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Design, Development and Performance Evaluation of a Pull Type Single Row Maize Seeder

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ABSTRACT

Maize (*Zea mays)* is the second most widely grown cereal crop in Sri Lanka. As the attention for mechanization is very poor, high labor cost is the crucial problem in maize cultivation. Despite having several seeders in the market, farmers are unwilling to use them due to high initial cost and some operating drawback. Therefore, this study intended to introduce a user-friendly and affordable maize seeder with high capacity and efficiency. The fabricated seeder's performance was tested in both completely prepared (with primary and secondary tillage) fields and incompletely prepared fields (only with secondary tillage) using male and female laborers, separately with three replicates. The suitable forward speed for the better operation was 0.25 ms^{-1}. The within row spacing is properly maintained by the machine itself, and between row, spacing is controlled by the operator with the help of the marker. The results manifested that, the actual field capacities for female and male laborers at completely prepared fields were 0.12 hah^{-1} at 79% efficiency and 0.13 hah^{-1} at 82% efficiency respectively. Corresponding values in incompletely prepared fields were 0.11 hah^{1} at 76% efficiency and 0.11 hah^{-1} at 78% efficiency, respectively. The results showed that the type of land preparation and gender do not affect (p>0.05) on the machine's efficiency. Due to the affordability, user-friendliness, higher capacity and efficiency, the machine can be recommended for maize cultivation in Sri Lanka.

1. Introduction

Sri Lanka is an agricultural country and agriculture acts the leading role in the economy of the country. Annual crops, such as paddy, maize, sugarcane, green gram, vegetables, finger millets, cover about 0.887 million hectares [1]. Maize is one of the important cereal crop, around 50,000 ha of land dedicated annually. Maize is second only to rice from total cereal cropped area in Sri Lanka. Maize productionis 32011 mt in *yala* 2017 and 163733 mt in *maha* in 2016/2017 [2].

Our annual maize requirement is about 200,000 mt from which we imported about 125,000 mt. Imports have significantly dropped since the increment in production; in 2011, only 8244 mt were imported against 83195 mt imported in 2008 [3].

Maize cultivation comprises several management practices such as land preparation, seeding, fertilizer application, weeding and earthingup, irrigation, harvesting and threshing. Seeding is one of the most important maize cultivation practices as the maize yield depends on the sowing depth and inter and intra row spacing. Researches such as Malaviarachchi et al. [5] found that 'labor cost for seeding account for 16% of the total production cost of maize'. Manual seeding is the most popular and widely used technique for maize seeding in Sri Lanka. Major drawbacks of the manual seeding are difficulties maintaining the seed rate, highly time-consuming and causing severe muscle pains to farmers. Although high tech heavy machines with higher capacities are in practice in some countries, existing mechanization in Sri Lanka is not satisfied. Despite having several mechanical seeders/ planters in Sri Lankan market, most of the farmers are reluctant use those due to several drawbacks like high initial cost, low seeding efficiency and accuracy of available small scale seeders, difficulties in operating some seeders due to poor land preparation practices, muscle pains and some muscular-skeletal disorders.

A recently introduced single row seed driller, popularly called *Atabatta* in the farming community is somewhat popular among farmers for seeding due to its low weight and low cost. However, Senarathne et al. [4] found that 'the capacity and efficiency are not satisfied and both within the row and between row spacing cannot be controlled'.

Therefore, by introducing an efficient seeder with all the Sri Lankan small-scale maize farmers' requirements and their fields, both the production and profitability can be increased. This study aimed to introduce a low-cost seeder by overcoming the problems mentioned above to make the small-scale maize cultivation easy.

2. Material and Methods

All the design and fabrication work was carried out at the Engineering workshop, and the evaluation process was carried out at the research field of Faculty of Agriculture, Rajarata University of Sri Lanka.

2.1. Design Considerations

Single seed metering mechanism was used as the seeder's main metering mechanism, and bulk seed metering mechanism was used to fill the seed container from the refill bottle. The diameter of the seeder's traction wheel was 95 mm in order to have 300 mm circumference, because of drive sprocket is connected with the shaft of the wheel. Power is transmitted to the metering mechanism from the traction wheel with chain and sprockets. Manual power was expected to operate this seeder in order to reduce the operational cost and production cost. The seeder's operation should be conducted on both completely prepared lands according to the recommendations using four-wheel operated disk plough and rotovator and incompletely prepared lands only using four-wheel operated rotovator so that majority of the Sri Lankan farmers can get the advantages from the seeder. Pull type operation was conducted, because of required power can be applied easily on any field condition. Light, but strong materials were used to facilitate the manual operation, and seed tank was designed with two sections as seed container and refill unit to minimize the weight.

2.2. Components of the Maize Seeder

Main components of the maize seeder were seed container, seed refill unit, seed metering mechanism, furrow opener, furrow closer, ground wheels, power transmission system and handle. Figure 1 shows the main components of the pull-type single row maize seeder.

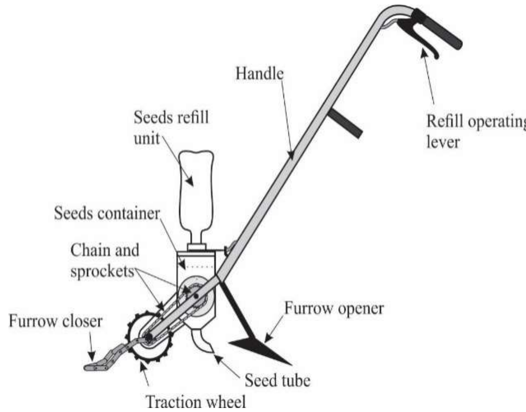

Figure 1: Components of the pull type single row maize seeder

Designing of the Seeds tank

The seed tank consists of seed refill part and seed container. A disposed of plastic bottle with 400 cm^3 capacity was used as seed refill part to reduce the machine's weight and the cost. The seed capacity of this bottle is 350 g (1250- 1300 seeds). The volume of the seed container is 350 cm^3 in order to carry 300 g of maize seeds. Therefore, the total capacity of the seed tank is 750 cm^3 so that 650 g of maize seeds can be put in the tank. Figure 2 shows the front view and side view of the seeds tank.

The volume of the trapezoidal sections was calculated using the following equation [6].

$$V = [\frac{a+b}{2}] \times h \times l$$

Where, *a* is the top width, *b* is bottom width, *h* is height between top and bottom and *l* is height of the trapezoidal.

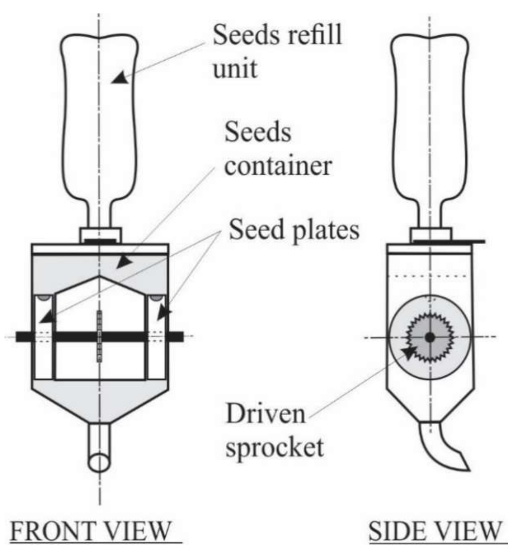

Figure 2: Front and side views of the seed tank

All the slopes of sidewall of the seed container were higher than 50^0, because Atere et al. [7] found that the maximum repose angle of maize is 46.66^{0}'. Mohsenin [8] has argued that the angle of repose is the angle with the horizontal at which the materials will stand when piled. Abiodun et al. [9] reported that 'the angle of the slope is higher than the repose angle; seeds can freely flow down under the gravity'.

The seed tube is underneath the seed tank, and it comprises of two parts as funnel shape upper part and transparent tube.

Designing of Furrow Opener and Closer

The design of furrow openers of seed planters varies to suit the soil conditions of a particular region. In this design, the furrow opener was duck foot shape, and the width of the furrow was expected as 60 mm. The furrow opener is located in front of the seed tube. The furrow closer was designed to close the furrow made by furrow opener properly and here it was used a heavy chain for this purpose.

Designing of Ground Wheels and Metering Mechanisms

The ground wheels or the traction wheels are the devices that help to move the seeder facing for the friction created by the soil and at the same time rotating power is transmitted to operate the metering mechanism. The metering mechanism's purpose is releasing one seed from the seed container and delivering it to the planting hole by maintaining the proper spacing. Seed metering of the seeder is done with two mechanisms as bulk seed metering and single seed metering. Bulk seed metering mechanism releases maize seeds from seed refilling unit to seed container. As the seed container's lid is made of transparent plastics, when the seed container is empty, seeds can be supplied to the seed container from the refilling unit by operating a lever of the handle. Single seed metering mechanism consists of two rotating plates, rotating through the seed container. Atere et al. [7] state that 'the maximum effective diameter of a maize seed is 9.2 mm'. Two holes with a depth of 10 mm and diameter of 10 mm were made on the periphery of the wheel to carry one maize seed by a plate. Rotating plates were placed just below the seed container.

Designing of Power Transmission System

Chain and sprockets were used to transmit the power from ground wheels to the seed metering mechanism to avoid the slips. The diameter of the ground wheel is 95 mm so that the circumference is nearly 30 cm. The spacing between two planting holes within a row is expected to have 60 cm. Therefore, the speed ratio between ground wheels and seed plates should be 2:1. The drive sprocket is connected to the shaft of the ground wheels, and the driven sprocket is connected to the shaft of the seed plates. Akinnuli et al. [10] showed the relationship between speeds and number of teeth of sprockets is given by the following equation.

$$\frac{N1}{N2} = \frac{T2}{T1}$$

Where *N1* is the speed of the drive sprocket, *N2* is the speed of the driven sprocket, *T1* is the number of teeth of the drive sprocket, and *T2* is the number of teeth of the driven sprocket. As the number of teeth of the drive sprocket was 14, according to the equation, the number of teeth of the driven sprocket should be 28.

2.3. Material Selection

According to Khurmi and Gupta [11], the materials' availability, the suitability of the materials for the working conditions and the cost of the materials are the major factors that should be considered when selecting materials for a machine. Table 1 summarizes the selection of suitable material for each component of the machine and the criteria considered at the selection.

Table 1: Material and selection criteria for each component

Component	Selected material	Criteria for selection
Seed tank	Galvanized metal sheets	Corrosion resistance, Cost, Workability
Seeds refill unit	Plastic	Lightness, Cost
Shafts	Mild steel	Workability, wear resistance, strength
Handle	Galvanized steel	Strength, Lightness, and Corrosion resistance
Ground wheels	Mild steel	Strength, cost, wear resistance and availability
Seed plates	Wood	Lightness, Workability

2.4. Performance Evaluation

The performance of the newly fabricated pull-type single row maize seeder was evaluated at different field conditions with both male and female laborers. Twelve plots (Plot size – 5 m ×10 m) were prepared at the research field, Faculty of Agriculture, Rajarata University of Sri Lanka. Since most of Sri Lankan maize farmers practice only secondary land preparation attention was paid to evaluate the new design maize seeder at an incompletely prepared land also. Primary land preparation was done using a four-wheel tractor operated disc plough and the four-wheel tractor driven rotavator was used for the secondary preparation. Ambient temperature, wind speed, relative humidity and rainfall data were recorded before field testing. The moisture content of soil (% dry weight basis by oven-dry method) and bulk density (gcm^{-3}) (by core sampler method) of prepared plots were measured using following equations [12].

$$\text{Soil moisture (\%)} = (\text{Mass of moisture in soil sample} / \text{Mass of oven dried soil sample}) \times 100$$

$$\text{Bulk density of soil } (\text{gcm}^{-3}) = (\text{Mass of the soil of core sample} / \text{Volume of the core})$$

Performance evaluation was done under four treatments and each treatment consisted of three replicates.

T_1 - Complete land preparation with female labor (consists of primary land preparation and secondary land preparation)

T_2 - Incomplete land preparation with female labor (consists only secondary land preparation)

T_3 - Incomplete land preparation with male labor

T_4 - Complete land preparation with male labor

The experimental design was two factor factorial Complete Randomized Design (CRD).

At the evaluation process, time taken to complete one row (10 m), the area covered within 1-hour, the average depth of seeding, number of seeds per hill, within row spacing, between row spacing, number of seed emerged and time loss per one row were recorded. Travelling speed, theoretical field capacity, actual field capacity and field efficiency were calculated using the following formulae [12, 13].

$$\text{Travelling speed } (\text{ms}^{-1}) = \text{Travelling distance(m)} / \text{Time taken(s)}$$

$$\text{Theoretical field capacity } (\text{hah}^{-1}) = [\text{Rated speed } (\text{kmh}^{-1}) \text{ x Rated width (m)}] / 10$$

$$\text{Actual field capacity } (\text{hah}^{-1}) = \text{Area covered (ha)} / (\text{Actual operating time (h) x } 10000)$$

Getting User's Feedback

Feedback of twenty operators, including all the operators involved in the evaluation process, was collected using a pre-tested questioner. According to the operators' view, comments on the appearance, user-friendliness and affordability were collected and summarized.

3. Results and Discussion

After a series of field trials and some modifications, a successful seeder for maize cultivation was manufactured. The total cost of production, including both material and labor of the machine was LKR. 6500.00. The fabricated Pull-type single row maize seeder is shown by following Plates 1 and 2.

Plate 1: Fabricated pull type single row maize seeder

Plate 2: Seeds tank of the pull type single row maize seeder

3.1. Specifications of the Pull Type Single Row Maize Seeder

Specification of the newly designed pull-type single row maize seeder is shown in Table 2.

Table 2: Specification of the machine

Parameter	Specification
Total weight	4.65 kg
Width of the machine	20 cm
Diameter of seed metering wheel	9.5 cm
Diameter of ground wheel	9.5 cm
Length of the handle	115 cm
Capacity of seed tank	300 g
Capacity of the seed refill unit	350 g
Field capacity of the seeder	0.1182 ha h^{-1}

3.2. Performance of the Pull Type Single Row Maize Seeder

Actual Field Capacity, Theoretical Field Capacity, Field Efficiency, seeding depth, within row spacing and between row spacing at different field conditions with male and female laborers were used to elaborate the performance of the maize seeder. Table 3 shows the relevant figures for the above parameters.

According to Table 3, under the given conditions, the average forward speed of any field condition was 0.25 ms^{-1} while it was 0.26 ms^{-1} in completely prepared fields (T_1 and T_4). Due to the comparatively higher uniformity in completely prepared fields, the forward speed had shown a higher value in completely prepared fields. The average Actual Field Capacity of the seeder was 0.12 hah^{-1}. The highest Actual Field Capacity (0.13 hah^{-1}) had shown by male laborers in completely prepared fields. The female laborers also have shown a higher field capacity in completely prepared fields compare to the incompletely prepared fields. Uniformity and fine soil particles in the field facilitate the convenient operation of the seeder in completely prepared fields. Almost similar result has shown by a manually operated push type maize seeder introduced by Rabbani et al. [14] recording 0.13 hah^{-1} of average actual field capacity under 77% efficiency.

According to Senarathne et al. [4], the field capacity of manually operated single row seed driller (*Atabatta*), one of the very popular mechanical maize seeders in Sri Lanka, has recorded that 0.098 hah^{-1} under 71% field efficiency. The average field efficiency of the newly introduced manually operated pull-type maize seeder was 79%. The highest efficiency (82%) has shown in completely prepared fields by male laborers. Actual Field Capacity, Theoretical Filed Capacity and efficiencies in each treatment were statistically analyzed. All the probability values are greater than 0.05, and it reveals that there is no significant difference in theoretical field capacities, actual field capacities and filed efficiencies on level of land prepared and gender of the operator. The lightweight of the seeder, user-friendliness and no special knowledge required for the operation were the reasons to have no significant difference between genders of laborers.

Department of Agriculture in Sri Lankan has recommended 60 cm × 30 cm one plant per hill or 60 cm × 60 cm with two plants per hill especially for tall varieties to provide more sunlight [15]. In this study, it has shown that the average within row spacing is 65.02 cm and average between row spacing is 62.07 cm. Wheel slippage happens in the field due to the conditions of the field affects this inaccuracy. However, both within the row and between row spacing of the manually operated single row seed driller (*Atabatta*) cannot be controlled.

Table 3: Evaluation parameters of the pull type single row maize seeder

Parameter	T_1	T_2	T_3	T_4	Average	P values
Average forward speed (ms^{-1})	0.26	0.24	0.24	0.26	0.25	-
Actual Field Capacity (AFC) ha h^{-1}	0.1232	0.1094	0.1123	0.1279	0.1182	0.3245*
Theoretical Field Capacity (TFC) ha h^{-1}	0.156	0.144	0.144	0.156	0.1500	0.0522*
Field Efficiency (%)	79	76	78	82	79	0.7311*
Average depth of seed placement (cm)	4.08	3.52	3.36	4.04	3.75	-
Average spacing between 2 rows (cm)	62.23	63.04	62	61.01	62.07	-
Average spacing between 2 planting holes within a row (cm)	62.46	67.16	66.96	63.52	65.02	-

*Not significantly different at p>0.05, Ambient temperature = 27.8 °C, Relative humidity = 53.62%, Wind speed = 0.417 kmh-1, MC =5.34%, Bulk density = 1.64 gcm^{3-}

The average planting depth is recorded as 3.75 cm, and it is in the recommended range of the Department of Agriculture (2-4 cm depth for adequate moist soil and 5- 10 cm for dry planting [15]).

3.3. User's Feedback on the Seeder

Summary of the feedback of twenty operators involved in the questionnaire survey is given in the Table 4.

According to the feedback summary, every aspect considered in the questionnaire survey is appreciable, but there is a possibility to improve them more except the safety. According to the operators' experience during the operation, all the operators have commented positively on the user-friendly nature of the seeder.

Table 4: Summary of user's feedback

	Very good	Good	Satisfactory	Bad	Very bad
Weight of the seeder	70%	30%	-	-	-
Safety of the operator	100%	-	-	-	-
Overall performance of the machine	80%	20%	-	-	-
Appearance of the product	80%	10%	10%	-	-
Overall product quality	50%	50%	-	-	-
Affordability of the machine	80%	20%	-	-	-

4. Conclusion

The newly introduced manually operated pull-type maize seeder has shown very satisfactory results, 0.12 hah^{-1} under 79% field efficiency. Recommended spacing for the maize cultivation can be maintained easily while keeping the recommended planting depth. As the seeder's capacities for both male and female are almost the same, it can be concluded that both male and female laborers can conveniently operate the device without any special skill. According to the feedback of users, it can be concluded that the safety, weight of the machine, appearance of the machine, affordability and overall performance of the machine are up to the expected level.

As the total production cost is meager (LKR 6500.00), the manually operated pull-type single row maize seeder is affordable even for small scale farmers. Overall, the manually operated pull-type single row maize seeder can be recommended for maize cultivation.

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