SUSTAINABLE RICE PRODUCTION: A CASE STUDY ON PERFORMANCE EVALUATION OF A SEEDER

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Global rice production is confronting issues such as climate change and the scarcity of resource availability whilst the world’s population continues to increase. The issues and opportunities for sustainable increase of rice production differ from one rice ecosystem to another due to degrees of intensification, crop management operations, and differences in environmental and socio-economic conditions. The existing, improved and promising technologies can employee to boost farmers’ production and to increase their incomes, while ensuring sustainable rice production. By employing improved production methods can restore homeostatic mechanisms conductive to community stability, optimize the rate of turnover, ensure an efficient energy flow, and encourage local production of food items adapted to the natural and socioeconomic settings. This can reduce costs whilst increasing the efficiency and economic viability of small and medium-sized farms by promoting a diverse, potentially resilient agricultural system. This manuscript illustrates a case study of technological improvement introduced for manual rice seeder used for line hill seeding. Also, it provides a comparison between performance of manual broadcasting and improved manual conical rice hill seeder.

Keywords
rice seeder, sustainable rice production, performance.

Introduction

Rice cultivation plays significant role in south Asia as it is the most important staple food crops grown in sequence [1, 2]. Inadequate Planting density and delayed transplanting are the major yield-limiting factors causing approximately 20% yield reduction [3, 4]. The non-availability of skilled labour at the planting season delays rice transplanting and ultimately results in poor yield. Mechanical transplanting was tested but failed under local condition due to high requirement for trained labour and high rate of missing hills [5].

In Sri Lanka, rice being one of the leading cereal crops of the country occupies first position as the staple food of the people and supplies more calories than any other cereal. In addition rice cultivation occupies 34% of the total cultivated land of the country and 1.8 million farmer families are engaged in rice cultivation [6]. For instance, in Pakistan, rice crop plays a vital role in the economy of Pakistan as it contributed about US $ 1.132 billion to the total national foreign earning during 2005–2006 [7] and rice is grown on an area of 2.5 million hectares, with annual production of 4.95 million tones and an average yield of 1970 Kg/ha [8]. However, other rice growing coun-
tries of the world like; Australia, Japan, U.S.A and Mexico have comparatively high yields 10269, 6997, 6219, 6059, 5283, 5650 and 4738 Kg /ha, respectively. Hence, it is vital to increase rice production as well as its effectiveness and efficiency with the help of appropriate mechanization.

There exists a great scope of increasing rice production as present yield level is much lower than the potential of the existing varieties. Traditionally, rice has been transplanted in puddled soil containing a plow pan developed due to the long-term puddling (wet-tillage operation) [9]. There might be a number of factors contributing to the low yield of this crop. The main cause of low density of rice plant is scarcity of labor during the peak period of rice transplantation. Therefore, the lack of labor along with the increased labor cost has compelled the engineers, researchers, scientists and farmers to think about the substitution of conventional ways of rice transplanting. The only alternative for labor is mechanization. Among the various activities in rice cultivation, plant establishment is the least mechanized activity. The aim of plant establishment is to establish a plant population whose spacing contributes to the maximum return per surface area [10].

Although manual transplanting is the common method of rice cultivation but it is too much laborious, cumbersome, time consuming and entails a lot of expenditure on raising, uprooting and transplanting of nursery. Also, transplanting has added disadvantages such as stress on seedlings and raising nurseries. Despite the fact that mechanized transplanting is the best method of plant establishment, it is not feasible to introduce it at this moment due to lack of local technology and also due to high machinery cost which farmers cannot afford. Careless transplanting by hired labor results in low planting densities in the farmer’s field. The scarcity and high cost of farm labor invariably delays transplanting and often leads to the use of aged seedlings [11] which causes low yield [12]. Hence manual transplanting results in yield reductions due to low plant population. In many parts of the world alternative methods such as manual or mechanized broadcasting are being practiced. For instance, majority of Sri Lankan farmers follow traditional manual broadcasting. It is an old method of planting rice, a good option for very clear reason, where, reduction of labor cost, though it has many disadvantages such as excessive seed usage and high plant density which leads to competition among plants.

Seed distribution refers to the planting of seeds according to a predetermined pattern [13]. Dropping Seeds at an equal interval and nearly uniform number has the potential to further reduce seed requirement per hectare to achieve uniformly spaced planting similar to transplanted rice providing enough space to grow [14]. Optimizing the density of plants is a prime importance, and this requires precision in terms of seed metering and distribution by the seeding machine. The objective of seed metering is accurate and uniform seeding [15] causes no damage to the seed [16].

Line seeders have been introduced by various institutes and personals over the past decades in order to achieve aforementioned requirements. All of them have advantages as well as unique disadvantages. As such, line seeding is still not popular among farmers. Furthermore, numbers of researchers have reported that the direct sowing of paddy rice using a drum seeder has resulted in lower cost of production and higher yield as compared to manual transplanting [17–20]. However, it has been observed that the flow rate of paddy rice seed through the orifices on the circumference of drum is not uniform during operation leading to variation in seed spacing and seed rate [21]. A non-linear increase in seed rate with decrease in the percent fill of drum has been observed [22]. Hence, a study started to eliminate shortcomings of existing rice seeders. This manuscript describes the improvements made to eliminate shortcomings of existing rice seeders. Also, it provides a comparison of performance with respect to formal drum seeder.

**Technological opportunities for sustainable rice production**

Presently, the world’s population continues to increase whilst global rice production is confronting issues such as climate change and the scarcity of water, land and energy resources. The issues and opportunities for sustainable increase of rice production differ from one rice ecosystem to another due to differences in environmental and socio-economic conditions, degrees of intensification, and crop management operations. However, the existing, improved and promising technologies can employ to boost farmers’ production and to increase their incomes, whilst ensuring sustainable rice production [23].

To emphasize long-term sustainability rather than short-term productivity, the system shall reduce energy and resource use; employ production methods that restore homeostatic mechanisms conducive to community stability, optimize the rate of turnover and recycling of matter and nutrients, maximize the multiple-use capacity of the landscape and ensure an efficient energy flow; encourage local production of food items adapted to the natural and socioeconomic-
ic setting; and reduce costs and increase the efficiency and economic viability of small and medium-sized farms, thereby promoting a diverse, potentially resilient agricultural system [24]. Hence, in order to achieve sustainable rice production, it is essential to have a new orientation (e.g., reengineering of agriculture mechanization), new strategies and an unprecedented commitment from national policy makers.

In addition, this kind of production requires the collective effort of all the stakeholders involved in rice development: researchers, engineers, service providers, seed producers, farmers, traders, etc. Information on rice and its production factors and latest development in technologies are essential for constructive efforts towards sustainability in rice cultivation. Hence, the advances in various areas should be worked out and shared among researchers and further disseminated to farmers for their widespread adoption. Hence, current study focused to develop a manual row seeder which would seed pre-germinated paddy uniformly with minimum operator skill. The machine was designed with the following requirements in mind: 1) lightweight for one man operation; 2) locally manufactured; 3) simple and low cost, to achieve sustainability requirements.

Current status of drum seeders

Various types of drum seeders were produced by individuals and institutes and all these seeders have several features that are common. They have several cylindrical shape drums to contain seed and these drums are rotated by an axle connected to one or two wheels. Also there is a handle to pull the seeder. The seeds are dropped from the openings at the circumference of both sides of the drums (Fig. 1 and Fig. 2).

All these seeders have following shortcomings/disadvantages at Sri Lankan farming conditions:

- All are band sowing, without having a distance between plants within the row,
- When the drum is full of seeds, the seed rate is low and it becomes high when the seed level gets low making irregular seed rate,
- Difficult to use in small plots which are common in Sri Lanka,
- No proper mechanism to control seed rate according to size/variety of the seeds.

Initial design: a conical drum seeder

During the initial design, following design criteria has been taken into consideration.

1. A uniform seed rate should be maintained.
2. Seeds should be planted in hills in spacing of 20 cm × 10 cm.
3. Manually operated hence light in weight.
4. Should be floated in boggy fields.

To obtain a uniform flow rate, the drum is made into conical shape, so that grains flow to the bottom most position due to the gravity. To obtain hill sowing, grains are allowed to flow through a tube, so that there will be a delay when dropping out from the drum (see, Fig. 3 and 4). Inside the drum, agitators are fixed to block the flow of grains as when grains get a centrifugal flow, it prevents falling out from the seeder. A floater is designed and attached to float at boggy conditions and sheet metal of gauge 18 is used to fabricate drum and skid/floater.
Figure 4 illustrates the configuration of the initial design of the conical drum seeder on a paddy field. The initial design had three drums forming 6 rows at once. Drums are fixed to an axel (see, Fig. 5: Part 8) which is connected to two wheels (see, Fig. 5: Part 2) having lugs to facilitate rotating even at boggy fields. A skid (see, Fig. 5: Part 13) is attached to the frame for floating at boggy conditions. It is also designed to open furrows. Two rows of orifices are provided on the circumference of each drum in order to obtain recommended spacing of 20 mm between the rows and 15 mm between hills [26]. Drums are rigidly fitted on the axel. Wheels of about 60 cm diameter are connected to the axel such that when the wheels rotate, drums rotate along with shaft and wheels placing 12 hills in 6 rows per revolution. Handle (see, Fig. 5: Part 9) is connected to the axel by nylon/steel bushes. Skid is supported by the frame and hinged to the axel so that the operator can adjust the angle according to his height and field condition.

In order to make use the conical drum seeder effectively, three steps (field preparation, seed preparation, and seeder application) have been identified as follows.

**Field preparation**

The initial field preparation for the seeder is same as for manual broadcasting or transplanting. After the 2nd or 3rd tillage, field should be properly puddled. Day before seeding, excess water should be cut off and the field should be properly leveled. It is advisable to put low number of canals as possible and the canals should be put perpendicular to the direction of seeder application (Fig. 3).

**Seed preparation**

Seed are soaked in water for nearly 36 hours and drained and incubated for 24 hours. Pre-germinated seeds are used at the stage where only the sprout has immerged from the seed. If seeds are incubated more than 24 hours, immerged roots get entangled inside the drum and prevent seeds dropping out from the seeder.

**Seeder application**

Drums are filled with grains up to 2/3rd from the feeder and pulled along the field as shown in Fig. 3. It is advisable to pull along the lengthwise of the field as it will reduce the number of turnings. The floater/skid should be adjusted according to the height of the operator and also the field condition.

**Challenges identified in the initial design and major modifications in the revised design**

Nearly 25 trails were done with the initial design of the conical drum seeder and following challenges were identified.

1. No proper mechanism to control the seed rate according to the variety of the seed.
2. Note: If the hole (Fig. 4) size is kept at 12 mm for Nadu (a long grain rice), excessive number of Samba (a short grain rice) are dropped. If the hole size is kept at 8 mm for Samba, Nadu will not drop at all. Hence a mechanism is needed to control the hole size according to the variety.
3. The weight of the machine is excessive (25 kg without seeds).
4. Difficult to turn at end of the plot, need a support of another person.
5. Drums and floater/skid get corroded easily as used in mud.
Hence, after a several modifications the model illustrated in Fig. 5, has been finalized and fabricated for testing.

1. The drum of the new design consists of two parts, an inner and an outer (see, Fig. 6: Part 4 and Part 5). 8 mm and 12 mm holes are drilled on the periphery of the inner and 12 mm holes are drilled on outer. Outer drum can be rotated relative to the inner. When 12 mm hole of outer coincide with inner 12 mm hole, Seeder is set to Nadu varieties. When 8 mm hole of inner is co-inside with 12 mm hole of outer, Seeder is set for Samba varieties. Seed rate can be adjusted by offsetting the two holes by trial and error.

2. In the new design also, drums are kept conical shaped as earlier design proved that conical shape gives a uniform flow rate. But both the drum and skid/floater are fabricated with fiber glass to prevent corrosion and to reduce weight. Though the ideal material is plastic, it is not possible to use it at this stage due to the high cost of molding.

3. Numbers of drums are reduced from three to two to reduce weight and facilitate turning (see, Fig. 7).

Performance indicators and formulas for performance evaluation of conical drum seeder

For evaluating the performance of the conical drum seeder the indicators were selected and illustrated in Table 1 [27].

<table>
<thead>
<tr>
<th>Performance indicator</th>
<th>Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical Field Capacity</td>
<td>( C )</td>
</tr>
<tr>
<td>Effective Field Capacity</td>
<td>( EFC )</td>
</tr>
<tr>
<td>Field Efficiency</td>
<td>( FE )</td>
</tr>
<tr>
<td>Seeding Rate</td>
<td>( S_r )</td>
</tr>
<tr>
<td>Missing Hills</td>
<td>( M_h )</td>
</tr>
<tr>
<td>Wheel Slippage</td>
<td>( S_w )</td>
</tr>
</tbody>
</table>

Equations

The equation for each performance indicator is as follows.

\[
C = \frac{S \cdot W}{10},
\]

where \( C \) – theoretical field capacity [ha/hr] (Note: 1 ha = 0.01 km\(^2\), \( S \) – forward speed [km/hr], \( W \) – width of cut of the device [m].

The EFC includes the time lost during the actual field operation such as time lost due to turning, loading, adjustment and other time losses during the operation.

\[
EFC = \frac{A}{T},
\]

where \( EFC \) – effective field capacity [ha.hr\(^{-1}\)], \( A \) – area [hectare], \( T \) – time to finish the area [hr].

\[
FE = \frac{EFC}{C} \times 100,
\]

\[
S_r = \frac{W_{seeds}}{A} \times 100,
\]

where \( W_{seeds} \) – weight of seeds consumed [kg], \( A \) – area [ha].

\[
M_h = \frac{(H_T - H_A)}{H_T} \times 100,
\]

where \( H_T \) – theoretical number of hills to be seeded, \( H_A \) – actual number of hills to be seeded.

\[
S_w = \frac{(\pi D_w N - L)}{\pi D_w N} \times 100,
\]

where \( D_w \) – diameter of the wheel, \( N \) – number of revolutions travelled, \( L \) – actual distance travelled in \( N \) revolutions.
Data analysis and discussion

Effective Field Capacity is calculated assuming that an average farmer works 8 hours a day continuously, which shall not practically correct. In actual practice, the speed of travelling of a farmer can decrease with time due to hard labor and also there are other time expenditures such as lunch breaks and rests. Hence, in reality, the EFC value will be much lower if a single person operates the conical drum seeder. It is also noted that the EFC value is almost same as in manual seed broadcasting. The seed rate is approximately 25 kg/ha. However, in conventional manual broadcasting a farmer uses nearly 101 kg/ha. Therefore, by utilizing mechanized approach with conical drum seeder, about 75% of seed paddy is saved. Wheel slippage is negative as due to the floating or skidding, where, the machine tends to float in boggy conditions. Table 2 illustrates the values of the conical drum seeder performance.

<table>
<thead>
<tr>
<th>Performance indicator</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical Field Capacity</td>
<td>0.22 ha/h</td>
</tr>
<tr>
<td>Effective Field Capacity</td>
<td>0.18 ha/h</td>
</tr>
<tr>
<td>Field Efficiency</td>
<td>81%</td>
</tr>
<tr>
<td>Seeding Rate</td>
<td>25 kg/ha</td>
</tr>
<tr>
<td>Missing Hills</td>
<td>3.70%</td>
</tr>
<tr>
<td>Wheel Slippage</td>
<td>−1.50%</td>
</tr>
<tr>
<td>Average Row Distance</td>
<td>19.3 cm</td>
</tr>
<tr>
<td>Average Hill Distance</td>
<td>13.4 cm</td>
</tr>
</tbody>
</table>

Conclusion

It can be concluded that the conical drum seeder application saves seed paddy nearly by 75% and increase yield significantly, if proper field management practices are followed, compared to traditional manual seed broadcasting. Also, the study indicates how technological improvements reinforce sustainable rice production via low cost and low energy consumed mechanization.

Further research should be carried out to compare different kind of manual hill seeders’ performance and make a yield comparison between conical drum seeder and manual broadcasting.

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