Energy and economic assessment of manual and self-propelled rice transplanter

Manish Kumar and Janak Ghodasara

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Abstract
The energy and economic investigating of self-propelled rice transplanter and manually method of rice transplanting in the area of Sonpur, Chhattisgarh. The energy consumption for rice transplanting calculated by the use of standard formulas and the cost economy intended with the standard method. The data was collected with the reference of the field performance of different method of rice cultivation. Self-propelled rice transplanter has consumed 210 MJ/ha energy whereas the manual method consumes 470 MJ/ha energy. The cost of rice transplanting was Rs. 1145 and Rs. 6000 for self-propelled and manually method respectively.

Keywords: Transplanting, energy, cost-economics, self-propelled

Introduction
Rice (Oryza-sativa) is one of the most important crops of India growing over an area of 43.2mha with the production of 110 Mt according to the annual report 2017-18, Ministry of Agriculture and Farmer Welfare, GoI. The demand for rice in India to be increased 156 Mt by 2030. (ICAR, 2010). Harvesting of the rice in Chhattisgarh is in around 3.61mha with a production of 5.48 Mt and a productivity of 1517 kg per ha. Chhattisgarh is popularly known as the “Rice Bowl” of India. To meet the demand of rice is the major challenge for our government and scientist of India. The demand of rice is to be fulfilled by producing more rice in less land, optimum use of the energy inputs and farm mechanization (Jain et al., 2019) [11]. The energy requirement in the agricultural sector depends on the level of mechanization, cropping pattern, climatic condition, size of land and types of soil. All of them the mechanization is perform the lead role in agricultural energy management. Agriculture uses large quantities of locally available non-commercial energy, such as manure and animal energy, and commercial energy, directly and indirectly in the form of seed, diesel, electricity, fertilizer, plant protection chemicals, irrigation water, machinery, etc. (Singh, 2002; Alam et al., 2005) [2-3].

Manual transplanting is tedious, tiresome and labour consuming because a person has to stand in a puddled field and bending posture for many hours for putting seedling into the soil by hand. Manual transplanting is one of the labour-intensive operation comprising of nursery raising, uprooting of the seedlings and transplanting them in the main field, with total labour requirement of about 280-350 man-hours/ha. Some of the postures, taken by them were very harmful, but they were compelled to adopt those postures during work for a long time. During transplanting, the workers adopt a strongly bent posture in the muddy field for many hours for putting seedling into the soil by hand. The appropriate mechanization coupled with skill operators gives high productivity in agriculture. Mechanization means the introduction of improved tools and implements that increase production and productivity with reduce the unit cost of production without drudgery and reducing the time of production. Mechanization can reduce the energy requirement into the farm who consumed by the labours (Dave et al., 2000) [3].

In this study, we calculated the energy input in the operation of transplanting for the production of rice in the area of Sonpur, Block-Patan, District-Durg, and Chhattisgarh. To compare the energy consumption and cost economics in self-propelled rice transplanter and manually transplanting with objective of the energy and cost of the rice transplanting.
Methodology
The study was conducted at the farm of the Sonpur village. The field performance of the self-propelled 8-row transplanter was evaluated. In terms of overall dimensions, weight of the machine, planting speed, row to row and plant to plant spacing was evaluated and calculating. The technical specification of self-propelled rice transplanter is shown in Table-1.

Energy Calculation
The energy input of both mechanical and manually operation of rice transplanting was calculating using relevant energy equivalent shown in Table-2. The data was converted into a suitable energy unit and express in MJ/ha. The following formulas were used for energy calculation. (Nguyen et al., 2016)[10]

- Fuel Energy:
  \[ E_{fuel} = h \times FC \times FE_q \]

- Labour energy:
  \[ E_{labour} = (\text{No. of labour} \times \text{Time} \times H_q)/\text{Area} \]

- Machine Energy:
  \[ E_{machine} = (W \times ME_q \times h)/L \]

Table 1: Technical specification of self-propelled rice transplanter

| Model       | Yanji Shakti 8 row self-propelled rice transplanter: Model 2 ZT-238-8 |
|-------------|------------------------------------------------------------------------|
| Overall dimension L x W x H (mm) | 2410 x 2290 x 1200 |
| Weight (kg)      | 320 |
| Power unit                                    | 2.94 KW(4HP) single cylinder air cooled diesel engine |
| Planting speed (km/h) | 1-2 |
| Road traveling speed (km/h)      | 8.2 |
| Number of rows                  | 8 |
| Row spacing (mm)                | 238 |
| Distance between hill (mm)     | 140-170 |
| Growing density of seedlings hills/m² | 34-42 |
| No. of seedlings per hill, (adjustable) | 3-8 |
| Width of seedling mat (cm)       | 22 |
| Planting depth, (cm, adjustable) | 2-6 |
| Capacity (m²/h, adjustable)          | 1300-2000 |

Where, \( E_{fuel} \), direct fuel energy use, MJ/ha; \( h \), working hours per operation, h/ha; \( FC \), average fuel consumption, l; \( FE_q \), fuel energy equivalent, MJ/l; \( H_q \), human energy equivalent. \( W \), total weight of machine, kg; \( ME_q \), machine energy equivalent, MJ/kg; \( L \), life of machine, hr.

The fuel energy was calculated with measured fuel consumption and actual field capacity of the machine. The machine energy was estimated by the total weight of machine, a life of machine and total operating hour per operation.

Table 2: Energy equivalence of different inputs and outputs

| Particulars            | Energy equivalent (MJ/unit) | References                           |
|------------------------|-----------------------------|--------------------------------------|
| Human labour (h)       | 1.96                        | (Tabat et al. 2010)[15], (Mobtaker et al., 2010)[16] |
| Diesel (l)             | 56.31                       | (Mobtaker et al., 2010)[15]          |
| Farm machinery (Excluding self-propelled)(kg) | 62.7 | (Mobtaker et al., 2010)[15], (Pradhan et al., 2015)[16] |

Cost Economics
The economic analysis of self-propelled rice transplanter was calculated according to (Kamboj et al., 2012)[12].

A. Fixed cost
   a) Depreciation, Rs/h
   \[ D = \frac{C - S}{L \times H} \]

B. Interest, Rs/h
   \[ I = \frac{C + S}{2} \times \frac{i}{1+i} \]

C. Insurance, tax and housing cost Rs/h: 3% of purchase price

B. Variable cost
   a) Repair and maintenance, Rs/h : 2.5% of purchase price
   b) Fuel cost, Rs/h : Fuel price (Rs/l) × Fuel consumption (l/h)
   c) Lubricants cost, Rs/h : 30% of fuel cost
   d) Operator or labour cost, Rs/h: Number of day × Operator charges (Rs/day)

C. Total operating cost, Rs/h: Total fixed cost +Total variable cost

Where, C, the initial cost of the machine, Rs; S, salvage value, @10% of C; L, life of the machine, year; H, annual use, Hour and I, interest rate. The cost economics of self-propelled was estimated by the following assumptions shown in Table 3

Table 3: Assumptions of self-propelled for cost economics

| Total initial cost (Rs.) | 1,82,000 |
|--------------------------|----------|
| Expected life of machine (year) | 10 |
| Annually use of machine (days) | 30 |
| Fuel cost (Rs.) | 80 |
| Operating cost (Rs.) | 300 |

Fig 1: Transplanting of rice in manual and mechanical method
Results and Discussion
The performance of the self-propelled rice transplanter was done in Sonpur village. The area of the experiment was 0.8 ha and performance was conducted in leveled and well- puddled field. The actual field capacity of the machine was found at 0.21 ha/h, the other parameters of the field test of machine are shown in Table 4.

The energy analysis of different methods of rice transplanting was estimated and compared. The total energy consumption by self-propelled transplanter is 210 MJ/ha and by manually energy consumption is 470 MJ/ha shown in Table 5. In the manual method, there was no indirect energy used in the process of transplanting. The energy consumption of self-propelled transplanter has included energy consumption by fuel energy, the total human hour for the operation of self-propelled and included machine own energy.

Table 4: Field test data of self-propelled rice transplanter

| Sr. No | Parameters                             | Value |
|--------|----------------------------------------|-------|
| 1      | Total study area, (ha)                  | 0.8   |
| 2      | Speed of operation, (km/h)              | 1.433 |
| 3      | Actual field capacity, (ha/h)           | 0.21  |
| 4      | Theoretical field capacity, (ha/h)      | 0.27  |
| 5      | Field efficiency (%)                    | 77.79 |
| 6      | Labour required, (man-days/ha)          | 6     |
| 7      | Fuel consumption, (l/h)                 | 0.522 |

The manually process was engaged 30 labours to cover 1 ha area for rice transplanting. That means 240 man-hours was consumed for covering the area of cultivation (Dave et al., 2000) [3]. Manually process consumed more time and more energy than self-propelled. It also has many limitations like planting laborers can suffer from back problems (health risk), difficult to get enough labor at peak periods to plant on time and difficult to maintain optimum spacing and uniform plant density, especially with random transplanting and contract labor.

Table 5: Energy inputs of mechanical and manual transplanting operation

| Parameters                     | By Self-propelled (MJ/ha) | By Manually (MJ/ha) |
|--------------------------------|---------------------------|--------------------|
| Total Fuel Energy              | 47                        | -                  |
| Total Indirect Energy          | 47                        | -                  |
| Human Energy                   | 10                        | 470                |
| Machine Energy                 | 153                       | -                  |
| Total Direct energy            | 163                       | 470                |
| Total                           | 210                       | 470                |

The use of self-propelled transplanter provides economic benefits to the farmers over the manual transplanting methods because the total energy required for complete operation for transplanting with self-propelled was less than manually process. The operation with self-propelled consume less energy means less afford that can decrease the time and cost of the operation and save the energy of the farmers.

The economics of the mechanical rice transplanting and manually rice transplanting was calculated. The manual rice transplanting method is taken 240 h for covering the area of one hectare as compared to the self-propelled is taken 4.76 h. The labour charge for transplanting has Rs. 200 per day and driver charges Rs. 300 per day was taken. The variable cost and fixed cost are shown in Table 6.

Table 6: Cost economics of mechanical and manual rice transplanting

| Particular               | By Self-propelled (Rs) | By manually (Rs) |
|--------------------------|------------------------|-----------------|
| Fixed Cost               | 133                    |                 |
| Variable Cost            | 108                    | 25              |
| Total Cost per hour      | 241                    | 25              |
| Total Cost per hectare   | 1145                   | 6000            |

Conclusions
The observation of the results shown that the energy consumption of the manually rice transplanting is more than double than self-propelled transplanting or mechanically transplanting method. As well as the cost of the transplanting is 81% lower in the self-propelled rice transplanting method. Results showed that the manually rice transplanting is a highly time-consuming process and more labour is required. In the peak season period, the availability of enough labour could very difficult. The result concluded that for improving our farmer’s profitability and doubling the income in agricultural the mechanization must be required.

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