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RESEARCH PAPER

Does the Mechanized Rice Production more Resource Use Efficient than the Conventional Method? - A Case of Telangana State

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ABSTRACT

Traditional transplantation is the widely practiced crop establishment method in rice. The present study attempted to compare the resource use efficiency (RUE) among various crop establishment techniques in rice. A sample of 320 rice farmers was selected using a multistage sampling technique. The Cobb-Douglas production function results revealed that expenditure on seed, machine labour, and herbicide had a positive and significant impact on yield in the Dry direct seeded rice (DDSR) method. In the case of conventional transplanting (CT) method, insecticide, human labour, and irrigation charges had a positive and significant effect. The elasticity of fertilizer, machine labour, and irrigation charges was positively significant on yield in the DSDSR method, while human and machine labour were found to be significant in CT method. The RUE ratio was less than one for fertilizer (-0.32), herbicide (-0.14) and human labour (0.05) which indicated excess utilization of these resources, implying the need to reduce the quantity of these resources to achieve maximum returns in Wet direct seeded rice (WDSR) method. There is an inefficient use of resources in all the rice establishment methods, but more profound in traditional CT method than DSR and machine transplanting. More extension interventions are needed on the recommended dose of fertilizer application for enhancing the gross returns in rice cultivation. The study suggests awareness creation among the farmers on timely herbicide application and Cono-weeder usage for effective weed control in the WDSR method, which was found to be more resource efficient.

HIGHLIGHTS

- The study found mechanized rice cultivation as more resource-efficient.
- The resource use efficiency ratios indicated scope for resource reallocation in all methods of rice cultivation.

Keywords: Resource use efficiency, Direct seeded rice, machine transplanting, and transplanting method

Rice (Oryza sativa) is one of the most important cereal crops grown and serves as staple food globally. The world's population is expected to grow from 7.21 billion in 2015 to 8.27 billion by 2030, increasing the demand for rice from 680 million tonnes in 2015 to 771 million tonnes in 2030. The current level of production will not be enough to meet this demand (Badawi, 2004; Nirmala *et al.* 2016). India is the second largest producer of rice

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with a cultivated area of 47.83 million hectares and a production of 137.83 million tonnes in the year 2022-2023 (GoI, 2023). It is the main source of food security in India (Devi and Singh, 2014). Telangana occupies the second place in terms of rice production with 15.88 Mt, accounting for 11.5 % (GoI, 2023). Rice is the major crop and is cultivated mostly by manual transplanting in the state (Bandumula *et al.* 2022; Venkat *et al.* 2024). However, due to a decline in groundwater availability, labour scarcity, the percentage of agricultural workers decreased from 54.6% in 2011 to 40.6% in 2020, of which 45% were women workers (Mehta *et al.* 2019). Also, growing resource scarcity (water, labour), urbanization, and labour migration in Telangana imperil the productivity and sustainability of rice cultivation (Mounika *et al.* 2022; Manohar, 2017). All these aspects highlight the necessity of alternative methods of crop establishment. The direct seeded rice (DSR) method is one such technique that enables direct sowing of rice in dry fields as well as puddled soil (Venkat and Mohan, 2022). Mechanization plays an important role in rice crop establishment and using machine transplanter, reducing the time and cost of transplanting while increasing productivity (PJTSAU, 2020). The optimum allocation of resources is essential for increasing the gross returns in rice cultivation (Dhakal, 2019). Resource use efficiency is the ability to maximize output while minimizing input, which is an essential factor in crop production. The efficient use of resources is crucial in agriculture, as it can reduce production costs, increase yields, and enhance the sustainability of agricultural practices (Langangmeilu, 2022). However, so far, there are few systematic studies on the efficiency of resources in Direct Seeded Rice (DSR), and Machine Transplanting (MT) over conventional transplanting CT methods in Telangana state. Therefore, the study was undertaken to assess the comparative resource use efficiency of DDSR, WDSR, (Drum Seeder Direct Seeded Rice) DSDSR and MT method over CT method.

MATERIALS AND METHODS

Crop establishment methods under the study

In dry direct-seeded rice (DDSR), dry seeds are sown directly into the main field without prior germination. This method is commonly used in rainfed uplands, medium lowlands, lowlands, and deepwater ecologies during the wet season.

In wet direct seeded rice (WDSR), seed is normally pre-germinated prior to broadcasting onto recently drained, well-puddled seedbeds or into pre-standing water in the fields. Wet direct seeding is more commonly used in irrigated areas. It helps in timely establishment of crop, reduces labour costs for crop establishment, and requires less water than manual transplanting method.

In wet direct seeded rice using drum seeder (DSDSR), the soaked and germinated seeds are directly sown on a well-puddled, levelled wet field using an eight-row drum seeder. The seeds are dropped in rows @ 20 cm row-to-row spacing, and the seed rate required is just 25-37.5 kg/ha, depending on the size of the grain.

Machine transplanting (MT) involves planting young rice seedlings into puddled soil by a machine. It requires considerably less time and labour than manual transplanting.

Sampling

Multi-stage purposive sampling technique was employed for the selection of the farmers. The selection of four districts, namely Khammam, Nalgonda, Suryapet, and Karimnagar based on the highest area under DDSR, WDSR, DSDSR, and MT crop establishment methods respectively, was the first stage and selection of two mandals from each district and two villages from each mandal was second and third stage of sampling adopting the same criterion. At last stage of sampling, 20 farmers (10 farmers cultivating rice by each of above crop establishment methods and 10 farmers cultivating rice by conventional transplanting method) from each village were selected purposively. Finally, the sample size comprised of 320 farmers. The data pertains to 2023-24.

Analytical framework

The Cobb-Douglas production function was fitted separately for paddy production under DDSR, WDSR, DSDSR, and MT over the CT method to compare the resource use efficiency. Explicit form of lead equation was given as:

$$ln\ Y = ln\ a + lnXb_1 + lnX_2b_2 + lnX_3b_3 + lnX_4b_4 + lnX_5b_5 + lnX_6b_6 + lnX_7b_7 + e \quad ...(1)$$

Where,

Y = Gross returns per farm (₹/ha)

X_1 = Seed cost (₹/ha)

X_2 = Chemical fertilizer (₹/ha)

X_3 = Insecticide (₹/ha)

X_4 = Human labour (₹/ha)

X_5 = Machine labour (₹/ha)

X_6 = Irrigation charges (₹/ha)

X_7 = Herbicide (₹/ha)

e = random error

b_1 to b_7 are elasticity coefficients of respective inputs.

Allocative efficiency

The ratio of marginal value productivity and marginal factor cost of each individual determines the economic efficiency of resource use.

$$MPP_i = b_i \times \frac{Y}{X_i} \quad ...(2)$$

MPP_i = Marginal physical productivity

b_i = elasticity coefficient of i^{th} independent variable, Y, X_i are the geometric mean of the output and input.

MVP was calculated by

$$MVP = Py.\ MPP_i \quad ...(3)$$

Py = price per unit of paddy

Allocative efficiency is calculated by the ratio of Marginal Value Product (MVP) to Marginal Factor cost (MFC) for each input.

$$r = \frac{MVP}{MFC} = 1 \quad ...(4)$$

MVP = Marginal value product

MFC = Marginal factor cost (price per unit of input)

RESULTS AND DISCUSSION

The comparative resource use efficiency of DSR, MT over CT method was analysed using Cobb Douglass production function. The results reveal that the coefficient of multiple determination R^2 was 0.81, which implies an 81% variation was explained by the variables included in the model, in the DDSR method, whereas it was 78% (R^2 = 0.78) in the CT method (Table 1). The elasticity coefficient of seed cost was 0.29 for DDSR which was positive and significantly influenced gross returns contrary to the CT method which was -0.02 negative and non-significant. In the DDSR method production elasticity for machine labour was 0.03, positive and significant and in the CT method, it was 0.057 which was positive and insignificant. These are in line with the results of Meena *et al.* (2022). The production elasticity of fertilizer cost was positive but insignificant in both methods. Human labour was positive and significantly influenced the gross returns from rice cultivation in the CT method and was supported by earlier findings of Lone *et al.* (2021).

Table 1 illustrates the elasticity coefficients of the Cobb-Douglas production function. The values of (R^2) were 0.91 and 0.89 indicating 91% and 89 % of the variation was explained by the variables included in the models, in the gross returns of WDSR and CT methods. Production elasticity of seed cost, machine labour, and herbicide positively and significantly impacted gross returns in the WDSR method. In case of CT method, the insecticide, human labour, and machine labour were found to have positive and significant at 5% and 10%, respectively. These findings are consistent with those of Debnath *et al.* (2017) who stated that agrochemicals, human and machine labour had a significant impact on rice yield in Tripura. The expenditure on fertilizer and irrigation charges had a positive impact on gross returns but was insignificant in CT method. The sum of elasticity coefficients were 0.97 and 0.73 respectively, in WDSR and CT methods which were less than one indicating decreasing returns to scale.

It could be inferred from Table 2, that the estimated production function reveals that 90% of the variation in gross income was explained by explanatory variables in the Drum Seeder Direct Seeded Rice (DSDSR) method and 0.62 (62%) in the CT method. The production elasticity of fertilizer was 0.47 positive and significant in the DSDSR method. Expenditure on insecticide was found positive but not significant which due to the intensive application of insecticide in both methods. The

Table 1: Estimated production elasticity of Cobb-Douglass production function of DDSR and CT methods, WDSR and CT methods of paddy cultivation

DDSR (n=40)			CT (n=40)		WDSR (n=40)		CT (n=40)	
Explanatory variables	**Co-efficient value**	**P-value**	**Co-efficient value**	**P-value**	**Co-efficient value**	**P-value**	**Co-efficient value**	**P-value**
Seed cost	0.29**	0.05	-0.02	0.73	0.68***	0.0000	-0.09	0.30
Fertilizer cost	0.031	0.47	0.022	0.86	-0.027	0.370	0.015	0.86
Insecticide	0.001	0.91	0.41*	0.06	0.02	0.25	0.146**	0.044
Human labour	-0.010	0.37	0.08**	0.01	0.15	0.48	0.204**	0.019
Machine labour	0.03**	0.02	0.057	0.61	0.16***	0.05	0.37*	0.07
Irrigation charges	0.16	0.48	0.15**	0.03	-0.4	0.965	0.093	0.44
Herbicide	0.21**	0.05			0.39**	0.043		
R^2	0.81		0.78		0.91		0.89	
Adjusted R^2	0.80		0.77		0.90		0.87	
$\sum b_i$	0.71		0.69		0.97		0.73	

Note: **,**,and *** denote significance at 10%, 5%, and 1% respectively.*

Table 2: Estimated production elasticity of Cobb-Douglass production function for DSDSR and CT methods, MT and CT methods of paddy cultivation

DSDSR (n=40)			CT (n=40)		MT (n=40)		CT (n=40)	
Explanatory variables	**Co-efficient value**	**P-value**	**Co-efficient value**	**P-value**	**Co-efficient value**	**P-value**	**Co-efficient value**	**P-value**
Seed cost	-0.029	0.53	-0.064	0.235	0.0257	0.554	0.103**	0.025
Fertilizer cost	0.471***	0.000	0.054	0.32	0.120**	0.027	0.035	0.372
Insecticide	0.080	0.100	0.07	0.15	0.1752	0.148	0.182	0.203
Human labour	0.064	0.231	0.22**	0.04	-0.066*	0.091	0.14**	0.050
Machine labour	0.214**	0.03	0.016*	0.07	0.312***	0.003	0.053	0.483
Irrigation charges	0.091**	0.05	0.08	0.14	0.060	0.242	-0.0064	0.832
Herbicide	0.013	0.64			0.017*	0.06		
R^2	0.90		62		0.88		0.76	
Adjusted R^2	0.90		60		0.87		0.72	
$\sum b_i$	1.00		0.50		0.65		0.55	

***Note:** *,**,and *** denote significance at 10%, 5%, and 1% respectively.*

elasticity coefficients of machine labour were 0.21 and 0.016 and found to have a positive and significant effect on gross returns of rice in DSDSR and CT methods. The elasticity of human labour was 0.064 and 0.22, both positive but significant only in the CT method, as more labour is required for transplanting. A study by Sani *et al.* (2010) reported that human labour had a positive and significant impact on rice yield in the Kano State of Nigeria. Irrigation charges (0.09) were positive and significant only in the DSDSR method. The return to scale was found to be constant returns to scale (1.00) in the DSDSR method which revealed that a 1% increase in expenditure on all inputs results in a proportional increase in gross returns, decreasing returns to scale in CT method.

The value of R^2 was observed at 0.88, 0.76 in MT and CT methods (Table 2). The fertilizer had an elasticity of 0.12 which indicated that a 1% increase in expenditure on fertilizer would raise gross income by 0.12 in the MT method. The coefficient of machine labour and herbicide were 0.31 and 0.017 found positive and significant impact on gross income in the MT method. Similar findings were reported by Teja *et al*. (2022) in Telangana state. In the case of the CT method elasticity of seed (0.10), and human labour (0.14) had positive and significant effects on gross returns. Parasar *et* *al.* (2016) also reported that the expenditure on seed and human labour had a significant effect on gross returns of rice cultivation in Assam. From the above results, it could be concluded that there is potential for a rise in gross income with increased use of these inputs in both methods of rice cultivation in the study area. The sum of elasticity coefficient ($\sum b_i$) was 0.65, and 0.55 in MT and CT methods of rice cultivation which reveals decreasing returns to scale implying overutilization of resource.

Table 3 describes a comparative economic efficiency of resources used in Dry Direct Seeded Rice (DDSR) and CT methods. The RUE ratio was high for insecticide (44.12), followed by human labour (17.3), machine labour (3.35), fertilizer (2.28), and seed (1.23) in DDSR method. In case of CT method, the RUE ratio is more than one for insecticide and irrigation charges, which indicates that still there is a scope to increase and reallocate expenditures on these resources to maximize profits in rice cultivation. However, the RUE ratios for human labour (-0.9) in DDSR method and for seed (-1.7) and fertilizer (-0.55) were less than one, indicating excessive use of these resources in CT method of rice cultivation.

In case of seed, the RUE ratio was more than one in the WDSR method (18.86) which revealed underutilization, whereas in conventional (-2.73) it was less than one which indicated over-utilized (Table 4). A similar observation was reported by

Table 3: Economic efficiency of resource used in DDSR and CT methods in Khammam district

Particulars		MPP	MVP	MFC	RUE	Decision rule
Seed	**DDSR**	0.048	110.99	90	1.23	Under utilized
	CT	-0.079	-176.96	100	-1.7	Over utilized
Fertilizer	**DDSR**	0.03	68.44	30	2.28	Under utilized
	CT	-0.007	-16.75	30	-0.55	Over utilized
Insecticide	**DDSR**	3.98	90.44	2.05	44.12	Under utilized
	CT	4.25	94.74	3	31.58	Under utilized
Herbicide	**DDSR**	3.12	70.95	4.1	17.3	Under utilized
	CT					
Human labour	**DDSR**	-0.17	-404.76	450	-0.9	Over utilized
	CT	0.06	147.19	500	0.29	Over utilized
Machine labour	**DDSR**	1.55	3519.37	1000	3.35	Under utilized
	CT	0.58	1291.55	1250	1.00	Optimum utilized
Irrigation charges	**DDSR**	0.021	3084	340	17.89	Under utilised
	CT	0.04	5672	340	16.68	Under utilised

Table 4: Economic efficiency of inputs used in WDSR and CT methods in Nalgonda district

Particulars		MPP	MVP	MFC	RUE	Decision rule
Seed	**WDSR**	0.80	1886.84	100	18.86	Under utilized
	CT	-0.12	-273.06	100	-2.73	Over utilized
Fertilizer	**WDSR**	-0.004	-11.22	35	-0.32	Over utilized
	CT	0.008	22.71	35	0.64	Over utilized
Insecticide	**WDSR**	8.795	206.61	2.13	97.00	Under utilized
	CT	4.91	111.73	2.8	39.90	Under utilized
Herbicide	**WDSR**	0.024	0.57	3.98	0.14	Over utilized
	CT					
Human labour	**WDSR**	0.010	25.54	500	0.05	Over utilized
	CT	0.055	136.30	50	0.27	Over utilized
Machine labour	**WDSR**	1.086	2553.12	1200	2.12	Under utilized
	CT	0.99	2271.74	1200	1.89	Under utilized
Irrigation charges	**WDSR**	-0.005	-5470	450	-12.15	Over utilized
	CT	8.7	6086	450	13.52	Under utilized

Thejaswi *et al.*(2021) who found that seed was underutilized in the aerobic method and over utilised in conventional method in Karnataka. The RUE ratio of fertilizer was (-0.32) in WDSR and (0.64) in CT methods, implying overutilization, and reducing fertilizer use could improve rice output. This result corroborates findings of a study by (Malik and Pawar, 2023) stated that fertilizer was over-utilized in rice cultivation in Haryana. The RUE of herbicide (0.14) overutilized in WDSR method may be due to lack of awareness of the timely application of herbicide, This finding aligns with the results of Tasila *et al.* (2019). It can be observed (Table 4) that the RUE ratio for insecticide (97.00), and machine labour (2.12) exceeds unity in WDSR method. The RUE ratio for insecticide (39.90), irrigation charges (13.52), and machine labour (1.89) exceeded unity except for fertilizer (0.64), and human labour (0.27) which were excessively used and need to be rationalized in CT method.

The RUE ratio for seed was -1.48 and -0.94 in both DSDSR and CT methods, suggesting overutilization. This implies that a reduction in seed quantity usage improves rice output. For the fertilizer and machine labour the resource use efficiency ratio was found to be greater than one in both methods and there is a scope for enhancing gross returns by increasing these inputs. RUE ratio was less than one for herbicide and human labour which indicated excess utilization of these resource in DSDSR and CT methods of rice cultivation (Table 5).

Economic efficiency of resource used in MT and CT methods

The RUE ratio was 0.63 for seed implying it was over utilized in machine transplanting, which

Table 5: Economic efficiency of inputs used in DSDSR and CT methods in Suryapet district

Particulars		MPP	MVP	MFC	RUE	Decision rule
Seed	**DSDSR**	-0.06	-148.92	110	-1.48	Over utilized
	CT	-0.04	-113.04	120	-0.94	Over utilized
Fertilizer	**DSDSR**	0.38	964.52	38	25.38	Under utilized
	CT	0.14	335.00	38	8.81	Under utilized
Insecticide	**DSDSR**	0.58	14.39	2.82	0.01	Over utilized
	CT	3.37	77.15	3.4	22.69	Under utilized
Herbicide	**DSDSR**	5.15	127.63	2.05	0.08	Over utilized
	CT					
Human labour	**DSDSR**	0.07	197	500	0.39	Over utilized
	CT	0.01	38.20	500	0.07	Over utilized
Machine labour	**DSDSR**	1.40	3479.87	1350	2.89	Under utilized
	CT	1.20	2763.66	1350	2.04	Under utilized
Irrigation charges	**DSDSR**	3.22	7922.45	500	15.98	Under utilized
	CT	3.88	8888.54	500	17.76	Under utilized

Table 6: Economic efficiency of inputs used in MT and CT methods in Karimnagar district

Particulars		MPP	MVP	MFC	RUE	Decision rule
Seed	**MT**	0.034	75.89	100	0.63	Over utilized
	CT	0.12	271.21	100	2.71	Under utilized
Fertilizer	**MT**	0.037	82.82	32	2.58	Underutilized
	CT	0.02	44.02	32	1.37	Under utilized
Insecticide	**MT**	3.42	75.40	3.36	22.44	Underutilized
	CT	6.61	142.45	3.9	36.52	Under utilized
Herbicide	**MT**	6.16	135.91	1.8	75.50	Underutilized
	CT					
Human labour	**MT**	-0.06	-146.10	500	-0.29	Over utilized
	CT	0.10	223.31	450	0.44	Over utilized
Machine labour	**MT**	0.91	2008.18	1250	1.60	Under utilized
	CT	0.21	2611	1250	2.08	Underutilized
Irrigation charges	**MT**	5.82	12821.46	500	25.64	Under utilized
	CT	-83.13	-6789	500	-13.57	Over utilized

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indicates that farmers should reduce the quantity of seed used in production to increase the rice output. Contrary to this, in CT method the RUE of seed was 2.71 implying underutilized and farmers could increase the quantity of seed to enhance rice yield (Table 6). The RUE ratio for fertilizer and machine labour was observed to be greater than one in both MT and CT methods. Acharya *et al.* (2020) who compared the RUE of mechanized and traditional rice farmers in Nepal revealed that fertilizer and machine labour were underutilized. In the MT method the RUE ratio for herbicide (75.50), irrigation charges (25.64) insecticide (22.44) was more than one which indicates underutilization of these resources, suggesting that increasing the use of these inputs may boost rice output. However human labour and irrigation charges were over utilised. In case of the CT method seed, and insecticide were underutilized, and human labour, irrigation charges were excessively used, a decrease in the use of these inputs may enhance rice output.

CONCLUSION

The comparative analysis of the resource use efficiency of DDSR over the CT method reveals that seed, machine labour, and herbicide were positive and significantly contributed to gross income. In case of the CT method insecticide, human labour, and irrigation charges were significant. The RUE ratio was less than one for inputs such as fertilizer and labour which indicates that excessive use of these resources lowers the gross returns in WDSR and CT methods. To optimize resources, paddy farmers should apply the recommended dose of fertilizer. In the DSDSR method, seed, insecticide, and herbicide were overused. Farmers should reduce insecticide usage and awareness should be created among the farmers for timely herbicide application and use of a cono-weeder to be promoted for effective weed control. This study found that seed, and human labour were overused in MT method, and seed, fertilizer, and insecticide were underused in the CT method. There is a need to educate the farmers on the optimum allocation of resources through trainings and demonstrations by extension agencies for better productivity and cost efficiency.

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