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Energy Assessment of Manual Transplanting Rice and Dry Direct Seeding Rice Production Systems in Combined Nalgonda District, Telangana

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ABSTRACT

Background: Rice is the major crop in India in terms of area, production and consumption. Rice occupies about 23% of the gross cropped area and 35% of the total area under food grains in the country. Rice is of one key importance to the economy as well as a staple food for Telangana people, requiring about 50 lakh tons annually to feed the state population. In recent times the area under rice cultivation has been increased and is expected to hit the one crore acre mark by *rabi* season 2022. In any type of crop production system an accountability of inputs, energy spent, yield and costs must be monitored, by that one can modify it or substitute it for obtaining the better results.

Methods: Due to decline in the share of agriculture workers in the country, there is a need to adopt new technologies in rice cultivation. Dry direct seeding of rice refers to direct sowing of rice seeds in the dry field rather than by transplanting seedlings from the nursery. A study was conducted to compute the inputs and energy consumptions in manual transplanted rice production (MTR) and dry direct seeding rice production (DDSR) methods of paddy cultivation in the combined Nalgonda district of Telangana State, during 2020-21. Firstly, the different operations performed in these two methods were listed out, then by using suitable energy equivalents total energy consumed in two methods of operations were calculated.

Result: The human energy spent in the manual transplanted rice production and dry direct seeded rice productions were 506 and 92.84 MJ/ha respectively. Specific energy noted for dry direct seeded rice production and manual transplanted rice productions were 2.10 and 2.28 MJ/kg respectively. A total saving of Rs. 16,000/- ha^{-1} was recorded by practicing the dry direct seeded rice production method over the manual transplanted rice production method. On comparing both the methods for overall energy consumption, manual energy consumption and cost of cultivation DDSR method was found to be more efficient than MTR method in the district.

Key words: Cost analysis, Dry direct seeding of rice, Energy analysis, Manual transplanting of rice, Specific energy.

INTRODUCTION

Rice is a highly cultivated food grain crop of the world and is the staple food for the most of Asian population. Rice is the major crop in India in terms of area, production and consumption. Rice occupies about 23% of the gross cropped area and 35% of the total area under food grains in the country (Samarpitha *et al.,* 2016). Rice is being cultivated both in *Kharif* and *rabi* seasons as one of the most important crops in the Telangana region. Within a short span of five years, the area under paddy cultivation in Telangana state has doubled from 22.7 lakh acres in 2014-15 *Kharif* to 40.7 lakh acres in the 2019-20 *Kharif* season and expected to hit the one crore acre mark by yasangi 2022 (Anonymous, 2021). The percentage of agricultural workers decreased from 59.1 in 1991 to 54.6% in 2011 and projected to be 40.6% in 2020, of which 45% will be women workers (Mehta *et al.,* 2019). This trend is hinting that in the near future share of manual workforce in agriculture will decrease to a lower extent.

Manual rice transplanting is highly labour intensive, tedious, costly and time-consuming operation. During manual transplanting operation, a woman has to stand in a puddled field for long time with frequent changes in their posture which results in lot of musculoskeletal disorders. Because of rapid increment in paddy cropping area farmers are facing crucial labour shortage during peak transplanting period. To overcome the labour scarcity and unnecessary energy spent in the field, farmers need to adopt different alternative methods of paddy cultivations. DDSR method is one such method that helps in direct sowing of rice in the dry field without the need of transplanted seedlings (Venkat and Mohan, 2022).

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Adequate availability of the machine energy and its efficient use is essential to reduce the cost of cultivation and to increase mechanization in agriculture. By introducing advanced farm machines and implements in agriculture, productivity increases and minimizes the human energy spent in the field.

Energy is one of the most vital inputs of agriculture. It is invested in various forms such as mechanical (farm machines, human labor, animate), fertilizer (urea, NPK), chemical (pesticides, herbicides), electrical, *etc*. Considering the importance of paddy cultivation in promoting agricultural development in the country, in general in the Telangana state, in particular combined Nalgonda district, an attempt has been made in this study to estimate the energy consumption of MTR and DDSR farms.

Different types of Rice cultivation methods practicing in Telangana state are Manual transplanting, machine transplanting, dry direct seeding, drum seeding and broadcasting. Among these methods, the most profitable method seems to be very direct seeding of rice but many of farmers are not aware of actual benefits of this method. A very low-level research was reported on the energy assessment of Dry direct seeding of rice production. In view of these, a study on the energy use pattern and cost of production in manual transplanted rice (MTR) production and dry direct seeding rice (DDSR) production systems in the Nalgonda district was taken.

Description of the study area

Combined Nalgonda is one of the ten old districts in the Telangana state (Fig 1). The geographical area of the district is 14,240 square kilometers. It is located in the Southern Telangana zone which receives an average annual rainfall of 700-900 mm. Agriculture is one of the major occupations in the district. It is supported by a well-planned irrigation system which includes 26 lift irrigation and 1,16,007 irrigation wells (Samarpitha *et al.,* 2016). Nagarjuna Sagar is a major irrigation project that provides irrigation facilities to the extent of 1.24 lakh hectares in the district. In recent years, Kaleshwaram project, one of the largest lift irrigation project also sums up irrigation for combined district agricultural lands. Major crops grown in the district include rice, pulses, citrus fruits, millets and oilseeds.

MATERIALS AND METHODS

Energy requirement in agriculture is divided into two groups *i.e*., direct and indirect. Direct Energy is essential for performing various tasks related to crop production processes such as land preparation, irrigation, intercultural, threshing, harvesting and transportation of agricultural inputs for farm produce (Singh, 2000). Indirect energy is used in the manufacturing, packaging and transporting of fertilizers, seeds, farmyard manure, chemicals and machinery (Mani and Patel, 2012). A higher input of energy accounts for higher energy costs, which significantly reduces the net return of the farms and is a challenging issue (Dev and Ponnarasi, 2009).

In many advanced agricultural systems, an increase in yield is the result of an efficient energy input which is directly related to the use of improved mechanized tools and the introduction of high-yield crop varieties. Energy use patterns and consumption of energy inputs vary depending on the method of cultivation adopted and crop season at that time. Calculating energy inputs of agricultural production is more difficult than in the industrial sector due to the many factors affecting the production system (Chaichana *et al.,* 2014) (Soni *et al.,* 2018).

Manual transplanting of rice is mostly practiced in the Nalgonda district. Dry direct seeding of rice method is getting popular in few parts of the district from recent years because of timeliness and reduced labor force.

Different energy inputs required in the manual transplanted rice (MTR) and direct seeding rice systems (DDSR) are noted down from the progressive farmers of the district from different areas. A proforma was formulated to collect the required information related to manual transplanting of rice and dry direct seeding of rice. Machinery used in those methods, time of operation, fuel consumption for different implement operations, fertilizer inputs, chemicals used, manual labor requirements and electricity consumption were recorded in proforma. The energy inputs in both the rice production methods were calculated by using the energy conversion coefficients listed in Table 1.

The energy spent in crop production was is calculated from the below formulae:

Energy input =

Human energy + Fuel energy + Machine energy

(Patel *et al.,* 2017)

Machinery energy =

$$\frac{[\text{Weight of the machine(kg)} \times \text{Self-propelled machine energy equivalent factor (MJ/kg)} \times \text{Useful working hours (h/ha)} \times \text{Number of passes}]}{\text{Life of machine (h)}}$$

(Patel *et al.,* 2017)

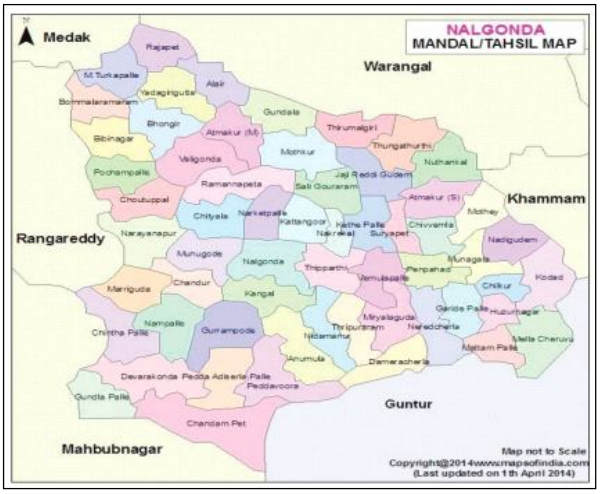


Fig 1: Mandal map of combined Nalgonda district.

Human energy =

Useful man-hour spent in operation × Man energy factor (MJ/h)

(Patel *et al.,* 2017)

$$\text{Energy ratio} = \frac{\text{Energy output}}{\text{Energy input}}$$

(Pradhan *et al.,* 2015)

Net energy gain =

Energy output (MJ/ha) - Energy input (MJ/ha)

(Patel *et al.,* 2017)

$$\text{Specific energy} = \frac{\text{Energy input, (MJ/ha)}}{\text{Grain output, (kg/ha)}}$$

(Pradhan *et al.,* 2015)

$$\text{Energy productivity (kg/MJ)} = \frac{1}{\text{Specific energy}}$$

(Patel *et al.*, 2017)

The major objective of any agricultural production system is to increase crop yield and decrease the cost of production. In this regard energy budget is an important thing that makes the understanding of numerical comparison of the relationship between inputs and outputs of a system in terms of energy requirement (Rahman *et al.,* 2015).

Dry direct seeding of rice production (DDSR)

Dry direct seeding is the direct sowing of rice in the dry field rather than by transplanting of seedlings from the nursery. For field preparation tillage operations were performed by tractor-operated implements. Different types of implements used in seedbed preparation were cultivator and rotavator. The energy used in seedbed preparation includes human energy, machinery energy, tractor energy and diesel energy. In this method, 30 kg/ha seeds were required for direct seeding operation. In this practice, tillage is done by 2 passes of cultivator and 1 pass of rotavator followed by 1 pass of seed drill. A 100 days crop period was considered for the Kharif paddy cultivation. After 20-25 days of sowing, dry direct seeded fields were given flood irrigation like manual transplanted rice fields. Borewell is used as an irrigation source for crop cultivation. Irrigation water of 10 mm height above surface was applied to the crop field by using a 5 hp electric motor pump, 8 times with an interval span of 10 days in a croping season. Irrigation application includes electrical and machinery energies for energy estimation purposes. Weeding operation in this crop field was done by power weeders because seed drill sowing maintains proper row to row spacing in the field. A power weeder with a field capacity 0.15 ha/h was used in crop production. Fuel consumption of power weeder was recorded as 0.65 l/h and human energy spent in power weeder operation was 13.07 MJ/ha.

The energy used for fertilizer application was calculated by human and fertilizer energies. Fertilizers were applied manually for the vegetative development of the crop. The DAP, MOP and urea are used for paddy cultivation at different crop stages. The recommended fertilizer doses used in crop production are 130 kg/ha of nitrogenous fertilizer, 50 kg/ha of phosphorus and 40 kg/ha of potassium fertilizer. Human energy spent in fertilizer application operation was 47.04 MJ/ha. To control the pests and diseases, a 5 kg/ha chemical was used in the crop with powered knapsack sprayer. The field capacity and fuel consumption of sprayer

Table 1: Energy equivalent of input and output of rice production system.

Different inputs provided in paddy production		
Particulars	Unit	Energy equivalents (MJ/unit)
Adult man	h	1.96
Woman	h	1.57
Large bullock	Pair hour	14.05
Diesel	L	56.31
Petrol	L	48.23
Electricity	kWh	11.93
Electric motor	kg	64.80
Tractor	kg	68.40
Farm machinery	kg	62.70
Self-propelled machinery	kg	64.8
Nitrogen fertilizer (N)	kg	60.6
Phosphorous fertilizer (P2 O5)	kg	11.1
Potash fertilizer (K2 O)	kg	6.7
Chemical (pesticide/herbicide)	kg	120.0
Different outputs produced from paddy production		
Paddy seed	kg	14.7
Paddy straw	kg	12.5

Table 2: Energy requirement (MJ/ha) for field preparation and sowing in dry direct seeding of rice method.

Machinery (Number of passes)	Human energy (MJ/ha)	Fuel energy (MJ/ha)	Machine energy (MJ/ha)	Total energy (MJ/ha)
Cultivator (2)	7.25	1250	16.77	1274
Rotavator (1)	3.92	563.10	19.15	587
Seed drill (1)	1.96	281.55	8.9	292.41
Energy for field preparations and sowing operation				2,153.41

were calculated as 0.67 ha/h and 0.5 l/h. The human energy spent in spraying operation was noted as 11.76 MJ/ha.

For harvesting and threshing operations combine harvester was used in the crop production. The field capacity and fuel consumption of combine harvester used were measured as 0.4 ha/h and 8 l/h. The human energy spent in harvesting operation was noted as 7.84 MJ/ha.

Recommended time for dry direct seeding of rice is June 10 to July 10 for better utilization of early rains of Southwest Monsoon of crop. For Telangana sona variety recommendable time of sowing is after July 10 because of agronomical considerations. In this dry direct seed drill sowing row to row distance is 25 cm and plant to plant spacing of 6-8 cm should be maintained.

Manual transplanted rice production (MTR)

For manual transplanting of rice, 40 kg/ha paddy seeds were required for nursery prior to transplanting. For manual transplanting of one hectare land, 800 m^2 area was required for nursery preparation. A good water supply and proper drainage system were facilitated for a good quality seedling nursery. For nursery preparation selected area of field should be plowed twice followed by one puddling operation in the weekly interval and leveled by any available power source (Mathew *et al.,* 1993). Paddy sprouts were uniformly broadcasted over the prepared nursery and after 20-25 days of sowing, seedlings were pulled out for transplanting. Energy spent in the nursery bed preparation and transplanting operation was classified as human energy, seed energy and machinery energy. Sowing costs include the charges for uprooting of seedlings, transportation of seedlings and transplanting by manual labour. On an average after 20 to 25 days, rice seedlings are uprooted from the nursery and transplanted in the main field at the rate of 2-3 seedlings per hill.

The main field preparations were performed by 2 passes of the cultivator and 1 pass of the rotavator. After field preparations, rice seedlings can be directly sown in the main field by woman labour picking the seedlings from a nursery. Irrigation water of 10 mm height above surface was applied to the field by a 5 hp electric motor pump of 10 times with an interval span of 10 days in a crop season. Irrigation application includes electrical and machinery energies for energy estimation purposes. About 140 women hours were consumed for seedlings pulling from nursery and transplanting operation. The recommended fertilizer doses used in crop production are a 125 kg/ha nitrogenous fertilizer, 50 kg/ha Phosphorus fertilizer and 40 kg/ha Potassium fertilizer. A 47.04 MJ/ha human energy was spent in fertilizer application operation. Weeding operation in the field was performed by manual labour only, mechanical weeders cannot be operated in manual transplanted field because of the irregular spacing of rows in the field. Weeding operation in a one hectare of rice field consumed about 120 women hours. For irrigation, fertilizer application, spraying and harvesting operations similar machinery was considered which was used in dry direct-seeded rice production.

Cost analysis

Since paddy is intensively grown in India, the total economic gain to a farmer is one of the most important indicators of the farmer's economic perspective and farm profitability (Goyal *et al.,* 2006). The cost incurred in both DDSR and MTR methods were calculated descriptively and quantitively in terms of Rs/ha and are detailed in the results.

RESULTS AND DISCUSSION

Energy analysis

Energy consumed for completion of the field preparations sowing operation for the DDSR method were shown in Table 2 and energy spent for different operations throughout the crop production are mentioned in Table 3.

Total energy consumed in dry direct seeding of rice method was measured as 14,730.85 MJ/ha. In this DDSR method highest energy was consumed for fertilizer and its application operation. After that, the major portion of total energy is spent in field preparation and sowing operations.

Energy consumed for nursery preparations (2 plough operations, 1 puddling, manual broadcasting, fertilizer, irrigation and herbicide application) in manual transplanted rice production was measured as 850 MJ/ha. Energy requirement for field preparations and transplanting operation in manual transplanted rice production were mentioned in Table 4. Energy requirements for different operations in manual transplanted rice production were mentioned in Table 5.

Total energy consumed in the manual transplanted rice production method was measured as 15,640 MJ/ha. In this MTR method, highest energy consumed was observed for fertilizer application and is measured as 53.99 % of total energy. After that, the major portion of total energy is spent in field preparation and sowing operations measured as 19.26% of total energy.

Amount of grain and straw produced in both the methods were mentioned in Table 6. Straw produced from DDSR and MTR methods are of the almost same quantity, but in the DSSR method, a 140 kg more grain was produced than the MTR method.

Table 3: Energy requirement (MJ/ha) for different operations in dry direct-seeded rice.

Different operations of crop production	Energy requirement (MJ/ha)
Seed energy	441
Field preparation and sowing operation	2,153.41
Power weeder operation	268.3
Irrigation operation by borewell	1,144.2
Fertilizer and Its application operation	8,748
Chemical spraying operation	705.94
Combine harvester operation	1,270
Total energy consumed for dry direct seeding of rice method	14,730.9

Table 4: Energy requirement for field preparations and transplanting in manual transplanted rice production.

	Type of operation				Energy requirement (MJ/ha)
	Machinery (Number of passes)	Machine energy (MJ/ha)	Fuel energy (MJ/ha)	Human energy (MJ/ha)	Total energy (MJ/ha)
Main field preparations	Cultivator (2)	16.77	1250	7.25	1,274
	Rotavator (1)	19.95	645.21	4.08	669.24
Nursery field preparations					850
Seedlings pulling from nursery and manual transplanting					219.8
Total energy for field preparations and transplanting					3,013.04

Table 5: Energy requirement for different operations in manual transplanted rice production.

Different operations of crop production	Energy requirement (MJ/ha)
Seed energy	588
Field preparations and transplanting	3,013.04
Manual weeding operation	188.4
Irrigation operation by borewell	1,430
Fertilizer and Its application operation	8,445
Chemical spraying operation	705.94
Combine harvester operation	1270
Total energy consumed for manual transplanted rice production	15,640.4

Table 6: Output energy produced in both the methods.

Type of method	Grain in kg	Straw in kg	Energy equivalent (MJ/ha)
DDSR out put	7,000	9,850	2,26,025
MTR out put	6,860	9,800	2,23,342

Table 7: Energy terms calculated.

Energy terms	DDSR method	MTR method
Energy ratio	15.34	14.28
Net energy gain (MJ ha^{-1})	2,11,294	2,07,702
Specific energy (MJ kg^{-1})	2.10	2.28
Energy productivity (kg MJ^{-1})	0.48	0.44

Different energy terms worked out in both the methods were presented in Table 7. In dry direct seeding of rice method, about 909.5 MJ/ha less energy consumption was recorded than manual transplanted rice production. The total manual energy consumed in the MTR method was noted as 506 MJ/ha, whereas in the case of the DDSR method it was noted as just 92.84 MJ/ha. DDSR method requires very little manual energy on comparing with the MTR method, ultimately it reduces the manual labor cost to a great extent in paddy cultivation. This shows that the DDSR method is a more mechanized cultivation method, it allows timeliness in different operations. Whereas in case of MTR method, with a huge shortage of labour during peak period, there is a delay in transplanting and weeding operations ultimately it leading to reduced yields. Moreover in the DDSR method, there is no need of nursery management practices and this helps in reducing the cost of cultivation.

Cost analysis

By practicing DDSR method farmer can save seed, eliminate nursery preparations and manual transplanting operations. In DDSR method, cost of field preparations, seed and sowing operation was noted as 11,000 Rs/ha. In MTR method, cost of field preparation was noted as 17,500 Rs/ha, cost of seed was noted as 2,000 Rs/ha and the cost of manual transplanting was measured as 7,500 Rs/ha. In MTR method overall cost of field preparations, seed and manual transplanting the operation was noted as 27,000 Rs/ha, whereas in the DDSR method farmer can complete these operations at just 11,000 Rs/ha. By adopting the DDSR method farmer can save directly 16,000 Rs/ha over the MTR method.

CONCLUSION

The energy required in dry direct seeding rice production (DDSR) and manual transplanted rice production (MTR) methods were found to be 14,730.9 and 15,640.4 MJ/ha respectively. In both practices, the maximum energy was found for fertilizer application and minimum energy was noted down for weeding operation. Manually transplanted rice was turning out to be most laborious practice of paddy cultivation in the Nalgonda district. The dry direct-seeded rice crop is a way for mechanized paddy cultivation in the district. Energy ratio, Net energy gain and Energy productivity were found to be more for the DDSR method. Specific energy consumed for the DDSR method was found to be 2.10 MJ/kg which is less than that of the MTR method. There is more uniformity in the DDSR rice field in terms row to row distance and number of plants per hill, which helps in even consumption of fertilizer and nutrients by plants. DDSR field undergoes proper vegetative development and almost all the plants in the field come to maturity stage at one time ultimately it helps in obtaining better yields. On comparing both the methods for overall energy consumption, manual energy consumption and

cost of cultivation DDSR showed better results than manual transplanted rice method in the district.

Conflict of interest

All authors declare that they have no conflict of interest.

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