also, among Kharif crops paddy was the main crop grown on about 87 per cent GCA followed by basmati (8.66%) and fodder (4.1%) and none of the farmers were reported to cultivate cotton. Among Rabi crops, the wheat crop was

cultivated on 95.57 per cent of the total operational area in case of adopters as against 97 per cent in case of non-adopters while other minor crops occupied about 0.28 and 0.29 per cent of GCA respectively. Summer moong was cultivated on an average area of 0.09 and 0.13 acres which constituted only 0.42 and 0.75 per cent share to the total operational area in case of adopters and non-adopters.

Table 4.2.2: Cropping Pattern followed by selected farmers in Punjab, 2021-22

(Acres per farm)

Season/Category	DSR-adopters		DSR non-adopters		Overall	
	Area	Per cent	Area	Per cent	Area	Per cent
<i>Kharif</i>						
Paddy	17.69*	83.34	15.11	87.24	16.83	84.46
Basmati	1.36	6.46	1.50	8.66	1.41	7.06
Fodder	0.55	2.60	0.71	4.10	0.60	3.04
Cotton	1.36	6.42	0.00	0.00	0.91	4.59
Sugarcane	0.25	1.18	0.00	0.00	0.17	0.85
Sub-total <i>Kharif</i> (A)	21.23	100.00	17.32	100.00	19.93	100.00
<i>Rabi</i>						
Wheat	20.29	95.57	16.8	97.00	19.13	95.99
Sugarcane	0.25	1.18	0.00	0.00	0.17	0.85
Fodder	0.63	2.97	0.47	2.71	0.57	2.86
Others (rapeseed and mustard, vegetables)	0.06	0.28	0.05	0.29	0.06	0.30
Sub-total <i>Rabi</i> (B)	21.23	100.00	17.32	100.00	19.93	100
<i>Zaid</i>						
Summer moong	0.09	0.42	0.13	0.75	0.10	0.50
Gross Cropped Area (GCA) (A+B)	42.46	100.00	34.64	100.00	39.86	100.00

*paddy area both under DSR and non-DSR method of cultivation

Note: Crop wise per cent area in *Kharif* and *Rabi* are from respective sub-totals

4.2.3 Source of irrigation

Analysis of data related to source of irrigation followed by the respondents indicated that use of both tubewell and canal was the major source of irrigation (87.5%) followed by only tubewell (11.67%) as shown in Table 4.2.3. Only one farmer was reported to use canal water for irrigation purpose.

Table 4.2.3: Distribution of sample households according to source of irrigation

Category	DSR-adopters		DSR non-adopters		Overall	
	Number	Per cent	Number	Per cent	Number	Per cent
Tubewell	2	2.50	12	30.00	14	11.67
Canal	0	0.00	1	2.50	1	0.83
Tubewell and canal	78	97.50	27	67.50	105	87.50
Total	80	100.00	40	100.00	120	100.00

Comparative analysis indicated that among the DSR adopters, about 98 per cent respondents followed both tubewell and canal and none used only canal water. Among non-adopters of DSR, about 68 per cent respondents used both tubewell and canal irrigation, while 30 per cent followed tubewell irrigation and only one respondent used canal water for irrigation. Farmers were using tractor-operated generator for irrigation purpose at the times of electricity power-cut or shortage in the study area.

4.2.4: Distribution of sample households on the basis of variety of paddy used cultivated

Analysis of data regarding use of paddy variety for cultivation revealed that about 69 per cent respondents used varieties recommended by the PAU only while one-fourth used only non-recommended varieties and about 6 per cent were using both kind of varieties (Table 4.2.4)

Table 4.2.4: Distribution of sample households on the basis of variety of paddy

Variety	DSR-adopters		Non-adopters		Overall	
	Number	Per cent	Number	Per cent	Number	Per cent
Only un-recommended	13	16.25	17	42.50	30	25.00
Only recommended*	63	78.75	20	50.00	83	69.17
Both	4	5.00	3	7.50	7	5.83
Total	80	100.00	40	100.00	120	100.00

*recommended by PAU

It was also observed that among the DSR adopters, the use of recommended varieties was as high as about 79 per cent which was only 50 per cent for the non-adopters. Only 16 per cent DSR adopters used unrecommended varieties and 5 per cent were using both kind of varieties. Among DSR non-adopters, about 43 per cent respondents were growing unrecommended paddy varieties and another eight per cent followed both kind of varieties for paddy cultivation.

4.2.5 Initial sowing and ploughing back of DSR

During the initial stage of crop establishment, on account of certain reasons, DSR adopters resort to plough back the DSR partially or entirely. The analysis of data revealed that about 14 per cent of the selected DSR respondents resorted to ploughing of their DSR and shifted to conventional PTR method of paddy cultivation (Table 4.2.5). It may be mentioned here that the farmers who ploughed back whole area under DSR were not included in the sample.

Table 4.2.5: Details of Plough back area by the respondents in Punjab, 2021-22

Category		Small		Medium		Large		Overall	
		No.	Area (acres)	No.	Area (acres)	No.	Area (acres)	No.	Area (acres)
DSR	Initial (A)	10	45.50	25	215.44	45	1083.00	80	1343.94
	ploughed back	1 (10.00)	2.00 (4.40)	4 (16.00)	17.94 (8.33)	6 (13.33)	31.00 (2.86)	11 (13.75)	50.94 (3.80)
	After plough back	10	43.50 (95.60) 4.35*	25	197.50 (91.67) 7.90*	45	1052.00 (97.14) 23.38*	80	1293.00 (96.20) 16.16*
Non-DSR		8	29.70	11	82.00	21	552.80	40	664.50

Note: Farmers who ploughed back whole DSR area under paddy were not included in the sample

Figures in parentheses indicate percentages to respective initial figures (A)

*area in acres per farm

It was also observed that the plough back area accounted for about four per cent (50.94 acres) of the initial area under the DSR. The total area under DSR ploughed back in case of small, medium and large farmers worked out to be 2.00, 17.94 and 31.00 acres which constituted about 4.40, 8.33 and 2.86 per cent to the initial area i.e. maximum proportion of plough back area was observed the medium farm category. After adjusting for the ploughed back area, the final area under DSR was 1293 acres and for the small, medium and large farm categories it was 43.50, 197.50 and 1052 acres respectively. Area under DSR was found to increase with the farm size as the area per farm for the large farmers was the maximum i.e. 23.38 acres followed by the medium i.e. 7.90 and small (4.35 acres/farm) farm category.

4.2.6 Reasons for ploughing back of DSR

Analysis of data relating to different reasons of ploughing back DSR by the respondents indicated that poor seed germination was the major reason as mentioned by about 45 per cent of the respondents (Table 4.2.6). Other reasons behind the plough back was poor crop establishment (36.37%), high weed infestation and rodent attacks (27.27%).

Table 4.2.6: Reasons of ploughing back of DSR by the respondents

(n=11)

Reasons	Number	Per centage
Poor germination	5	45.45
Poor crop establishment	4	36.37
High weed infestation and rodent attack	3	27.27
Heavy rain immediate after sowing	2	18.18
Pressure from relative and friends	1	9.09

Only two farmers i.e. 18.18 per cent of the respondents were forced to plough DSR area due to heavy rain immediately after sowing. One farmer ploughed the DSR field due to pressure generated by the relatives and friends related to poor performance of DSR in their villages.

4.3 Resource use pattern of direct seeded rice (DSR) to conventional puddled transplanted rice (PTR) by the respondents

On the basis of the existing resources among the sample respondents, the comparative assessment of input use pattern both in physical and value terms for the direct seeded rice (DSR) and conventional puddled transplanted rice (PTR) has been discussed in this section.

4.3.1 Farm category-wise input use pattern and output in paddy cultivation by DSR

The comparative assessment of resource use in paddy cultivation on different farm sizes under DSR method of cultivation is given in Table 4.3.1. Analysis of the data revealed that use of human labour (both man and women) worked out to be 101.03 hours per acre on an average, while the respective figures varied from 100.05 to 102.09 from small to large farms. Machine labour (use of machinery for various cultural operations comprising mainly land preparation, irrigation, harvesting and on farm post-harvest operations) ranged between 7.85 – 8.67 hours per acre and it was 8.3 hours per acre on an average. Thus, with farm size the use of human as well as machine labour increased. Consequently the diesel fuel used in prime movers and oil engines/generators for running pumps on small farms (39.80 litre per acre) was lesser than on large farms (46.00 litre per acre) with average figure being 42.75 litre per acre. On the contrary, the animal labour use for on farm transportation showed inverse relationship with the farm size. The use of animal labour was reported to vary between 0.40 hours on large to 1.11 hours per acre on small farms and average figure worked out to be 0.75 hours per acre. In a similar study for Punjab, it was observed that among different farm categories, the maximum value for mechanization index exists for the large farmers and that for marginal farmers in case of animal labour index (Kaur *et al* 2017).

Table 4.3.1: Input use pattern and output in paddy cultivation by DSR method among different farm size categories, 2021-22

(Per acre)

Sr. No.	Input/Farm category	Small	Medium	Large	Overall
1	Human Labour (h)	100.05	101.01	102.09	101.03
2	Animal Labour (h)	1.11	0.75	0.40	0.75
3	Machine Labour (h)	7.85	8.38	8.67	8.3
4	Diesel (litre)#	39.8	42.45	46	42.75
5	Seed (kg)	7.48	7.9	8.29	7.89
6	Fertilizers and micro nutrients				
A	Urea (kg)	143.0	141.0	147.5	143.80
B	Phosphatic (kg)	6.21	6.53	6.90	6.54
C	Muriate of Potash (kg)	5.62	6.30	6.50	6.14
D	Zinc (kg)	4.50	5.20	5.70	5.13
E	Iron Sulphate (kg)	4.90	5.90	6.66	5.82
F	Others (kg)##	2.50	3.20	3.60	3.18
G	FYM (Ton)	5.30	5.82	6.10	5.74
7	Plant Protection Chemicals				
A	Rodenticide (kg)	1.20	1.62	1.80	1.54
B	Insecticide (litre and kg)	2.30	2.60	3.20	2.70
C	Weedicide (litre)	2.80	3.30	3.55	3.21
8	Electricity for irrigation (KWh)	603.03	609.01	618.16	610.05
9	Total output				
	Grain (Qtl)	27.20	28.01	27.88	27.69
	Straw (Qtl)	36.72	37.81	37.63	37.38

Non-significant differences were observed among farm categories

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

##includes seed treatment chemicals and growth regulators

Seed rate is an important factor in optimizing the grain yield (Li *et al* 2020). In a study for Bangladesh, it was found that increasing seeding rate in DSR can suppress weed growth and reduce the grain yield losses from weed competition (Ahmed *et al* 2014). Thus, the crop establishment and germination of seed depends highly upon the seed rate. Seed rate was found to vary with the farm size. The results revealed that average seed rate was 7.89 kg for sowing one acre of paddy by DSR and it increased with the farm size. Seed rate was the

highest on large farms (8.29 kg /acre), followed by medium (7.90 kg/acre) and small farms (7.48 kg/acre). The average figures for the use of different chemical fertilizers and micro nutrients like urea, phosphatic fertilizers, muriate of potash, zinc, Iron sulphate and others (including seed treatment chemicals and growth regulators) were estimated to the tune of 143.80, 6.54, 6.14, 5.13, 5.82 and 3.18 kg per acre on an average and their use was found to increase with the farm size.

It was also observed that the dose of urea applied was higher for small farmers than the medium ones. Two reasons can be attributed to explain this pattern, lack of knowledge among farmers about the recommended package of practices and nutrient based subsidies on chemical fertilizers. High magnitude of subsidies for nitrogen fertilizer extended by the government indirectly encouraged the farmers to apply larger quantities of nitrogen fertilizer for paddy crop. Like-wise, the use of farm yard manure (FYM) was the highest on large farms (6.10 ton per acre) and the least on small farms (5.30 ton per acre) and this happened due to high availability of FYM from large livestock with the large farmers.

As regards the use of plant protection chemicals (PPC) is concerned, the average use of rodenticides, insecticides (both liquid and granular) and weedicides turned out to be 1.54 kg, 2.70 (litre and kg) and 3.21 litres per acre and their use was the highest by the large farm category. Similarly, the use of electricity for the irrigating one acre of DSR paddy turned out to be highest on large farms (618.16 KW) as compared to small (603.03 KW) and medium farms (609.01 KW) though it was freely available to all the farm categories. The pumping of irrigation water from deeper layers of underground water through submersible electric pumps and electric motors has led to the high electricity consumption in the state. Further, on account of free of cost supply of electric power to agricultural sector in Punjab state, farmers had no incentive in saving electricity. The output from paddy cultivation in terms of grain and straw production of paddy was to 27.69 and 37.38 quintals on an average.

The analysis revealed that the input use DSR paddy cultivation shared an increasing trend with the farm size except use of animal labour and statistically non-significant differences existed among the different farm categories. For resource use in terms of output, the average grain yield was 27.69 quintals (Qtls) per acre and it was the marginally higher for the medium farm category (28.01 Qtls per acre) while straw production was 37.81 Qtls per acre.

4.3.2 Comparative assessment of input use and output in paddy cultivation using DSR and PTR method

Results for comparative input use pattern and output of paddy cultivation under DSR and PTR method is given in Table 4.3.2. 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 about 13 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 4.3.2: Input use pattern and output from paddy cultivation using DSR and PTR method by the respondents, 2021-22

(Per acre)

Sr. No.	Input/Method	DSR	PTR	Mean difference	% change over TPR	t-value
1	Human Labour(h)	101.03	169.90	-68.87	-40.54**	129.34
2	Animal Labour(h)	0.75	1.00	-0.25	-25.00	0.375
3	Machine Labour(h)	8.3	9.50	-1.20	-12.63**	49.03
4	Diesel (litre)#	42.75	46.50	-3.75	-8.06**	18.24
5	Seed (kg)	7.89	5.30	2.59	48.87**	15.40
6	Fertilizers and micro nutrients					
A	Urea (kg)	143.80	170.62	-26.82	-15.72**	71.98
B	Phosphatic (kg)	6.54	6.80	-0.26	-3.82	0.480
C	Muriate of Potash (kg)	6.14	6.80	-0.66	-9.71	0.821
D	Zinc (kg)	5.13	6.50	-1.37	-21.08*	2.125
E	Iron Sulphate (kg)	5.82	4.60	1.22	26.52	1.351
F	Others (kg)##	3.18	2.70	0.48	17.78	1.121
G	FYM (Tonne)	5.74	5.90	-0.16	-2.71	0.752
7	Plant Protection Chemicals					
A	Rodenticide (kg)	1.54	0.50	1.04	208.00**	32.48
B	Insecticide (litre /kg)	2.70	2.23	0.47	21.08	1.658
C	Weedicide (litre)	3.21	1.20	2.01	167.50**	11.26
8	Electricity for irrigation (KWh)	610.05	725.40	-115.35	-15.90**	371.66
9	Total output					
A	Grain (kg)	2769.00	2801.30	-32.30	-1.15	1.34
B	Straw (kg)	3738.15	3781.76	-43.61	-1.15	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 free 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 different inputs was lower on DSR farms as compared to PTR farms except seed, PPC and micro-nutrients and 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 as revealed by the t-values.

4.4 Energy use in paddy cultivation for DSR and conventional PTR

The input-wise use of energy and the share of each input in total energy expenditure in the cultivation of paddy have been presented in this section. The results of study revealed that the farmers were using energy from nine different sources for paddy cultivation i.e. human, draught animals, machines, diesel fuel, seeds, fertilizers, farm yard manure (FYM), chemicals and electricity.

4.4.1 Farm category-wise energy use pattern in paddy cultivation by DSR method

The input wise energy use pattern in paddy cultivation by DSR method for different farm sizes is given in Table 4.4.1. The total energy expended for cultivating paddy was 21708.61 Mega Joules per acre (MJ/acre) and the total energy use was observed to vary with the farm size, being the highest i.e. about 22498.03 MJ/acre on large farms and the least i.e. 21109.05 MJ/acre on the small farms. Component wise analysis revealed that energy consumption with respect to human labour on an average was 198.02 MJ/acre which varied between 196–200 MJ/acre on the small to large farms respectively. Machine labour also ranged from 226.94–267.04 from small to large farms, respectively with average requirement of 233.96 MJ/acre. As a result of higher machine use on large farmers, the diesel fuel energy was the highest i.e. 2590 MJ/acre compared to small farms (2241 MJ/acre) and medium farms

(2390 MJ/acre) though it was 2407 MJ/acre on an average. Contrary to this, the energy requirements from draught animals varied from 5.62 to 15.45 MJ per acre on large to small farms respectively while average figure being 10.54 MJ per acre.

Table 4.4.1: Energy consumption pattern in paddy cultivation by DSR method among different farm size categories, 2021-22

(MJ Per acre)

Sr. No.	Input/Farm category	Small	Medium	Large	Overall
1	Human Labour	196	197.97	200.09	198.02
2	Animal Labour	15.45	10.53	5.62	10.54
3	Machine Labour	226.94	262.51	267.04	233.96
4	Diesel#	2241.13	2390.35	2590.26	2407.25
5	Seed	108.98	115.10	120.78	115.98
6	Fertilizers and micro nutrients				
A	Nitrogen	8598.17	8473.91	8863.23	8642.94
B	Phosphorus	68.82	71.48	76.59	72.59
C	Potassium	37.52	42.21	43.55	41.14
D	Zinc	94.05	108.68	119.13	107.22
E	Iron Sulphate	49	59	66.6	58.23
7	Others ##	25	32	36	31.80
8	FYM	1590	1746	1830	1722
9	Plant Protection Chemicals				
A	Rodenticide	144	194.4	216	185.98
B	Insecticide	234.6	265.2	326.4	275.44
C	Weedicide	285.6	336.6	362.1	327.62
10	Electricity	7193.79	7265.37	7374.64	7277.90
9	Total energy use	21109.05	21571.31	22498.03	21708.61
10	Total output energy	85884.00	88441.58	88094.25	87431.18
11	Energy Use Efficiency (EUE)	4.07	4.10	3.92	4.03

Non-significant differences were observed among farm categories for all input energies except human labour (F-ratio value for human labour was 2.66)

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

##includes seed treatment chemicals and growth regulators

Energy consumption with respect to seed was the highest on large farms (121 MJ

/acre), followed by medium (115 MJ/acre) and small farms (109 MJ/acre) and on an average 116 MJ/acre energy was derived from seed used for sowing one acre of paddy. Among the different chemical fertilizers, the energy use in the respect of Nitrogen (N), Phosphorus (P), Potash (K) contents available in the fertilizers used was 8643, 72.59 and 41.14 MJ/acre respectively and that from micro nutrients zinc, Iron sulphate and others (seed treatment chemicals and growth regulators) was estimated to the tune of 107.22, 58.23 and 31.80 MJ/acre on an average. Like-wise, the energy use with respect to FYM worked out to be highest on large farms (1830 MJ/acre) and least use on small farms (1590 MJ/acre).

The extent of input energy from PPC i.e. rodenticides, insecticides and weedicides turned out to be about 186, 275 and 328 MJ/acre on an average. The energy from the chemicals used was again found to increase with the farm size. Similarly, the energy use by electricity consumption came out to be highest on large farms (7375 MJ/acre) in comparison to medium (7265 MJ/acre) small (7194 MJ/acre) farms.

In terms of output, 87431.18 MJ of energy was obtained from the grain produced from each acre of paddy under DSR method. The total output energy was observed to increase with the farm size i.e. it was the highest (88094 MJ/acre) on large farms and the least i.e. 85884 MJ/acre on the small farms. The energy use efficiency (EUE) values indicated that medium farms with EUE of 4.10 were relatively more energy efficient as compared to small (4.07) and large farms (3.92). This happened due to higher grain yield on the marginal farms in comparison to other farm sizes. On an average EUE was 4.03 on the DSR farm. It may be mentioned here that non-significant differences were observed among farm categories for all input energies except human labour (F-ratio value for human labour was 2.66)

4.4.2 Comparative assessment of energy use pattern in paddy cultivation by DSR and PTR method

Comparative assessment of energy use with respect to different inputs used in paddy cultivated by DSR and PTR method is given in Table 4.4.2.

The results revealed that the total input energy use in paddy cultivation by conventional PTR method (21708.61 MJ/acre) was significantly higher by about 13 per cent than by DSR (24816.79 MJ/acre). Component wise analysis indicated that the share of human labour in the input energy was significantly higher in PTR (320.4 MJ/acre) by about 38 per cent than DSR (198.02 MJ/acre). Machine labour use was about 7 per cent higher in case of PTR (252.69 MJ/acre) than DSR adopters (233.96 MJ/acre) and similarly the diesel fuel use was 8 per cent higher for PTR (2618.4 MJ/acre) than DSR (2407.25 MJ/acre) and these differences were also significant statistically.

The input energy from animal labour was also marginally higher in case of PTR (14.05 MJ per acre) as compared to DSR (10.54 MJ/acre) though it was statistically non-significant. On the contrary, the energy use with respect to seed rate turned out to be higher

significantly in case of DSR (115.98 MJ/acre) as compared to PTR (77.91 MJ/acre).

Table 4.4.2: Energy consumption pattern in paddy cultivation by DSR and TPR method by the respondents, 2021-22

(MJ per acre)

Sr. No.	Input/Energy Use	Energy use		Mean difference	% change over PTR	t-stat
		DSR	PTR			
1	Human Labour	198.02 (0.91)	320.40 (1.29)	-122.38	-38.20	129.34**
2	Animal Labour	10.54 (0.05)	14.05 (0.06)	-3.51	-24.98	0.375
3	Machine Labour	233.96 (1.08)	252.69 (1.02)	-18.73	-7.41	49.03**
4	Diesel	2407.25 (11.09)	2618.40 (10.55)	-211.15	-8.06	18.24**
5	Seed	115.98 (0.53)	77.91 (0.31)	38.07	48.86	15.40**
6	Fertilizers and micro nutrients					
A	Nitrogen	8642.94 (39.81)	10339.57 (41.66)	-1696.63	-16.41	71.98**
B	Phosphorus	72.59 (0.33)	75.48 (0.30)	-2.89	-3.83	0.480
C	Potassium	41.14 (0.19)	45.56 (0.18)	-4.42	-9.70	0.821
D	Zinc	107.22 (0.49)	135.85 (0.55)	-28.63	-21.07	2.125*
E	Iron Sulphate	58.23 (0.27)	46.00 (0.19)	12.23	26.59	1.351
7	Others	31.80 (0.15)	27.00 (0.11)	4.80	17.78	1.121
8	FYM	1722 (7.93)	1800 (7.25)	-78	-4.33	0.752
9	Plant protection chemicals					
A	Rodenticide	185.98 (0.86)	60.00 (0.24)	125.98	209.97	32.48**
B	Insecticide	275.44 (1.27)	227.46 (0.92)	47.98	21.09	1.658
C	Weedicide	327.62 (1.51)	122.40 (0.49)	205.22	167.66	11.26*
10	Electricity	7277.90 (33.53)	8654.02 (34.87)	-1376.12	-15.90	371.66**
	Total energy use	21708.61 (100.0)	24816.79 (100.0)	-3108.18	-12.52	11.33**
	Total output energy	87431.18	88451.05	-1019.87	-1.15	1.64

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

Figures in the brackets indicate the per cent to total input energy use

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

##include seed treatment chemicals and growth regulators

The energy use with respect to chemical fertilizers in terms of Nitrogen (N), Phosphorus (P), Potash (K) contents as well as micro nutrients (zinc and Iron sulphate) was

lower for DSR and was estimated to the tune of about 8643, 73, 41, 107 and 58 MJ per acre as against the 10340, 75, 46, 136 and 46 MJ per acre in case of conventional PTR. It may be mentioned here that significant difference existed in use of N content and micro nutrient zinc only between the DSR and PTR. Like-wise, the energy use in case of FYM worked out to be higher on PTR farms (1800 MJ/acre) as compared to DSR (1722 MJ/acre) though it was non significant.

The input energy from different PPCs such as rodenticides, insecticides and weedicides turned out to be 186, 275 and 328 MJ/acre in case of DSR, while the respective figures were 60, 227 and 122 MJ per acre in case of PTR, respectively. The farmers were deriving about three times and 2.5 times significantly higher energy by use of rodenticides and weedicides for DSR than PTR. Also the energy from insecticide use about 21 per cent higher for DSR than PTR. The energy use from electricity used in irrigation turned out to be higher by 1376 KWh in case of PTR (8654MJ/acre) as compared to DSR (7278 MJ/acre).The result of independent t-test revealed that the mean difference of all major components of energy use such as human labour, machine labour, diesel consumption, seed rate, nitrogen, rodenticides, weedicides and electricity differed significantly for the DSR and PTR method of paddy cultivation. The energy consumption was significantly lower on DSR farms PTR farms by about 11 per cent.

The share of each input in total energy expended in the cultivation of paddy by DSR and PTR have been presented in Figure 1.

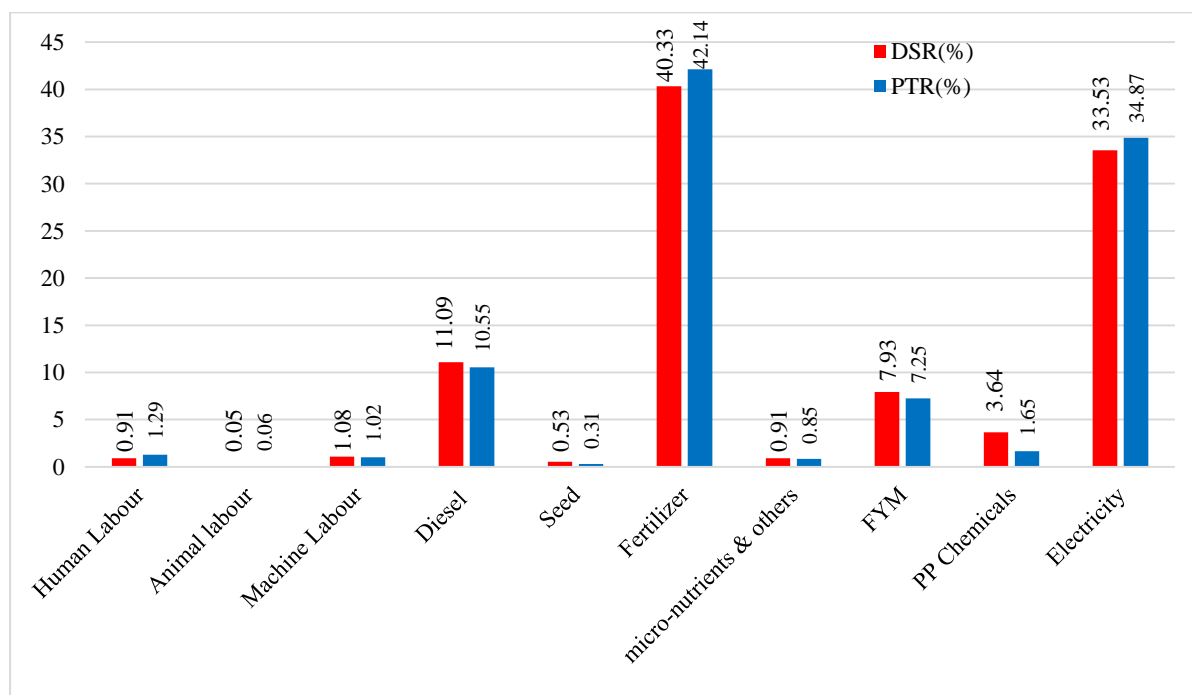


Figure1: Source of input energy in paddy cultivation by DSR and PTR

(Per cent share in input energy)

Among the different energy sources, chemical fertilizers were the dominant source of

energy contributing about 41 to 42 per cent of the total input energy (with maximum share being from nitrogenous fertilisers) utilized in paddy cultivation by DSR and PTR respectively. In a study for Bangladesh, inorganic fertilizers accounted for a major share (59.98%) of energy input in rice fields and among fertilizers, nitrogen category was the most dominant source (54.94%) of energy input (Rahman *et al* 2015). Further, electricity consumption for irrigation use also consumed a noteworthy share of 33 to 35 per cent in the total energy consumption in paddy cultivation for DSR and PTR respectively. A similar study in Karnataka also highlighted the indiscriminate use of nitrogen fertilizers and irrigation water accounting for about 36 per cent and 39 per cent of total energy input in the transplanted paddy (Basavalingaiah *et al* 2020). Another study on the rice production in India revealed that irrigation and fertilizers accounts for the largest share of total energy input (Chaudhary *et al* 2017). Further, diesel fuel formed about 11 to 10 per cent of the total input energy in case of DSR and PTR respectively. Plant protection (PP) chemical use contributed to as high as about 4 per cent of energy use in DSR as compared to only 2 per cent share in PTR. Agri-machinery energy used for various cultural operations of paddy cultivation and human labour contributed about one per cent each to the total input energy used though the share of human labour use was higher for the DSR. The results pointed out that input energy from fertilizers and electricity for irrigation was the major energy sinks in paddy cultivation. Thus, management of fertilizers (especially nitrogen) and electricity use for irrigation seemed to be the important areas for improving energy use efficiency. By using recommendations/need based fertilizers, and following DSR, the magnitude of energy use in paddy production can be reduced substantially which could translate into direct energy savings without compromising the productivity levels. Similar results were observed in a study for Iraq where the energy input of the two cultivation systems (DSR and PTR) was significantly different in the use of diesel fuel, pesticide, electricity, irrigation, human labour, and total input energy. The energy input of the DSR was lower than that of the PTR resulting in a higher EUE, which suggests that the DSR would increase energy efficiency and sustainability in rice production (Eskandari and Attar, 2015).

4.5 Comparative cost structure of input use for paddy cultivation by DSR and PTR method

In the present study, the cost structure of energy use refers to the actual cost of inputs being incurred by the farmers of producing one acre of paddy on the DSR and PTR farms and the results have been discussed in Table 4.5. The total variable cost positive for energy use in value terms turned out to be significantly lower by about 15.65 per cent on DSR farms (Rs 23344.06/acre) as compared to PTR farms (Rs 27677.33/acre).

Table 4.5: Cost of different inputs used in paddy cultivation by DSR and PTR method of cultivation in Punjab, 2021-22 (Rs/acre)

Sr. No.	Input/Method	DSR	PTR	Mean difference	% change over PTR	t-value
1	Human Labour	5354.82 (22.94)	9004.70 (32.53)	-3649.88	-40.53	129.34**
2	Animal Labour	262.50 (1.12)	350.00 (1.26)	-87.50	-25.00	0.375
3	Machine Labour [#]	3259.48 (13.96)	4106.20 (14.84)	-367.50	-9.87	49.03**
4	Combine Harvesting	1500.00 (6.43)	1500.00 (5.42)	0.00	0.00	-
5	Seed	681.20 (2.92)	394.50 (1.43)	417.69	105.88	15.40**
6	Fertilizers and micro nutrients					
a	Urea	852.76 (3.65)	1011.78 (3.66)	-159.02	-15.72	71.98**
b	Phosphatic	156.96 (0.67)	163.20 (0.59)	-6.24	-3.82	0.480
c	Muriate of Potash	128.94 (0.55)	142.80 (0.52)	-13.86	-9.71	0.821
d	Zinc	282.28 (1.21)	357.50 (1.29)	-75.22	-21.04	2.125*
e	Iron Sulphate	146.95 (0.63)	138.00 (0.50)	8.95	6.49	1.351
f	Others ^{##}	348.0 (1.49)	324.00 (1.17)	57.68	17.80	1.121
7	FYM (Tonne)	1148.30 (4.92)	1180.00 (4.26)	-31.7	-2.69	0.752
8	Plant Protection Chemicals	3946.27 (16.90)	2735.00 (9.88)	1211.27	44.29	28.23**
9	Electricity for irrigation	4270.35 (18.29)	5077.80 (18.35)	-807.45	-15.90	71.66**
10	Interest on variable cost @ 9 per cent p.a. for half the period of crop season	1005.25 (4.31)	1191.85 (4.31)	-186.6	-15.65	-
11	Total Variable Cost	23344.06 (100.00)	27677.33 (100.00)	-4333.27	-15.65	11.33**

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

Figures in the brackets indicate the percentage to total variable cost

[#] does not include diesel use for harvesting the crop and transport on farm

^{##} includes seed treatment chemicals and growth regulators

Comparison of different inputs used in DSR and PTR revealed that cost of labour use was higher by about 41 per cent in PTR than DSR. Further due to higher input energy derived from draught animals, machine use, chemical fertilizers (Urea, phosphatic, MOP), zinc, electricity for irrigation and FYM, the cost involved was also higher i.e., almost double for these inputs in case of PTR method of paddy cultivation with share being higher by about 25,10, 30 (16,4,10), 21,6 and 18 per cent than DSR. On the other hand, significantly higher seed cost was observed for seed in DSR because of higher seed rate and costly seed of short duration varieties used in comparison to long duration cheaper varieties used in PTR. Also DSR adopters were spending more by about 6 per cent on use of iron sulphate and 18 per cent on other chemicals though these differences were statistically non significant.

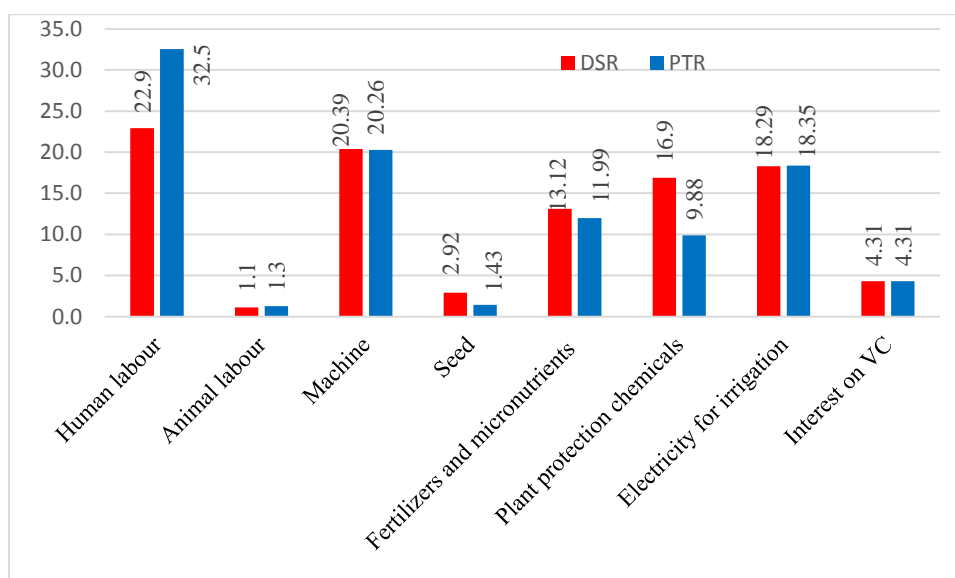


Figure 2: Cost of different inputs used in paddy cultivation by DSR and PTR method

(% share in total variable cost)

The shares of different inputs used in paddy cultivation by DSR and PTR methods have been shown in Figure 2. Out of the total variable cost spent to acquire input energy in paddy cultivation, the major share belonged to human labour i.e. about 23 per cent for DSR and about 33 per cent for PTR with higher human labour requirements. Machine labour used in all cultural practices as well as harvesting along with diesel fuel used accounted for about 20 per cent share in both the methods of cultivation. Further electricity used for irrigation consumed about 19 per cent of the TVC involved in paddy cultivation. The cost for fertilizers and micro nutrients was marginally higher in DSR (13%) than PTR (12%). Plant protection chemicals were costlier by about 7 per cent in DSR (16.9%) than PTR (9.88%). The share of seed cost was almost double for DSR (2.92%) than the PTR (1.43%).

4.6 Energy Indices

The comparative analysis of the energy use in paddy cultivation under DSR and PTR method has been assessed on the basis of various energy efficiency measures that are given in

the Table 4.6.

Table 4.6: Energy pattern in paddy cultivation on the selected farms in Punjab, 2021-22

Sr. No.	Item (Unit)/Method	DSR	PTR
1	Total Energy Input (MJ/Acre)	21708.61	24816.79
2	Total Energy Output (MJ/Acre)	87431.18	88451.05
3	Net Energy (MJ/Acre)	65722.57	63634.26
4	Energy Intensity (MJ/kg)	7.84	8.86
5	Energy Use Efficiency	4.03	3.56
6	Energy productivity (kg/MJ)	0.13	0.11

The comparative analysis of input and output energy in DSR and PTR cultivation indicated that both were on lower side on DSR farms as compared to PTR farms but the net energy gain for DSR was higher than the PTR. The respective estimates for input and output energy worked out to be about 21709 and 87431 MJ/acre on DSR farms as against the 24817 and 88451 MJ/acre on PTR farms while net energy gain was 65722.57MJ/acre against 63634.26MJ/acre, respectively. Higher EUE of 4.03 was observed in DSR paddy cultivation than PTR (3.56). In a study for Karnataka, EUE of 4.4 was for transplanted paddy while it was 7.3 under Direct Seeded Rice (DSR). The reason for higher EUE under DSR was mainly attributed to the significant decrease in energy inputs and the study also highlighted the scope for saving energy by 6 per cent in transplanting method (Basavalingaiah *et al* 2020). A study for Bangladesh, pointed towards the fact that increased energy input does not always lead to higher energy gains and thus it is necessary to practice environmentally sound management systems for sustainable rice production (Rahman *et al* 2015).

Like-wise, the level of energy intensity (7.84 MJ/kg) was lower in case of DSR as compared to PTR (8.86 MJ/Kg). Thus, the DSR farms were found to be relatively energy efficient than PTR farms in terms of EUE and energy productivity measures. High energy intensity of 8.86 MJ/kg was found with a low energy productivity index of 0.11 kg/MJ for PTR in comparison to DSR indicated that there is room for improving energy productivity of rice crop in traditional transplanting cultivation methods.

4.6.1 Extent of savings in use of different inputs in DSR in comparison to PTR method of paddy cultivation

In the above analysis, it is clear that the physical use of almost all the inputs was significantly lower in DSR as compared to PTR method of paddy cultivation. This section of the study highlights the physical units of inputs saved by adopting DSR in paddy cultivation in comparison to the PTR. It was observed that the DSR method saved the human labour by about 41 per cent as unlike PTR no human labour was required for transplanting paddy seedlings in DSR (Table 4.6.1).

Table 4.6.1: Extent of savings in physical use of different inputs in DSR method of paddy cultivation by the respondents, 2021-22

(Per acre)

Sr. No.	Particulars/Method	DSR	TPR	Savings in DSR (%)
1	Human labour (h)	101.03	169.90	40.54
2	Animal labour (h)	10.54	14.05	24.98
3	Machine labour (h)	8.30	9.50	12.63
4	Seed (kg)	7.89	5.30	-48.87
5	Fertilizers (kg)	156.48	184.22	15.06
6	Plant protection chemicals			
A	Rodenticide (kg)	1.54	0.50	-208.00
B	Insecticide (litre and kg)	2.70	2.23	-21.08
C	Weedicide (litre)	3.21	1.20	-167.50
7	Irrigation water use (m ³)	6365.74	7569.39	15.90

In the study area, farmers used tractor for land preparation, puddling as well as irrigation operations before transplanting rice seedlings in the PTR fields which was not so for the DSR. In PTR, water is required for raising rice seedlings in nurseries, puddling and transplanting operations. It also requires continuous submergence of water in the field. The DSR does not require raising seedlings in nursery, puddling, transplanting operations and continued water submergence. Hence, DSR reduces overall water requirement for paddy cultivation. Thus, the DSR method generated significant savings in the use of machine (12.63%), fertilizers (15.06%) and irrigation water (15.90 %) in comparison to PTR. Weeds infestation and rodent attacks was the major problem in DSR paddy cultivation which led to higher requirement of plant protection chemicals in DSR along with the higher seed rate.

Similar results have been cited in an earlier study where the use of human labour, machine labour and irrigation water were saved by 13.16, 41.34, and 11.88 per cent, respectively, in DSR as compared to the PTR method of rice production (Tripathi *et al* 2014).

4.6.2 Water productivity

The various estimates of water productivity are given in Table 4.6.2. The estimates of groundwater draft for paddy cultivation were estimated to the tune of about 6366 m³ per acre on DSR as against the 7569 m³ per acre in case of PTR method. As already mentioned that the crop yield obtained (in terms of rice) was marginally lower i.e. 1846 kg per acre in DSR than 1867.53 per acre in the 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. In our study it was found that on an average, production of one kilogram of rice required about 3448 litres groundwater and this figure was 4053 litres for PTR method. Hence, DSR reduces overall water requirement for rice cultivation. Due to substantially higher groundwater use, groundwater productivity (Rs per m³) of PTR (7.33) was also lower than DSR (8.61).

Table 4.6.2: Water productivity in paddy cultivation by DSR and TPR method of cultivation, 2021-22

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

Thus, paddy which is a dominant crop in the existing cropping pattern of the state is putting the groundwater resources in a jeopardy situation. Water for use in agriculture is becoming scarce and the problem of water shortage is expected to become more serious in the future. Further, due to drastic depletion of ground water table in rice-wheat areas, electricity demand is increasing for irrigating the paddy crop and it undermines the viability of the power sector as power for agricultural use is highly subsidized particularly in Punjab and Haryana. Under the prevailing conditions of electricity pricing and assured marketing of paddy which makes it the most remunerative kharif crop (Sarkar and Das 2014), the farmers may not move towards crop diversification but adoption of measures like DSR may help in reducing the pressure on depleting groundwater resources in the state.

Further, the savings of inputs by the DSR method of paddy cultivation in value terms has been assessed and the results are given in Table 4.7.2. DSR technology of paddy cultivation reduced the cost of human labour, machine labour, fertilizers, electricity for irrigation by 40.53, 15.10, 7.63, 15.90 per cent over the PTR method of paddy cultivation though, the DSR technology enhanced the cost of seed and plant protection measures by 72.67 and 44.29 per cent. The total VC involved in DSR was about 16% lower than the PTR.

Table 4.7: Extent of saving in Value terms in DSR and PTR methods of paddy cultivation by the respondents, 2021-22
(Rs per acre)

	Item/Method	DSR	PTR	Savings in DSR (%)
1	Human Labour	5354.82	9004.7	40.53
2	Animal Labour	262.50	350.00	25
3	Machine Labour	4759.48	5606.20	15.10
4	Seed	681.20	394.50	-72.67
5	Fertilizers, FYM and Micro nutrients	3064.19	3317.28	7.63
6	Plant protection chemicals	3946.27	2735.00	-44.29
7	Electricity for Irrigation	4270.35	5077.80	15.90
8	Overhead charges	1005.25	1191.85	15.66
9	Total variable cost (VC)	23344.06	27677.33	15.66

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 4.7.1.

Table 4.7.1: Economic benefits of DSR paddy cultivation, 2021-22

(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 though the yield in DSR (2769 kg per acre) was marginally lower than PTR (2801.3 kg per acre), 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.

Hence, the results of the present study indicated that DSR is an input saving as well as cost saving technology for paddy cultivation in comparison to traditional PTR method.

4.8 Adoption of recommended practices for DSR cultivation

Farmers' fields are intensively managed ecosystems (Singh and Benbi 2020), where farmers adopt varied crop production practices and make arrangements at their own level to solve the location specific problems (Singh *et al* 2019). The status of adoption of different agronomic practices recommended by the PAU for paddy cultivation using DSR method was also studied. As per recommendations, the field needs to be ploughed twice with a disc harrow followed by cultivation with cultivator and planking and laser levelling for seed bed and land preparation for sowing paddy. It was observed that among the DSR adopters, majority of the farmers i.e. 97.50 per cent followed this recommended practice for land preparation. Pre-sowing irrigation is applied after laser levelling and when the field reaches a satisfactory soil moisture state, it is cultivated and prepared, and paddy seeds are immediately sown. It was observed that all the farmers were apply the rauni irrigation though only 96% of them had sown the seed in tar-wattar condition. Further, it was also evident from the data that most of the farmers i.e. 91.25 per cent used recommended machinery i.e. lucky seed drill for sowing DSR and about 65 per cent of them used it on custom hiring basis. It might be due to

the reason that DSR drill was expensive to purchase and farmers preferred to hire it for sowing. Few farmers (8.75%) have made some modifications in the happy seeder and seed drills with them to directly sow the paddy crop. In a recent study for Punjab, it was found that about five per cent farmers had sown DSR after modifying implements like happy seeder, drills available with them (Kamboj *et al* 2022). It was also observed that the farmers had grown more than one variety at their DSR farms. About 90 per cent of the respondents had opted for the short duration and medium duration paddy varieties and among these about one-fourth had adopted most suitable variety PR-126 recommended by PAU for DSR. PR-126 is a short duration variety and advantageous for weed management. About 79 per cent of the DSR adopters had grown only recommended varieties of paddy, while 16.25 per cent had sown unrecommended ones and 5 per cent used both the recommended and un recommended varieties. Similarly, the proportion of the farmers following recommended date of sowing for DSR (1-15th June) and doing seed treatment worked out as 95.00 and 96.25 per cent, respectively.

Only about 48 per cent respondents were found to be using recommended quantity of seed (8 kg per acre), while rest were in practice of using lesser seed rate. The DSR adopters were found to be using much higher dose of urea than recommended by the PAU (130 kg per acre).

Table 4.8: Adoption of agronomic practices by the respondents using DSR

(n=80)

S.No.	Particulars	Recommended practice	Recommended/following
1	Land Preparation	Plough the field twice with disc harrow followed by cultivation with cultivator and planking and laser levelling	78 (97.5%)
2	Pre-sowing irrigation (Rauni)	Number of respondents	80(100.0%)
3	Variety of paddy	SD and MD	72(90.0%)
4	Sowing implements	Lucky seed drill	73 (91.25%)
5	Sowing method	Tarr-wattar condition	77(96.25%)
6	Sowing Time	1-15 June (16-30 June in PR 126)	76 (95.0%)
7	Seed Rate (kg/acre)	8	38 (47.5%)
8	Seed Treatment	Treated	77 (96.25%)
9	Fertilizer application		
A	Urea (kg/acre)	130	36 (45.0%)
B	Phosphorus	if recommended dose of phosphorus had been applied to the preceding wheat crop	12 (15.0%)
10	Irrigation		
	Scheduling of first irrigation in Tarr-wattar	21 days	58 (72.5%)
11	Harvesting	Ears are nearly ripened and straw has turned yellow	80 (100%)

Note : Figures in parentheses indicate percentages from total number of respondents

It may be mentioned here that in the Punjab state, the average N fertilization rate

(including both urea and DAP) was 36 per cent higher than the recommended dose of N for rice (PAU, 2017). Even after application of phosphorus in wheat, 15 per cent farmers were found to be applying phosphorus in paddy also. About 73 per cent respondents were found to be scheduling first irrigation after 21 days of sowing in tar-wattar conditions. It was also observed that all the farmers were using recommended practices in the context of harvesting of the paddy crop.

4.9 Factors affecting adoption of direct seeded rice by the respondents

The binomial regression analysis and marginal effects of different factors that influenced the adoption of DSR has been worked out and the results are presented in Table 4.9.1. Significance of regression coefficients shows the extent with which a variable contributes to the probability of adoption of DSR. The positive sign for an explanatory variable shows that when its value increases, it increases the probability of adoption of the DSR while the negative sign for an explanatory variable shows decline in the probability of adoption of the DSR. All the important variables that could influence the adoption level of DSR was included in the model, but only seven factors namely age, education, HP of tractor, availability of required implements, training related to DSR, farm size and number of extension contacts were found to significantly contributing towards the adoption of DSR by the respondents. Among these, only the age of the respondents an inverse relation with adoption of DSR technology i.e., the probability to follow DSR technology would decline with increase in age of the respondents.

The marginal effects of the explanatory variables on the choice of the adoption of DSR has also been presented in the table. It was found that with one per cent increase in age of the respondents, the likelihood of adoption for DSR declined by two per cent. However, with one per cent increase in all other explanatory variables such as education, tractor HP, availability of required implements, training of DSR, farm size and extension contacts, the adoption level of DSR technology would increase by 4.0, 4.0, 33, 20.0, 1.0 and 23 per cent among the sample farmers. Among these statistically significant factors for promoting adoption of the DSR, direct seeding implements, trainings related to DSR and extension contacts maintained by the farmers emerged as the most positively influencing variables as one per cent rise in the direct seeding implement, DSR trainings and extension contacts increased the adoption level by 33, 20 and 23 per cent respectively.

Table 4.9.1: Results of binomial regression and marginal effects for different factors influencing the adoption of DSR by the respondents, 2021-22

Variable	Coefficient	Standard Error	Marginal effects
Age	-0.13*	0.06	-0.02
Education	0.33*	0.11	0.04
Tractor HP	0.33*	0.16	0.04
Availability of required implements	2.49*	0.75	0.33
Trainings related to DSR	2.53*	1.20	0.20
Farm Size	0.08*	0.04	0.01
Extension contacts	1.76*	0.71	0.23
Intercept	0.025	0.013	

Note: *indicates $p < 0.05$

Pseudo R^2 : 0.6833

Log likelihood: -28.33

Hence, the study suggested that there is need to increase the availability of seeding equipments along with more trainings of the farmers for the speedy adoption of DSR and spread more awareness among the farmers by enhancing the extension contacts.

4.10 Perceptions of the respondents regarding adoption and non-adoption of DSR

Some genuine reasons and perceptions of the respondents for ‘adopting’ and ‘not adopting’ the DSR has been presented in Table 4.10.1. The major push factors behind the use of DSR for paddy cultivation included the burden of high transplanting cost for human labour used (Rs 3500-4000 per acre) mentioned by about 84 per cent respondents followed by other reasons like expert advice (65%), easy availability of required machinery/implement (61.25%), fear of labour shortage (28.75%), timely sowing of paddy crop (21.25%), savings of irrigation water (15%), encouragement generated after attending the trainings related to DSR (13.75%).

Table 4.10.1: Perceptions regarding adopting DSR method of cultivating paddy by the respondents, 2021-22 (n=80)

Reasons/Perceptions	Number	Per cent
High transplanting charges for the human labour	67	83.75
Followed expert advise	52	65.00
Easy availability of required machinery/implement for sowing	49	61.25
Fear of labour shortage	23	28.75
Timely sowing of paddy crop	17	21.25
Saving of irrigation water	12	15.00
Prompted by trainings related to DSR	11	13.75

(Multiple Response)

A similar study conducted by Vatta *et al* during the COVID epidemic period i.e. during 2020. found labour shortage as the major reason of adopting DSR during the year 2020. During the study period 2021-22, the farmers still had a fear of facing such labour shortage which prompted them to adopt DSR. Also, an enquiry was made regarding the reasons for non-adoption of DSR by the non- adopter respondents as shown in 4.10.2

Table 4.10.2: Perceptions for not adoption of DSR by the respondents, 2021-22

(n=40)

Perceptions	Number	Per cent
Easy availability of human labour	32	80.00
Lack of technical knowledge related to DSR	31	77.50
Diffidence in adopting DSR	29	72.50
Non-availability of required machinery/implements	22	55.00
High weed infestation and rodent attack	11	42.50
Experiences of fellow farmers	17	27.50

The results revealed that easy availability of labour for transplanting paddy emerged to be the major reason for not following the DSR by 80 per cent respondents. Other perceptions like lack of technical knowledge of DSR (77.5%), diffidence in adopting DSR (72.50%) and non-availability of required machinery/implements (55%) for sowing were the major reasons of not adopting the DSR. Other reasons such as high risk of weed infestation and rodent attack and experiences of fellow farmers were reported by about 28 and 43 per cent, respectively. In a study by Kaur and Singh, (2017) at Punjab Agricultural University Ludhiana several constraints associated with shift from PTR to DSR included, high weed infestation, evolution of weedy rice, increase in soil borne pathogens (nematodes), nutrient disorders, poor crop establishment, lodging, incidence of blast, brown leaf spot etc.

CHAPTER-V

SUMMARY

The problem of ground water depletion which has arisen due to continuous cultivation of water-guzzling paddy crop is of major concern to the Punjab state. Direct seeded rice (DSR) is one of the cost, input, energy and time saving and an environmentally friendly alternative solution to the traditional puddled transplanted rice (PTR) planting method. Keeping this in view, the present study was carried out with the following objectives:

1. To compare the resource-use pattern of direct seeded rice (DSR) to conventional puddled transplanted rice (PTR) in Punjab;
2. To measure the energy use efficiency of paddy cultivation for direct seeded rice and conventional puddled transplanted rice in Punjab;
3. To study the different factors affecting the energy use efficiency of direct seeded rice technology in Punjab.

Methodology

The present study was conducted in the Punjab state during the agricultural year 2021-22. Multi-stage sampling technique was followed to draw a representative sample for the study. One district namely Sri Mukatsar Sahib having maximum area under the DSR technology for paddy cultivation was selected at the first stage. Keeping in view the concentration of DSR technology, two blocks namely Gidderbaha and Mukatsar were selected at the second stage and from each block, two villages with widespread adoption of DSR were selected at the third stage. From block Gidderbaha, Kauni and Doda villages were selected and from block Mukatsar, Bhullar and Thandewala villages were chosen for the study. 20 DSR adopter farmers were chosen from each selected village and ten DSR non-adopter farmers from the same vicinity were also taken as a control group in the analysis. Thus, the total sample comprised of 120 farmers (80 adopters and 40 non-adopters) spreading over three different farm size groups based on operational holding i.e. small (5 acre or less), medium (5 to 15 acres) and large (more than 15 acres). Data were collected on structured pre-tested interview schedule by personally visiting the selected farmers.

The socio-personal characteristics such as age, education, farming experience, family size, cropping pattern followed etc. are expected to be the important determinants of adoption of the DSR by the respondents. Age-wise distribution of adopters and non-adopters of DSR indicated that the maximum proportion of respondents were in the age group of 41-50 years in both the categories but respondents with age more than 60 years formed about 8 per cent sample of the non-adopters in comparison to only 3 per cent for the DSR adopters. Highest number of the DSR adopters as well as non-adopters (25 % each) was educated upto senior secondary level only but those having completed graduation and above formed about 9 per

cent of DSR adopters in contrast to only about 3 per cent non-adopters. About 55 per cent respondents had medium family size of 5 to 7 members in both adopters and the non-adopters. About 54 per cent DSR adopters had 21 to 30 years of farming experience while about 40 per cent non-adopters belonged to this category. As regards extension contacts of the respondents, the DSR adopters mostly followed institutional sources (such as State Agriculture Department (SDA), Krishi Vigyan Kendra's (KVKs) and Punjab Agricultural University (PAU) for acquiring latest information related to agriculture as against the non-adopters. The DSR adopters approached SDA (31%) and KVK (20%) and PAU (12.5%) as against only 7.50 and 5.00 per cent each of the non-adopters to acquire new knowledge. On contrary, more than half of the non-adopters were relying on their friends and relatives, neighbours and other non-institutional sources. Further, it was observed that only 5 DSR non-adopters (12.50%) had attended any training or camp in the context of DSR, whereas, the proportion of DSR adopters attending these trainings formed about 21 per cent (17) of the sample. Compared to non-adopters (17.32 acres/farm), the total operational area was higher among DSR adopters (21.23 acres/farm). Data regarding plough back area under DSR indicated that 11 farmers (13.75% DSR adopters) ploughed back 50.94 acres which was about four per cent to the initial DSR area (1343.94 acres). Effective area under DSR was estimated to the tune of 1293 acres i.e 43.50, 197.50 and 1052 acres on small, medium and large farms, respectively. Poor seed germination (45.45%) and pitiable crop establishment (27.27%) were the main reasons of ploughing back the DSR followed by heavy rain immediately after sowing (18.18%). Data related to adoption of practices recommended by PAU revealed that most of the farmers followed the recommendation i.e. seed treatment (96.25%), recommended date of sowing (95%) and recommended machinery for sowing DSR (91.25%). Only 38 farmers used recommended seed rate of 8 kg per acre. None of the respondents were using recommended dose of urea though all farmers were using recommended practices in the context of irrigation schedule in tar-wattar and harvesting of the paddy crop.

The comparative assessment of resource use in paddy cultivation on different farm sizes under DSR method indicated that with farm size the use of different inputs increased though the differences were statistically non significant. Human as well as machine labour and consequently the diesel fuel used in prime movers and oil engines/generators for running pumps was the highest on the large farms. The average seed rate was 7.89 kg for sowing one acre of paddy by DSR and it also increased with the farm size. The use of different chemical fertilizers and micro nutrients was found to increase with the farm size. It was also observed that the dose of urea applied was higher for small farmers than the medium ones because of lack of knowledge among farmers about the recommended package of practices and nutrient based subsidies. The use of plant protection chemicals (PPC), electricity for irrigation water from deeper layers of underground water through submersible electric pumps and electric

motors was also directly related with the farm size. On the contrary, the animal labour use for on farm transportation declined with the farm size. The output from paddy cultivation in terms of grain and straw production of paddy reported to be 27.69 and 37.38 quintals on an average.

Results for comparative input use pattern of paddy cultivation under DSR and PTR method indicated that human labour use was found to be about 41 per cent higher for PTR (169.9 hours) than for DSR (101.03 hours) because of no need for transplanting the paddy seedlings in the latter. Machine labour use was also higher by 13 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 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 for self-confidence in their farming practices. Among the different fertilizers, the use of urea, Phosphatic fertilisers, Muriate of Potash, and micro nutrients 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 (3.21 litre) was observed for DSR than PTR (1.20 litre). Further, use of rodenticides to avoid rodent attack was three times higher in DSR (1.54 kg) than PTR (0.50 kg). Insecticide application was also higher in DSR (1.64) than PTR (1.33) though the difference was statistically non-significant. The use of free 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 28.01 and 37.82 quintal per acre on PTR farms, which was marginally higher than DSR but this difference was statistically non significant.

The input wise energy use pattern in paddy cultivation by DSR method for different farm sizes revealed that the total energy expended for producing paddy was 21708.61 Mega Joules per acre (MJ/acre) and the total energy use was the highest i.e. 22498.03 MJ/acre on large farms and the least i.e. 21109.05 MJ/acre on the small farms. Component wise analysis revealed that energy consumption with respect to human labour was 198.02 MJ per acre which varied between 196–200 MJ/acre on the small to large farms respectively. Machine labour also ranged from 226.94–267.04 from small to large farms, respectively with average requirement of 233.96 MJ/acre. As a result of higher machine use on large farmers, the diesel fuel energy was the highest i.e. 2590 MJ/acre compared to small farms (2241 MJ/acre) and medium farms (2390 MJ/farms) though energy from diesel consumption was 2407 MJ/acre on an average. Contrary to this, the energy requirements from draught animals varied from 5.62 to 15.45 MJ per acre on small to large farms respectively. Energy consumption with respect to seed was the highest on large farms (121 MJ /acre). Among the different chemical

fertilizers, the energy use in the respect of Nitrogen (N), Phosphorus (P), Potash (K) contents available in the fertilizers used was 8643, 72.59 and 41.14 MJ/acre respectively and that from micro nutrients zinc, Iron sulphate and others was estimated to the tune of 107.22, 58.23 and 31.80 MJ/acre on an average. The extent of energy consumed from the PPC used increased with the farm size. In terms of output, 87431.18 MJ of energy was obtained from the grain produced from each acre of paddy under DSR method and it was the highest (88094 MJ/acre) on large farms. The energy use efficiency (EUE) values indicated that medium farms with EUE of (4.10) were relatively more energy efficient as compared to small (4.07) and large farms (3.92) due to higher grain yield on the marginal farms. It may be mentioned here that non-significant differences were observed among farm categories for all input energies except human labour.

Comparative assessment of energy use with respect to different inputs in paddy under DSR and PTR method revealed that the total input energy use in paddy cultivation by conventional PTR method (24816.79 MJ/acre) was significantly higher by about 14 per cent than by DSR (21708.61 MJ/acre). Component wise analysis indicated that the share of human labour in the input energy was significantly higher in PTR by about 38 per cent than DSR. Machine labour use was about 7 per cent higher in case of PTR and similarly the diesel fuel use was 8 per cent higher for PTR. The input energy from animal labour was also marginally higher in case of PTR though it was statistically non significant. On the contrary, the energy use with respect to seed rate turned out to be higher significantly in case of DSR. The energy use with respect to chemical fertilizers as well as micro nutrients was lower for DSR with significant difference only in use of N content and micro nutrient zinc. The farmers were deriving about three times and 2.5 times significantly higher energy by use of rodenticides and weedicides for DSR than PTR. Also the energy from insecticide use was about 21 per cent higher for DSR than PTR. The energy use from electricity used in irrigation turned out to be higher by 1376 KWh in case of PTR (8654MJ/acre) as compared to DSR (7278 MJ/acre).

Among the different energy sources, chemical fertilizers were the dominant source of energy contributing about 41 to 42 per cent of the total energy (with maximum share being from nitrogenous fertilisers) utilized in paddy cultivation by DSR and PTR respectively. Further, electricity consumption for irrigation use also consumed a noteworthy share of 33 to 35 per cent for DSR and PTR respectively. Diesel fuel used formed about 11-10 per cent of the total input energy in case of DSR and PTR respectively. PPC use contributed to as high as about 4 per cent of energy use in DSR as compared to only 2 per cent share in PTR. Agri-machinery energy used for various cultural operations of paddy cultivation and human labour contributed about one per cent each to the total input energy used though the share of human labour use was higher for the DSR. The result of independent t-test revealed that the mean difference of all major components of energy use such as human labour, machine labour,

diesel consumption, seed rate, nitrogen, rodenticides, weedicides and electricity differed significantly for the DSR and PTR method of paddy cultivation. The energy consumption was significantly lower on DSR farms PTR farms by about 11 per cent.

The total variable cost for energy use in value terms turned out to be significantly lower by 16 per cent on DSR farms (Rs 23344.06 per acre) as compared to PTR farms (Rs 27677.33 per acre). Comparison of different inputs used in DSR and PTR revealed that cost of labour use was higher by about 41 per cent in PTR than DSR. Further due to higher input energy derived from draught animals, machine, chemical fertilizers (Urea, phosphatic, MoP), zinc, electricity for irrigation and FYM, the cost involved was also higher for these inputs in case of PTR method of paddy cultivation with share being higher by about 25,10,30 (16,4,10), 21, 16 and 3 per cent than DSR. On the other hand, significantly higher seed cost was observed for seed in DSR because of higher seed rate and costly seed of short duration varieties used in comparison to long duration cheaper varieties used in PTR. Also DSR adopters were spending more by about 7 per cent on use of iron sulphate and 18 per cent on other chemicals though these differences were statistically non significant.

Out of the total variable cost (TVC) spent to acquire input energy in paddy cultivation, the major share belonged to human labour i.e about 23 per cent for DSR and about 33 in PTR followed by machine use which accounted for about 14 per cent share in both the methods of cultivation. Further electricity used for irrigation consumed about 19 per cent of the TVC involved in paddy cultivation. The cost for fertilizers and micro nutrients was marginally higher in DSR (13.15) than PTR (12.01 %). Also, the money spent on PPC was higher in DSR than PTR by about 7.04 per cent.

The comparative analysis of input and output energy in DSR and PTR cultivation indicated that both were on lower side on DSR farms as compared to PTR farms but the net energy gain for DSR (65722.57 MJ/acre) was higher than the PTR (63634.26 MJ/acre). Higher EUE of 4.03 was obtained in DSR paddy cultivation than PTR (3.56). Like-wise, the level of energy intensity (7.84 MJ/kg) was lower in case of DSR as compared to PTR (8.86 MJ/Kg). Thus, the DSR farms were found to be relatively energy efficient than PTR farms in terms of EUE and energy productivity measures. High energy intensity of 8.86 MJ/kg with a low energy productivity index of 0.11 kg/MJ for PTR in comparison to DSR indicated that there is room for improving energy productivity of rice crop in traditional transplanting cultivation methods.

The analysis of savings generated by following DSR indicated that physical use of almost all the inputs was significantly lower on DSR as compared to PTR method of paddy cultivation. DSR method saved the human labour by 40.54 per cent and generated significant savings in the use of machine, fertilizers and irrigation water by 12.63, 15.06 and 15.90 per cent in comparison to PTR. The estimates of water productivity indicated that the

groundwater draft was estimated to the tune of about 6366 m³ per acre on DSR as against the 7569 m³ per acre in case of PTR. On an average, production of one kilogram of rice in required about 3448 litres groundwater and this figure was 4053 litres for PTR method. Due to substantially higher groundwater use, groundwater productivity (Rs per m³) of PTR (7.33) was also lower than DSR (8.61). The results revealed that though the yield in DSR (2769 kg per acre) was marginally lower than PTR (2801.3 kg per care), 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. Due to significant decline in total variable cost by about 16 per cent, the DSR enhanced the net income by about 13 per cent over PTR and the energy use and cost of producing one kg paddy declined by 11.50 and 14.67 per cent, respectively.

Analysis of factors affecting adoption of DSR using the binomial regression analysis indicated that major seven factors namely age, education, tractor HP, availability of required implements, training of DSR, farm size and extension contacts were contributing significantly towards the adoption of DSR. Only with one per cent increase in age, probability of DSR adoption declined by two per cent. Among other six statistically significant factors for promoting adoption of the DSR, the availability of direct seeding implements, extension contacts maintained by the farmers and trainings related to DSR attended by the respondents emerged were the most positively influencing variables as one per cent rise in the DSR trainings and extension contacts increased the DSR adoption level by 33, 23 and 20 per cent respectively. Hence, there is need to increase the availability of seeding equipments along with more capacity building through trainings of the farmers (especially youth) and spreading more awareness among the farmers by enhancing the extension contacts for speedy adoption of the DSR.

Data regarding perceptions of farmers for following DSR indicated that high transplanting cost for Human Labour, expert advice and non availability of required machinery/implement were the major hurdles in adopting DSR. On contrary, easily available of labour for transplanting paddy, lack of technical knowledge of DSR, diffidence in adopting DSR and non-availability of required machinery/implements were the major reasons of not adoption of DSR by the non-adopters.

The results indicated that DSR technology has the potential to increase farmer's income and save scarce resources. Though, the DSR technology is a viable alternative to overcome the problems of rising cost of cultivation, labour and water shortages for sustainable rice production yet it has not been adopted at a very large scale in the state. Following few suggestions may help in to accelerate the wider adoption of DSR technology:

- There is a need to generate more awareness of recommended DSR production practices among the farmers along with the benefits of such practices. Embracing of such 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.
- Further, approaches like appropriate field levelling (e.g. using a laser leveller), use of efficient irrigation systems, optimal time of sowing i.e. not following early sowing, optimal interval of irrigation to save water can prove to be effective solutions for reducing electricity and water energy consumption by increasing the water use productivity.
- Government initiatives like subsidizing the cost of direct seeding of rice per acre can help in its implementation by all the farmers and area under DSR may get extended. 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.
- There is a need for auxiliary research and development efforts in developing suitable agronomic practices, varieties and mechanized devices to overcome the problem of weeds. More research is needed to develop high yielding rice varieties with desirable traits, viz., vigorous growth, weeds suppressing ability, tolerance to micronutrient deficiency which are suitable for DSR.
- Developing literature on success stories in printed matter, audios and videos and distributing it through traditional and Information and Communication Technology tools will be beneficial in generating awareness regarding DSR. Study underlines the importance of extension interventions to disseminate DSR practices like efficient management practices for insects, pests, weeds and enhancement of grower skills through trainings for its speedy adoption at farmers' fields.
- There is a need to focus more on capacity building by educating/training the young farmers for promotion of DSR. A campaign with the combined efforts of various stakeholders such as government agencies and non-government organisations including these change agents will help in fast pacing the adoption process of DSR.

REFERENCES

- Aghaalikhani M, Kazemi-Poshtmasari H and Habibzadeh F (2013) Energy use pattern in rice production: A case study from Mazandaran province, Iran. *Energy Convers Mgmt* **69**: 157–62.
- Ahmed S, Salim M and Chauhan B S (2014) Effect of weed management and seed rate on crop growth under direct dry seeded rice systems in Bangladesh. *PLoS one* **9**(7): e101919.
- Alam M S, Alam MR and Islam KK(2005) Energy flow in agriculture: Bangladesh. *Amer J Environ Sci* **1**(3):213-20.
- Anonymous (2015) Price Policy for The Marketing Season 2015-16. Commission for Agricultural Costs and Prices Department of Agriculture and Cooperation Ministry of Agriculture Government of India New Delhi:1-183
- Bandumula N, Mahajan G Kumar R M (2018) Farm Level and Aggregate Economic Impact of Direct Seeded Rice in Punjab. *J Exptl Bio Agri Sci* **6**(1): 253-57.
- Basavalingaiah K, Ramesha Y M, Venkatesh P, Rajanna G A, Shankar LJ, Shiva D M, Kumar A, Girisha HC, Yogesh G S, Raveesha S, Roopa T K, Shashidhar K S, Kumar B, Ansary DOE and Elansary H O (2020) Energy Budgeting, Data Envelopment Analysis and Greenhouse Gas Emission from Rice Production System: A Case Study from Puddled Transplanted Rice and Direct-Seeded Rice System of Karnataka, India. *Sustainability* **12**: 6439-58.
- Bautista E G and Minowa T (2010) Analysis of the energy for different rice production systems analysis of the energy for different rice production systems in the Philippines. *Philippine Agril Sci* **93**(3): 55-65.
- Begum M, Juraimi A S, Amartalingam R, ManA B and Rastans S (2006) The effects of sowing depth and flooding on the emergence, survival, and growth of *Fimbristylis lismiliacea* (L.) Vahl. *Weed Biol Manage* **6**: 157-64.
- Bhullar M S, Singh S, Kumar S and Gill G (2018) Agronomic and economic impacts of direct seeded rice in Punjab. *Agril Res J* **55**(2): 236.
- Canakci M, Topakci M, Akinci I and Ozmerzi A (2005) Energy use pattern of some field crops and vegetable production: Case study for Antalya region, Turkey 2005. *Energy Convers Mgmt* **46**(4): 655-66.
- Chaichana T, Phethuayluk S, Tepnual T and Yaibok T (2014) Energy consumption analysis for SANGYOD rice production. *Energy Procedia* **52**: 126-30.
- Chaudhary V P, Singh K K, Gudapaty P, Bhattacharyya R, Shamim M, Srinivas I and Patel A (2017) Energy conservation and greenhouse gas mitigation under different production systems in rice cultivation. *Energy* **130**: 10.1016/j.energy.2017.04.131.
- Chauhan B S, Mahajan g, Sardana V, Timisina J and Jat M L (2012) Productivity and sustainability of the rice-wheat cropping system in the Indo-Gangetic plains of the Indian Subcontinent: Problems, Opportunities and Strategies. *Adv Agron* **117**: 315-69.
- Chauhan S (2012) District wise agriculture biomass resource assessment for power generation: A case Study from an Indian state, Punjab. *Biomass Bioener* **37**: 205-12.
- Elsoragaby S, Yahya A, Mahadi M R, Nawi N M and Mairghany M (2019) Analysis of energy use and greenhouse gas emissions (GHG) of transplanting and broadcast seeding wetland rice cultivation. *Energy* **189**.<https://doi.org/10.1016/j.energy.2019>.

- Eskandari H and Attar S (2015) Energy comparison of two rice cultivation systems. *Ren Sustain Energy Rev* **42**: 666-71.
- FAO (2000) The energy and agricultural nexus. *Environ. Nat Resour Work Paper* 4. FAO, Rome.
- Farooq M, Siddique K H M, Rehman H, Aziz T, Lee Dong-Jin and Wahid A (2011) Rice direct seeding: Experiences, challenges and opportunities. *Soil Till Res* **111**: 87-98.
- Freedman S M (1980) *Modifications of traditional rice production practices in the developing world: an energy efficiency analysis*. *Agroecosystems* **6**: 129-46.
- Gajaseni J (1995) Energy analysis of wetland rice systems in Thailand. *Ecosyst Environm* **52**:173-78.
- Garg S, Aggarwal R, Singla C and Kochhar V (2012). Estimating Pump Capacity and Power requirement at Farm Level. *Agric Eng* **36**(4):35-40.
- Gevao M B, S, Ishak bin Wan Ismail, W Yahya, A Chee Wan, C Bockari-Gevao, A Ishak, W and Sci S J (2005) Energy consumption in lowland rice-based cropping system. Songklanakarin. *J Sci Technol* **27**(4):819-26.
- Halim R A, Saikia H C and Bhowmick B C (1999) Pattern of Energy Use in Crop Production: A critical analysis in Golaghat district of Assam. *Agric Econ Res Rev* **12**(1): 1-6.
- Harazono Y, Kim J, Miyata A, Choi T, Yun J I and Kim J W (1998) Measurement of energy budget components during the International Rice Experiment (IREX) in Japan. *Hydrolog Proc* **12**:2081-92.
- Hatirli S A, Ozkan B and Fert C (2006) Energy inputs and crop yield relationship in greenhouse tomato production. *Renew Energy* **31**(4): 427-38.
- Iqbal T (2007) Energy input and output for production of Boro rice in Bangladesh. *Electr J Environ Agril Food Chem* **7**: 2717-22.
- Ishfaq M, Akbar N, Anjum S A and Anwar-Ijl-Haq M (2020) Growth, yield and water productivity of dry direct seeded rice and transplanted aromatic rice under different irrigation management regimes. *J Integra Agri* **19**(11): 2656-73.
- Jat R K, Meena V S, Kumar M, Jakkula V S, Reddy I R and Pandey A C (2022) Direct Seeded Rice: Strategies to Improve Crop Resilience and Food Security under Adverse Climatic Conditions. *Land* **11**(3): 55-65.
- Kamboj R, Singh D and Kaur L (2022) Adoption Status of Direct Seeded Rice Technology by the Farmers of Punjab. *Indian J Ext Educ* **58**(1): 76-80.
- Kaur J and Singh A (2017) Direct Seeded Rice: Prospects, Problems/Constraints and Researchable Issues in India. *CurrAgri Res J* **5**(1): 13-32.
- Kaur K and Kaur P (2017) Reasons for Adoption and Non-adoption of Direct Seeded Rice in Punjab. *Indian J Ext Educ* **53**(1): 157-59.
- Khan M A, Awan I U and Zafar J (2009) Energy requirement and economic analysis of rice production in western part of Pakistan. In *Soil Environ* **28**:1.
- Khan S, Khan M A and Latif N (2010) Energy Requirements and Economic Analysis of Wheat, Rice and Barley Production in Australia. *Soil Environ* **29**(1): 61-68.
- Kosemani B S and Bamgboye A I (2020) Energy input-output analysis of rice production in Nigeria. In *Energy* (207). Elsevier Ltd. <https://doi.org/10.1016/j.energy.2020.118258>

- Kumar A, Kumar S, Dahiya K, Kumar S and Kumar M (2015) Productivity and Economics of Direct Seeded Rice. *J App Natus Sci* **7**(1): 410-16.
- Kumar H (2017) Energy Input Usage and its Efficiency in Punjab Agriculture. Ph.D Thesis submitted to Punjab Agricultural University, Ludhiana, Punjab.
- Kumar H, Kaur A and Bhangu P K S (2020) Analysis of energy use efficiency in Punjab agriculture. *Economic Affairs* **1**: 97-105.
- Kumar N, Nath C P, Hazra K K, Das K, Venkatesh M S, Singh M K, Singh S S, Praharaj C S and Singh N P (2019) Impact of zero-till residue management and crop diversification with legumes on soil aggregation and carbon sequestration. *Soil Till Res* **189**:158-67.
- Kumar R and Batra S C (2017) Economic and Constraint Analysis of Rice Cultivation by DSR Technology in Karnal District of Haryana. *Adv Econ Bus Mgmt* **4**(2): 61-64.
- Li X, Dou F, Watkins K B, Wang S, Chen K, Zhou X G, Clung A M, Storlien J O and Hons F M (2020) Seeding rate effects on organic rice growth, yield, and economic returns *First Published* **112**: 5.
- Manohar Y, Nirmala B and Suhasini K (2017) Economic comparison of direct seeded rice and transplanted rice cultivation in TBP command area of Karnataka. *Agri Update* **12**(6): 1705-09.
- Mishra P, Singh U, Pandey C, Mishra P and Pandey G (2019) Application of student's t-test, analysis of variance, and covariance. *Annals Cardiac Anaesthesia* **22**(4): 407.
- Mobtaker H G, Keyhani A, Mohammadi A, Rafiee S and Akram A (2010) Sensitivity analysis of energy inputs for barley production in Hamedan Province of Iran. *Agri Ecosyst Environ* **137**(3-4): 367-72.
- Muazu A, Yahya A, Ishak W I W and Khairunniza-Bejo S (2014) Yield prediction modeling using data envelopment analysis methodology for direct seeding, wetland paddy cultivation. *Agri Agril Sci Procedia* **2**: 181-90.
- Muazu A, Yahya A, Ishak W I W and Khairunniza-Bejo S (2015) Energy audit for sustainable wetland paddy cultivation in Malaysia. *Energy* **87**: 182-91.
- Nassiri S M and Singh S (2009) Study on energy use efficiency for paddy crop using data envelopment analysis (DEA) technique. *Appl Energy* **86**(7-8): 1320-25.
- PAU (2022) *Package of Practices for Cultivation of Khairf Crops*, Punjab Agricultural University (PAU), Ludhiana: 1-21.
- Pervanchon F, Bockstaller C and Girardinc P (2002) Assessment of energy use in arable farming systems by means of an agro-ecological indicator: the energy indicator. *Agri Syst* **72**: 149-72.
- Pimentel D, Stachow U, Takacs D A, Brubaker H W, Dumas A R, Meaney J J, O'neil J A S, Onsi D E and Corzilius D B (1992) Conserving Biological Diversity in Agricultural/Forestry Systems. In *Source: Bio Sci* **42**: 5.
- Piringer G (2006) Re-evaluation of energy use in wheat production in the Unites States. *J Ind Ecol* **10**(1-2): 149-67.
- Pishgar-Komleh S H, Sefeedpari P and Rafiee S (2011) Energy and economic analysis of rice production under different farm levels in Guilan province of Iran. *Energy* **36**(10): 5824-31.
- Rahman M, Halder M, Hassan N and Haque F (2015) Energy input-output analysis of rice

- cultivation in the coastal region of Bangladesh. *Songklanakarin J Sci Techno* **37**(4): 455-64.
- Ranguwal S and Singh J (2022) Energy Use Pattern and its Efficiency in Paddy Cultivation in Indian Punjab. *Indian J Ecol* **3**: 372-78.
- Saber Z, Esmaeili M, Pirdashti H, Motevali A and Nabavi-Pelesaraei A (2020) Exergo environmental-Life cycle cost analysis for conventional, low external input and organic systems of rice paddy production. *J Cleaner Prod* **263**(12): 15-29.
- Samarpitha A, Vasudev N and Suhasini K (2016) Technical, economic and allocative efficiencies of rice farms in Nalgonda district of Telangana state. *Econ Affairs* **61**(3): 365.
- Sarkar A and Das A (2014) Groundwater irrigation - electricity - crop diversification nexus in Punjab: trends, turning points and policy initiatives. *Econ Pol Weekly* **49**(52): 64-73.
- Sidana B K, Singh J M, Kumar H, Singh J and Sachdeva J (2020) Comparative economics of direct seeded rice technology and transplanted rice in Punjab. *J Pharm Phyto SP* **6**:35-41.
- Singh A and Basak P (2019) Economic and environmental evaluation of rice straw processing technologies for energy generation: A case study of Punjab, India. *J Cleaner Produc* **212**: 343-52.
- Singh A and Grover D K (2018) Adoption and impact assessment of direct seeded rice technology in Sri Muktsar Sahib District of Punjab. *Indian J Econ Dev* **14**(3): 439-47.
- Singh P, Singh G and Sodhi G P (2019) Energy auditing and optimization approach for improving energy efficiency of rice cultivation in South-western Punjab, India. *Energy* **174**: 269-79.
- Singh P, Singh G and Sodhi G P S (2019) Energy auditing and optimization approach for improving energy efficiency of rice cultivation in south-western Punjab. *Energy* **174**: 169-79.
- Singh P, Singh G and Sodhi G P S (2020) Energy and carbon footprints of wheat establishment following different rice residue management strategies vis-à-vis conventional tillage coupled with rice residue burning in north-western India. *Energy* **200**(11): 54-75.
- Singh S and Singh J (2002) *Research digest on energy requirement in agriculture sector*, Department of Farm Power and Machinery, Punjab Agricultural University, Ludhiana **29**: 1- 263.
- Singh, P and Benbi DK (2020) Nutrient management impacts on net ecosystem carbon budget and energy flow nexus in intensively cultivated cropland ecosystems of north-western India. *Paddy Water Environ* **18**(4): 697-715.
- Soni P, Sinha R and Perret S R (2018) Energy use and efficiency in selected rice-based cropping systems of the Middle-Indo Gangetic Plains in India. *Energy Reports* **4**: 554-64.
- Srivastava S, Chand R, Raju S, Jain R, Sachdeva J, Singh J and Pal Kaur A 2014. Unsustainable Groundwater Use in Punjab Agriculture: Insights from Cost of Cultivation Survey. In *J Agri Econ* **70**(3): 365-78.
- Tripathi RS, Raju R and Thimmappa K (2014) Economics of direct seeded and transplanted methods of rice production in Haryana. *Oryza* **51**(1): 70-73.
- Vatta K, Singh J, Kaur P, Bhardwaj S and Singh K (2021) Appraisal of Direct Seeding of

Rice in Kharif 2020. Department of Economics and Sociology, Punjab Agricultural University Ludhiana : 1-47.

- Wang X, Lv W, Guo L, Zhai M, Dong P and Qi G (2016) Energy and exergy analysis of rice husk high-temperature pyrolysis. *Int J Hydrogen Energy* **41**(46): 21121-30.
- Wang Z, Khan S, Sun M, Ren A, Lin W, Ding P, Ding P, Noor H, Yu S, Feng Y, Wang Q and Gao Z (2021) Optimizing the Wheat Seeding Rate for Wide-Space Sowing to Improve Yield and Water and Nitrogen Utilization. *Int J Plant Produc* **15**(4): 553-62.
- Yadav G S, Babu S, Das A, Mohapatra K P, Singh R, Avasthe R K and Roy S (2020) No-till and mulching enhance energy use efficiency and reduce carbon footprint of a direct-seeded upland rice production system. *J Cleaner Prod* **271**(12): 27-45.
- Yadav S N, Chandra R, Khura T K and Chauhan N S (2013) Energy input-output analysis and mechanization status for cultivation of rice and maize crops in Sikkim **15**: 3. <http://www.cigrjournal.org>
- Yousefi M and Mohammadi A (2011) Economical analysis and energy use efficiency in alfalfa production systems in Iran. *Sci Res Essays* **6**(11): 2332-36.
- Yuan S and Peng S (2017) Input-output energy analysis of rice production in different crop management practices in central China. *Energy* **141**(11): 24-32.

APPENDIX-I

Table 1: Trends of area, production and yield of paddy in Punjab

Sr. No.	Time Period	Area	CAGR (%)	Production	CAGR (%)	Yield	CAGR (%)
1.	1961-62 to 1970-71	300.40	5.71	385.50	11.67	493.20	17.56
1.	1971-72 to 1980-81	750.60	12.99	1928.90	17.70	2475.80	4.16
2.	1981-82 to 1990-91	1663.70	4.85	5247.80	5.61	3143.80	0.73
3.	1991-92 to 2000-01	2294.50	2.72	7696.60	2.84	3353.50	0.12
4.	2001-02 to 2010-11	2652.10	1.25	10168.50	2.55	3829.5	1.29
5.	2011-12 to 2019-20	2970.11	1.50	11955.66	2.65	4020.55	1.14

Note: Area in 000 hectare, Production in 000 Metric ton and Yield kg/hectare

Source: Statistical Abstract of Punjab, Economic and Statistical Organisation, Government of Punjab, Various issues

Table 2: District wise area under paddy in Punjab (up to 11th July 2020)

(000 hectare)

Sr.no	District	Area under paddy-PTR	Area under paddy-DSR	Total area under paddy (DSR+PTR)	Per cent area under DSR w.r.t total area under paddy
1	Amritsar	112.17	33.43	145.6	22.96
2	Bathinda	89.93	43.95	133.88	32.83
3	Barnala	40.66	25.78	66.44	38.8
4	Faridkot	40.07	29.72	69.79	42.59
5	Pathankot	12.24	4.68	16.92	27.66
6	Moga	106.3	18.77	125.07	15.01
7	Hoshiarpur	33.15	21.95	55.1	39.84
8	Gurdaspur	109.56	33.71	143.27	23.53
9	Jalandhar	28.08	19.93	48.01	41.5
10	Ludhiana	115.42	16.46	131.88	12.48
11	Fazilka	45.21	26.3	71.51	36.78
12	Fategarh Sahib	64.32	6.55	70.87	9.24
13	Rupnagar	27.66	7.88	35.54	22.17
14	SAS Nagar	20.84	4.43	25.27	17.52
15	Sri Mukatsar Sahib	88.39	46.83	135.22	34.63
16	Ferozpur	111.62	33.98	145.6	23.34
17	Kapurthala	29.57	13.58	43.15	31.47
18	Mansa	37.86	22.4	60.26	37.18
19	Sangrur	155.75	27.68	183.43	15.09
20	Tarn Taran	64.91	23.96	88.87	26.96
21	Patiala	139.25	31.12	170.37	18.27
22	SBS Nagar	25.11	8.07	33.18	24.33
Total		1498.07	501.16	1999.23	25.07

Source: Department of Agriculture and Farmers Welfare, Government of Punjab, SAS Nagar

Table 3: Block wise area under DSR in Sri Mukatsar Sahib District of Punjab

(Hectares)

Sr.no	Block / Year	2019	2020	2021
1	Mukatsar	1600	14682	18300
2	Malout	750	5558	13690
3	Lambi	2000	7565	18696
4	Gidderbaha	8540	13395	19803
Total		12890	41200	70489

Source: Agriculture Department, Sri Muktsar Sahib, Punjab

VITA

Name : Gurpreet Singh
Father's Name : Sh. Gurmeet Singh
Mother's Name : Smt. Sukhjeet Kaur
Nationality : Indian
Date of Birth : 8th April 1998
Permanent Address : V P O Kanianwali, Teh & Distt. Sri Muktsar Sahib, Punjab
E-mail : gurpreetsinghbhullar14@gmail.com

EDUCATIONAL QUALIFICATION

Bachelor's Degree : B.Sc. Agriculture (Hons)
University : Punjab Agricultural University, Ludhiana
Year of award : 2020
OCPA : 7.37/10.00
Master's Degree : M.Sc. (Agricultural Economics)
University : Punjab Agricultural University, Ludhiana
Year of Award : 2022
OCPA : 8.01/10.00
Title of Master's Thesis : Energy use efficiency of direct seeding of rice in Punjab
Awards/Distinction/Scholarship/Fellowship : Grameen Chintan Scheme Fellowship