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MANUFACTURING AND TESTING OF LOCAL RICE TRANSPLANTING MACHINE

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Abstract

Mechanical transplanting of rice is considered one of the safest methods of rice cultivation. It is also one of the most desirable methods for Egyptian farmers, saving about 70% of the seeds, saving labor costs, better plant density, water saving, and weed control. Due to the fragmentation of agricultural holdings in Egypt and the high costs of mechanical transplanting with imported machines, the research aimed to manufacture a rice transplanting machine with local materials suitable for small rice holdings and achieve the technical recommendations of Egyptian conditions. Also, testing and evaluating the manufactured machine under different operation conditions. The rice transplanting machine was manufactured and tested at the Rice Mechanization Center, Agricultural Engineering Research Institute, Egypt. The machinecontains five rows and the distance between each row is 20 cm. The manufactured transplanter was tested and evaluated under four different forward speeds (1.00, 1.25, 1.50, and 1.75 km/h), four different intra-row hill spacing (16, 18, 20, and 22 cm), and two seedling cross-section area (1.00 and 2.00 cm^2). The obtained results indicated that the lowest percentages of missing, floating, and damaged hills were 2.92, 1.83, and 0.27%, respectively.The highest transplanting efficiency and field efficiency were94.98 and 83.75%, respectively, obtained at themachine forward speed of 1.00 km/h, intra-row hill spacing of 22 cm, and seedling cross-section area of 2.00 cm^2. Also, the lowest value of requirement energy was 4.599 kW.h/fed, which achieved the highest actual field capacity of 0.285 fed/h obtained at forward speed of 1.75 km/h, intra-row hill spacing of 22 cm, and seedling cross-section area of 1.00 cm^2.

***Key words**: mechanical transplanting, local rice transplanter, hill spacing, rice seedlings*

INTRODUCTION

Rice (*Oryzasativa* L.) is the most popular grain crop in Egypt because it is considered the major food for over 50% of Egyptians. Egypt cultivated about 1.309 million feddan of rice with a total production of about 4.89 million tons [5]. Mechanization of the operations in rice crop in Egypt is very important from seeding till harvesting [6]. The direct seeding of rice and transplanting are the two common rice cultivation methods. The transplanting method is more prevalent among farmers because of less weed growth and higher yield than direct seeded rice [9]. Rice is largely grown traditionally by manual transplanting. Manual transplanting requires numerous labors besides involving drudgery, and is also expensive. The scarcity of labor is another main problem in some paddy-growing areas in our country [1]. The mechanical transplanting of paddy has been considered the most promising option, as it saves labor, ensures timely transplanting, and attains optimum plant density that contributes to high productivity [10]. The mechanical transplanting offers higher field capacity than manual transplanting. Thus, farmers can transplant rice seedlings within an appropriate and very short time by mechanical transplanter [7]. Abdrabo [2] developed a double-purpose machine prototype for rice transplanting, locally manufactured, and evaluated. The proposed transplanter is 4 rows planting machine, and propelled on three ground wheels to suit small-scale farms. It fits both the traditional rice seedlings method, and the trays seedling method. The obtained results revealed that the maximum field capacity values were 0.29, and 0.283 fed/h, and the highest transplanting efficiency values were 72 and 68%, as the developed prototype was accomplishing the traditional, and in trays seedling methods. The present rice transplanters rows spacing is fixed at 30 cm, and this distance does not agree with technical recommendations for rice cultivation in Egypt. So he modified the planting unit mechanisms of a Japanese rice transplanter to suit narrow row spacing (20 cm). The developed transplanter was tested under different operating speeds (6.98, 7.85, and 8.96 m/s) to get different spaces under actual field conditions. He found that the lowest defective hills percentage was 4.3% and the highest distribution uniformity of lateral space was 99% was achieved as the developed machine at a finger speed of 6.98 m/s compared to 3.9% and 99.5% for the transplanter before modifications [4].Asha et al. [3] developed a manual (pull-type) two-row paddy transplanter. The developed transplanter can be helpful for small and marginal landholdings. They develop equipment that should be low-cost, fabricated locally, versatile in utility, reducing drudgery by making transplanting possible without bending, and useful for small farmers. The actual field capacity of 0.2 ha/day (8hours working daily) was achieved with the machine by considering a 5% - and 3%-time loss because of turning and filling trays, respectively. RRTC [11] recommended that planting spaceis 20 × 15 or 20 × 20 cm(row spacing × hill spacing)for Egyptian rice variety Sakha super 300 to obtain the higher grain yield The problems of this research are that the rice transplanters are imported from abroad at a high price, especially for smallholdings. Also, the distance between the rows of the transplanter is 30 cm, and this distance does not meet the farmer's desire in terms of the required density. Also, it does not fulfill the recommendations of the Rice Research Department, which recommends that the distance between the rows must be 20 cm to achieve the required plant density under Egyptian conditions. Therefore, the objectives of the current study areto manufacture a rice transplanting machine with local materials suitable for small rice holdings,and achieve the technical recommendations of Egyptian conditions. Also, testing and evaluating the manufacture machine under different operation conditions.

MATERIALS AND METHODS

The field trials were executedatRice Mechanization Center, Meet El Deeba, Kafr-El-Sheikh Governorate, Egypt, during the agricultural season of 2022 for Sakha super 300 (common Egyptian rice variety)

Materials

The manufactured ricetransplanting machine

The manufactured rice transplanting machine consists of main frame, transplanting unit, power source, power transmission system, guide rail, seedlings mat, floats, and drive wheels. The machine contains five rows, and the distance between each row is 20 cm,as shown in Photo 1.

Photo 1. The manufactured rice transplanting machine
Source: Authors' own illustration.

1. Main frame

The main frame of the manufactured transplanterwas made from square mild steel hollow sections (20×20×1.25 mm, height, width, and thickness, respectively).The main frame dimensionswere1300×950×440 mm, length, width, and height, respectively. The square sections were cut and welded together to form the main frame, as shown in Photo 2.

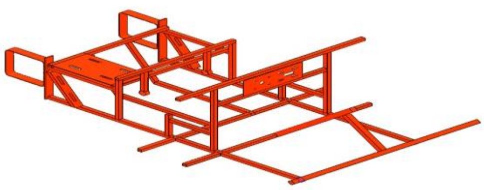

Photo 2. The main frame of the manufactured rice transplanting machine
Source: Authors' drawing.

2. Transplanting unit

The function of the transplanting unit is to pick the selected number of seedlings from the seedlings mat and transplant it into the soilin a standing position. It consists of two mechanisms. The first one is the transplanting mechanism which includes a transplanting arm (four-bar linkage mechanism), a finger holder with five planting tines, and a crankshaft to operate the mechanism. The second mechanism is the seedling push mechanism, which includes five seedling push rods mounted on one shaft called the push rods holder, two cams equipped with two levers, and four springs.

A. Four-bar linkage mechanism

A four-bar linkage is the simplest movable closed chain linkage. It consists of four bars or links connected together by four joints, as shown in Fig. 1. The lengths of the linkages vary from one another. One of the rotating links is known as the crank or driver, and the other link is a rocker. The member connecting the crank and the rocker is known as a coupler, and a fixed link is the frame. The crank is the shortest link and makes a complete revolution. The lengths of links were 50, 150, 100, 150, and 200 mm for the crank, fixed link, rocker, coupler, and coupler extension, respectively.

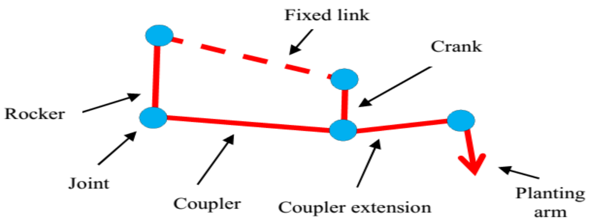

Fig. 1. Four-bar links mechanism
Source: Authors' own illustration.

B. Planting tines and tines holder

The planting tines are the main element thatis responsible for the plantation of the seedlings. It has aspecific shape thatpicks the seedlings and plantsthemin the mud. The tines holder is a horizontal bar of rectangular mild steel hollow sectionswith dimensions of 20 × 40 ×1,000 mm width, height, and length, respectively, and welded on it five pieces of square mild steel hollow sections with dimensions of 15 × 15 ×100 mm width, height, and length, respectively.Every piece of this square mild steel hollow sections installed on it two bolts with nuts to control the adjustment of the planting tines with pushing rods. The tines holder is mounted on the transplanting arm (four-bar linkage) via a hinged joint to control the height of the seedlings cut from the mat and thus control the vertical feeding of the machine. The machine contains five planting tines, and the distance between every planting tine is 20 cm, as shown in Photo 3.

C. Seedling push mechanism

Seedlings push rods

The push rods are the member responsible for pushing seedlings into the soil. It is a steel rod with a diameter of 8 mm and a length of 250mm. Itwelded at the end of the rod a piece of steel in the form of U- shape, and this piece slides inside the planting tines up and down to push the seedlings into the soil. It is fixed from the top by nuts in a horizontal bar called the push rod holder and fixed from the bottom inside a piece of square mild steel hollow sections with dimensions of 15 × 15 ×100 mm width, height, and length, respectively, to determine its path inside the planting tines.

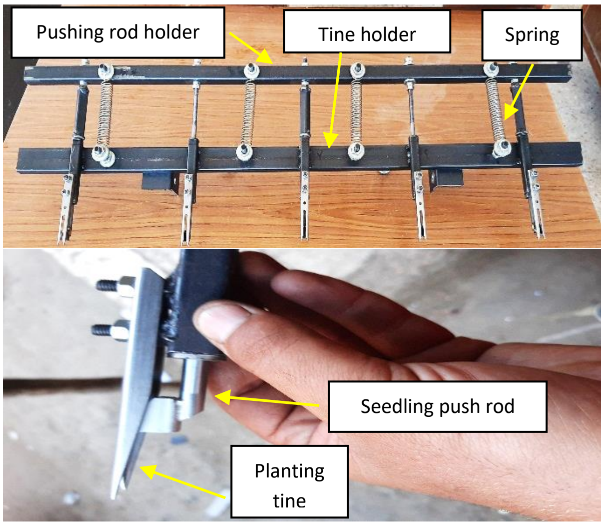

Photo 3. Seedlings push holder and seedlings pushrod
Source: Authors' own illustration.

The pushing rod holder is a horizontal bar of square mild steel hollow sections,with dimensions of 20 × 20 ×1,000 mm width, height, and length, respectively. The push rod holder is connected with the planting tines holder by four tension springs to push the seedlings pushing rod holder with the push rods inside the planting tines for pushing the seedlings into the soil, as shown in Photo 3.

Cams and levers

The machine contains two circular cams with a diameter of 100mm and a thickness of 10mm. A quarter of a circle cam was cut from each cam, and then they were fixed from the middle on the crankshaft extension. The machine also contains a pair of steel iron levers rolled into a Z-shape. The length of the lever from the top was 80 mm and from the bottom 100 mm, and the lever height was 160 mm; each lever is fixed by a nail installed on the transplanting arm so that part of it is located below the pushing rod holder and the other part is below the cams, as shown in Photo 4.The function of the cams and levers is to control the movement of the pushing rod holder, whether by lifting or pushing.

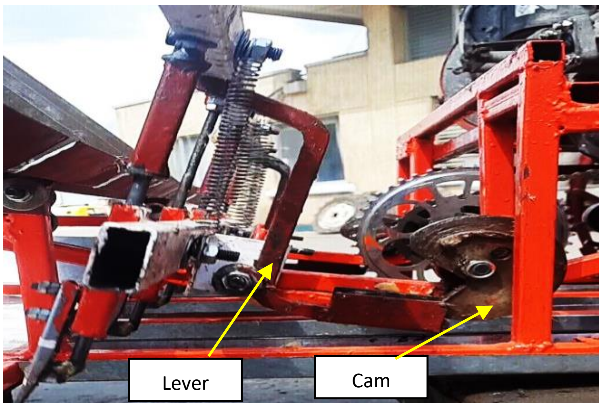

Photo 4. Cams and levers
Source: Authors' own illustration.

3. Power source

The power source of the rice transplanting machine is a 3kW engine, model GS130-2CN from Kubota. The engine power was transmitted to an internal attached gear box that reduced engine rotation speed between 60-100 rpm on the output shaft. The clutch was also provided to connect and disconnect power from the engine.

4. Power transmission system

The power transmission system contains three parts; the main engine shaft, the intermediate reduction unit, and the drive wheel's unit, as shown in Photo 5. The main shaft contains four different sprockets with 20, 25, 30, and 35 teeth to change the machine's forward speed in the field. The intermediate reductionunit is a round shaft with a diameter of 25 mm and 600 mm length. The shaft is installed inside two bearingsthat have the same diameter. The intermediate reduction unit was installed on itthree different sprockets with 49, 48, and 15 teeth. The drive wheel unit is a round shaft with a diameter of 25 mm and 1,200 mm length used as a wheel axle; itis installed inside two bearingswith the same diameter and installed on it a sprocket with 49 teeth.The movement was transmitted from the main engineshaft with different sprockets to the intermediate reduction unit sprockets by chains. The main shaft sprockets were connected to the 49-teeth sprocket in the intermediate reduction unit by a chain to reduce the output rotational speed of the engine. The intermediate reduction unit deliversmotion power from the engine and transmits it to the transplanting unit (A) and the drive wheel(B).

A. Transmit motion to transplanting unit

The movement is transmitted to the transplanting unit by sprockets and chains that are mounted on the intermediate reduction unit and transplanting unit axle. The movement is transmitted by a sprocket of 48 teeth installed on the intermediate reduction unit and connected to the transplanting unit axle by another cassette sprocket withsevensprockets (speeds) starting from 14 to 28 teeth. Its purpose is to change the number of hits of the transplanting unit per unit distance to obtain different intra-row hill spacing.

B. Transmit motion to drive wheel

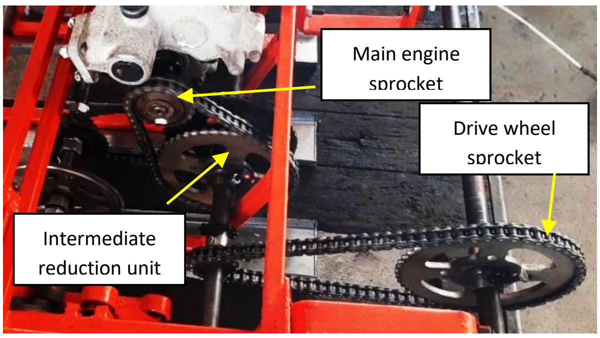

Photo 5. Power transmission system
Source: Authors' own illustration.

The movement is transmitted to the traction wheel by the 15-teeth sprocket installed on the intermediate reduction unit, and the 49-teeth sprocket installed on the axle of the drive wheel to reduce the machine's forward speed in the field to be proportional tothe desired hills spacing. The intermediate sprockets are connected to the wheel drive sprocket by a chain.

5. Guide rail

The guide rail is a L-shape steel section has dimensions of 40 × 40 × 1,300 mm, height, width and length, respectively with a thickness of 2.5 mm welded with a rectangular mild steel hollow section has dimensions of 20 × 40 × 1,300 mm, height, width and length, respectively with a thickness of 1.25 mm and fixed to the machine frame by adjustable screws. The guide rail has five slots through which seedlings are picked by planting tines.The width of the slot is 18 mm, the length is 65 mm, and the distance between the slot and the other is 188 mm. Slots were cut by a CNC machine to ensure cuttingaccuracy. The guide rail performs several functions, picking up the seedlings through it, and the seedling mat slides on it horizontally with a distance of 188 mm back and forth, as shown in Photo 6.

6. Seedlings mat

The seedlings mat was manufacturedwith a galvanized steel sheet with dimensions of 1,030×700 mm,width and length,respectively, with a thickness of 0.7 mm. It was divided into five compartments; the width of each compartment is 196 mm, and the separator between each compartment was made of square mild steel hollow sections with a dimension of 15×15×740 mm.

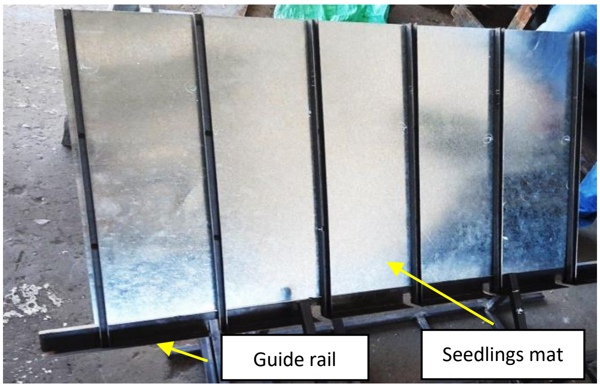

Photo 6. Seedling mat and guide rail
Source: Authors' own illustration.

The seedlings mat rests on the guide rail from the down side and the machine chassis from the upper side. It was fitted at a 50^{o} angle and supported from the rear side by a 20×20 mm square mild steel hollow sections frame.After every stroke of the transplanting arm, the seedlings mat slides horizontally along with a guide rail with a distance of 188 mm back and forth bythe mat movement mechanism, as shown in Photo 7.

7. Floats

The floats were made of a galvanized steel sheet and consist of two parts.The first one is the main float, and this part is one piece installed in front of the transplanter with bolts and has a dimension of 1,000×600 width and length, respectively, with a thickness of 0.7 mm. The floats were curved with a height of 150 mm from two sides and front to avoid the entry of soil on it, and this float work as a leveler and puddler. The second part is the secondary floats,consisting of four small floats installed in the rear section of the transplanter and fixed between rows of seedlings. Each one of the floats has a dimension of 80×700mm width and length, respectively, with a thickness of 0.7 mm, and the floats were curved with a height of 40 mm from two sides. The cross-section of the floats was made such that the soil in between the two floats will project up,ensuringgood placement of the seedling into it, as shown in Photo 7.

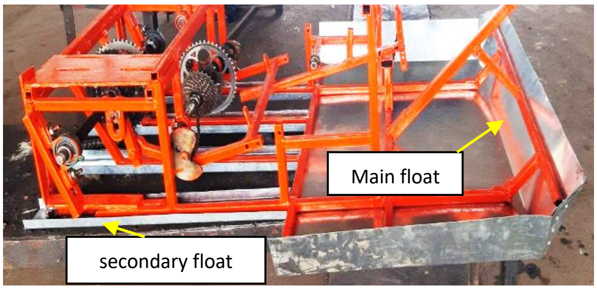

Photo 7. Rice transplanter floats
Source: Authors' own illustration.

8. Drive wheels

Two drive wheels of rubber lug wheel with thick rim were used in the transplanter. The wheel diameter was 600 mm. The wheels were installed on an axle shaft with 25 mm diameter and 1,200 mm length; this shaft was installed between two bearings, and the distance between wheels on the shaft was

1,000 mm to avoid damaging the seedlings on the way to go and back.

Soil conditions before transplanting

In order to obtain satisfactory operation, good quality work, and efficiency of the developed machine, besides ensuring good technical condition and correct operation of the machine, suitable soil conditions in the field should be available. Soil conditions before transplanting were shown in Table 1.

Table 1.Field condition before transplanting

Item	Treatment
Water depth, cm	1 - 2
Hardpan depth, cm	13
Hardpan hardness (kg/cm^2)	5.4
Cone depth, cm	8
Soil penetration resistance, kg_f/cm^2	24
Soil texture	Clay

Source: Authors' determination.

Plant parameter

Before starting the operation, the data on the targeted crop were collected, which was required for the proper functioning of the transplanter.

Table 2.Mean values of some seedlings characteristics of rice crop variety (Sakha super 300)

Characteristics	Mean values
Crop variety	Sakha super 300
Recommended transplanting distance (cm)	20 × 20
Age of seedling (days)	25
Seedlings height (cm)	17
Number of leaves	2.5-3.0
Number of plant / cm^2	4

Source: Authors' determination.

Photo 8. Rice transplanter in the experimental field
Source: Authors' own illustration.

The selected variety was (Sakha super 300) and recommended spacing was 20×20 cm [11]. After treatment, sprouted rice seed was sown in trays at a 250 g/tray seed rate. Seedling conditions recorded on the day of the transplanting operation are shown in Table 2.

Methods

1.Studied factors: The experiments were carried out to study some factors affecting on the performance of rice transplanting machine, such as:

(a)**Machine forward speed:** four different forward speeds, i.e., 1, 1.25, 1.5, and 1.75 km/h

(b)**Intra-row hill spacing:** fourdifferent intra-row hill spacing, i.e., 16, 18, 20, 22 cm

(c)**Seedling cross-section area:** twodifferent seedling areas,i.e., 1.00 and 2.00 cm^2

All tests were carried out at a constant seedlings depth of 5 cm.

2.Measuring indicators

Percentage of missing seedlings (P_m)

The percentage of missing seedlings was calculated according to RNAM [12], as follows in Eq. (1):

$$P_m = (N1/N2) \times 100, \quad (1)$$

where:

P_m= Percentage of missed seedlings (%)
N1 = Missing seedlings number per unit area
N2 = The theoretical number of seedlings per unit area

Percentage of floating seedlings (P_f)

The percentage of floating seedlings was calculated according to RNAM[12], as follows in Eq. (2):

$$P_f = (N3/N2) \times 100, \quad (2)$$

where:

P_f = percentage of floating seedlings (%)
N3 = Floating seedlings number per unit area
N2 = The theoretical number of seedlings per unit area

Percentage of damaged seedlings (P_d)

The percentage of damaged seedlings was calculated according to RNAM[12], as follows in Eq. (3):

$$P_d = (N4/N2) \times 100, \quad (3)$$

where:

P_d = percentage of damaged seedlings (%)
N4 = Damaged seedlings Number per unit area
N2 = The theoretical number of seedlings per unit area

Transplanting efficiency

Transplanting efficiency for each treatment was determined according to Eq. (4):

TE = [N_t – (N_d + N_m + N_f)] / N_t, %............(4)

where:
TE = Transplanting efficiency (%)
N_t= Theoretical number of seedlings per unit area
N_d = Number of damaged seedlings per unit area
N_m= Number of missed seedlings per unit area
N_f= Number of floated seedlings per unit area

Actual field capacity

The actual field capacity was calculatedaccording toKepner et al. [8], as follows in Eq. (5):

Af_c= 1/T .... (5)

where:
Af_c = Actualfield capacity, fed/h
T = The total transplanting time
T = $t_1 + t_2 + t_3$
t_1 = Actual time of operation (straight time)
t_2 = Timelost for turning
t_3 = Time lost for repairing and adjusting the machine

Energy requirements (kW.h/fed)

The energy requirements were calculated by dividing engine power on actualfield capacity, as follows in Eq. (6):

$$\text{Energy requirements} = \frac{\text{Engine power (kW)}}{\text{Actual field capacity}}, \text{(kW.h/fed)........ (6)}$$

RESULTS AND DISCUSSIONS

The data obtained from the present studycould be summarized under the following headings.

Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on missing hills percentage

The relationship between the missing hills percentage and the machines' forward speeds at different intra-row hill spacingandseedling cross-section area is shown in Fig. 2.

The data shows that increasing the forward speed tends to increase the missing hills percentage; which may be attributed to the increase in the rotational speed of the transplanting arm.

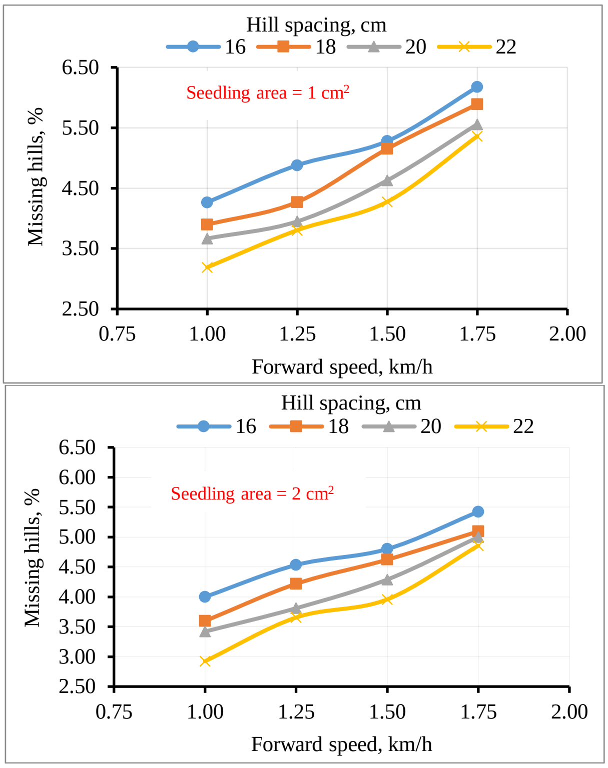

Fig. 2. Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on missing hills percentage
Source: Authors' determination.

Where a sincreasing intra-row hill spacing and seedling cross-section area decreased the missing hill percentage, this is may be attributed to the decrease in the rotational speed of the transplanting arm and the increase in the seedling cross-section area led to an increase in the finger pick-up efficiency.In the case of the seedling cross-section area of 1.00 cm^2, the results revealed thatincreasing the forward speed from 1.00 to 1.75 km/h increased the missing hills percentage from 3.19-5.36, 3.67-5.56, 3.90-5.89 and 4.37-6.18% at intra-row hill spacing of 22, 20, 18 and 16 cm, respectively.On the other side, at a seedling cross-section area of 2.00 cm^2, the results indicated that increasing the intra-row hill spacing from 16 to 22 cm decreased the missing hills percentage from

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5.42-4.86, 4.80-3.96, 4.53-3.65 and 4.00-2.92% at a forward speed of1.75, 1.50, 1.25 and 1.00 km/h, respectively.

Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on floating hills percentage

Figure 3 shows that increasing the forward speed tends to increase the floating hills percentage; this may be attributed to the increase in the rotational speed of the transplanting arm.

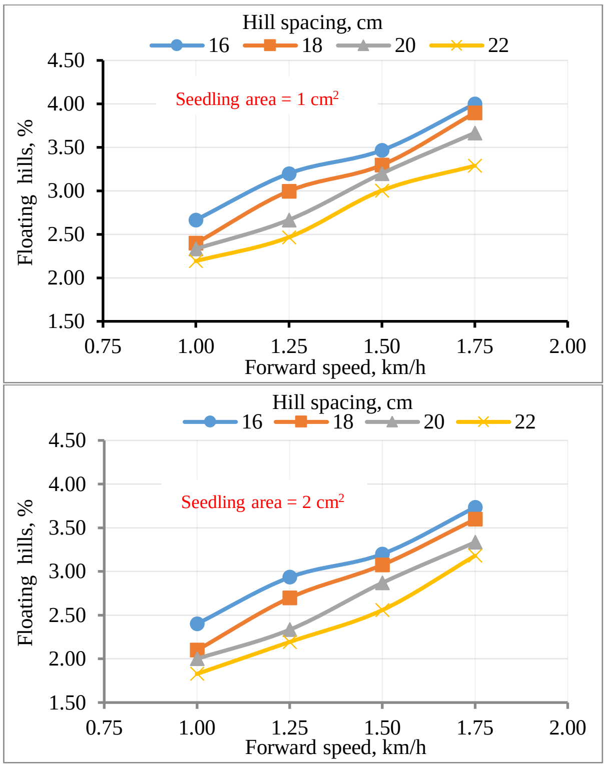

Fig. 3. Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on floating hills percentage
Source: Authors' determination.

Whereas increasing intra-row hill spacing and seedling cross-section area tends to decrease the floating hill percentage, this may be attributed to the decrease in the rotational speed of the transplanting arm and the increase in the seedling cross-section area led to increase the transplanting efficiency. The results indicated that the lowest missing hills percentage was 1.83%, obtained at a forward speed of 1.00 km/h, intra-row hill spacing of 22 cm, and seedling cross-section area of 2.00 cm^2. On the other hand, the highest floating hills percentage was 4.00%, obtained at a forward speed of 1.75 km/h, intra-row hill spacing of 16 cm, and seedling cross-section area of 1.00 cm^2.

Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on damaged hills percentage

The presented data in Fig. 4 illustrates the relationship betweenthe damaged hills percentage and the machines' forward speeds at different intra-row hill spacing and seedling cross-section area.

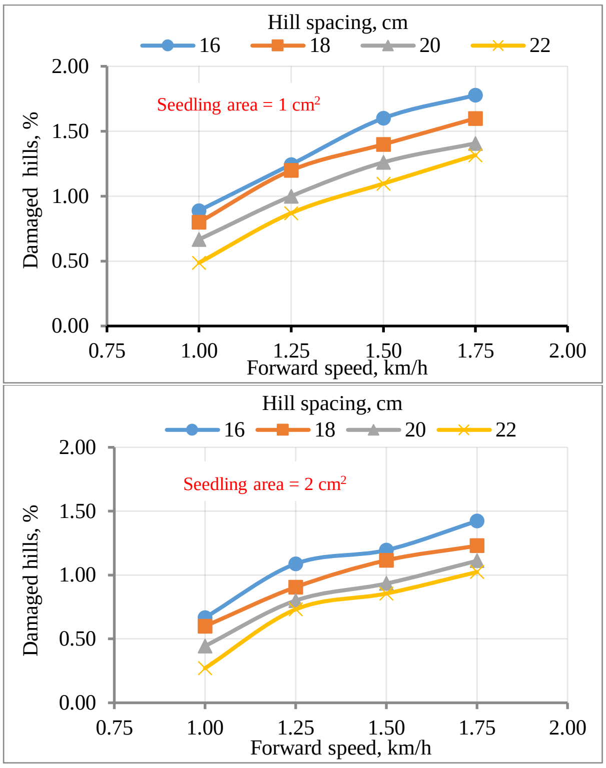

Fig. 4. Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on damaged hills percentage
Source: Authors' determination.

The same trend was observed in the damaged hills percentage, as stated in the missing and floating hills percentage.The results showed that the lowest damaged hills percentage was 0.27%, obtained at a forward speed of 1.00 km/h, intra-row hill spacing of 22 cm, and seedling cross-section area of 2.00 cm^2. Whereas, the highest damaged hills percentage was 1.78%, obtained at a forward speed of 1.75 km/h, intra-row hill spacing of 16 cm, and seedling cross-section area of 1.00 cm^2.

Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on transplanting efficiency

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The relationship between the transplanting efficiency and the machines' forward speeds at different intra-row hill spacingandseedling cross-section area is shown in Fig. 5. The data shows that increasing the forward speed tends to decrease the transplanting efficiency; whichmay be attributed to the increase in the transplanting losses.

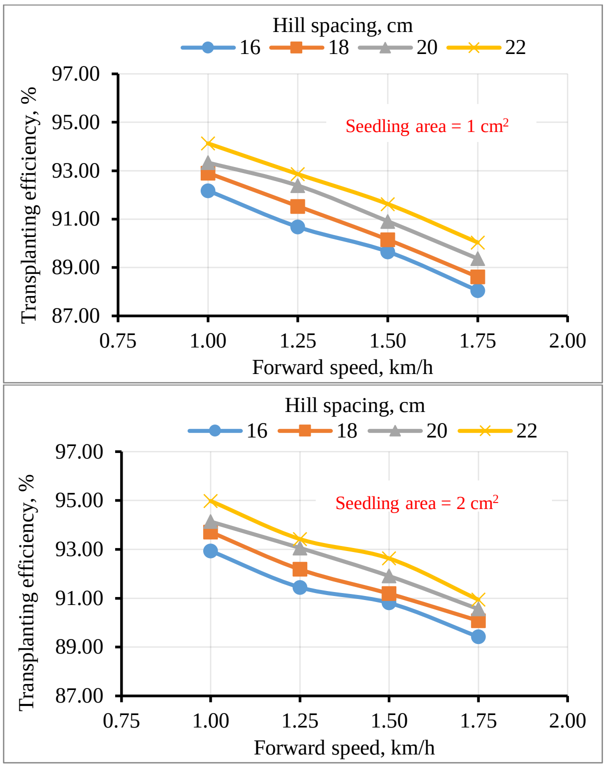

Fig. 5. Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on transplanting efficiency
Source: Authors' determination.

While an increase in intra-row hill spacing and seedling cross-section area tend to increase the transplanting efficiency. It was observed that, in the case of the seedling cross-section area of 1.00 cm^2, the transplanting efficiency recorded 94.13% and 92.18% witha forward speed of 1.00 km/h and decreased to 90.03% and 88.05% at a forward speed of 1.75 km/h when the intra-row hill spacing was 22 and 16 cm, respectively. Whereas, at seedling cross-section area of 2.00 cm^2, the results showed that increasing the intra-row hill spacing from 16 to 22 cm increased the transplanting efficiency from 89.42-90.94, 90.81-92.63, 91.45-93.42 and 92.93-94.98% at a forward speed of 1.75, 1.50, 1.25 and 1.00 km/h, respectively.

Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on actual field capacity

The data in Fig. 6 shows the relationship between actual field capacity and machine forward speed at different intra-row hill spacing, and seedling cross-section area. The figure shows that increasing the machine forward speed and intra-row hill spacing tends to increase actual field capacity. This may be attributed to the increase in the theoretical field capacity and decrease in the lost time in seedlings feeding.

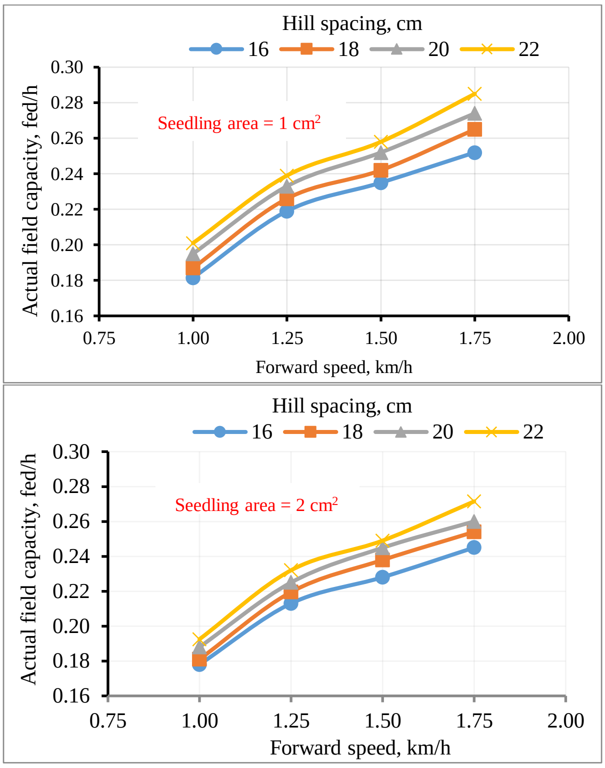

Fig. 6. Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on actual field capacity
Source: Authors' determination.

Whereas, increasing the seedling cross-section area led to a decrease in actual field capacity, this may be attributed to increase in the number of seedling trays needed per feddan, which tends to increase the lost time in seedlings feeding. The presented data shows that, in the case of the seedling cross-section area of 1.00 cm^2,increasing forward speed from 1.00 to 1.75 km/h led to an increase in actual field capacity from 0.182-0.252, 0.187-0.265, 0.195-0.274 and 0.201-0.285 fed/h at intra-row hill spacing of 16, 18, 20 and 22 cm, respectively. While,in the case of the seedling cross-section area of 2.00 cm^2, increasing intra-row spacing from 16 to 22 cm tends to increase the actual field capacity value from 0.178-0.193, 0.213-0.232, 0.228-0.249, and 0.245-271 fed/h at a forward speed of 1.00, 1.25, 1.50 and 1.75km/h, respectively.

Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on energy requirements.

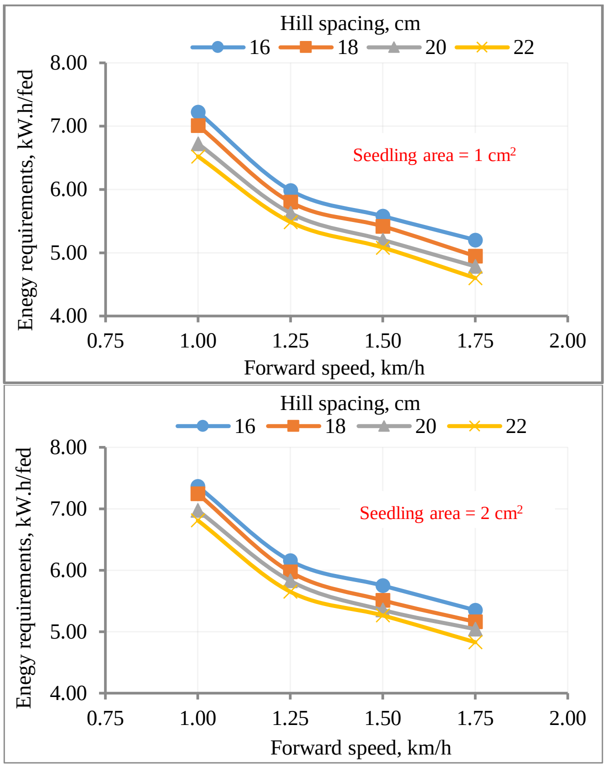

Fig. 7. Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on energy requirements
Source: Authors' determination.

It is clear from Fig. 7 that energy requirements decreased by increasing machine’s forward speed andintra-row hill spacing and slightly increased by increasing the seedling cross-section area.

Also, in the case of the seedling cross-section area of 1.00 cm^2, increasing forward speed from 1.00 to 1.75 km/h led to a decrease in the energy requirements from 7.22-5.20, 7.01-4.94, 6.72-4.78 and 6.52-4.59 at intra-row hill spacing of 16, 18, 20, and 22 cm, respectively. Whereas, increasing seedling cross-section area from 1.00 to 2.00 cm^2, the energy requirements increased by an average of 3.3%.

CONCLUSIONS

The research aimed to manufacture a rice transplanting machine with local materials suitable for small rice holdings. In addition, testing and evaluating themanufactured machine under different operation conditions. The machine was manufactured and tested at the Rice Mechanization Center, Agricultural Engineering Research Institute, Egypt. The machine contains five rows, and the distance between each row is 20 cm.The obtained results indicated that the lowest percentages of missing, floating, and damaged hill were 2.92, 1.83, and 0.27%, respectively. The highest transplanting efficiency and field efficiency were94.98 and 83.75%, respectively, obtained at a machine forward speed of 1.00 km/h, intra-row hill spacing of 22 cm, and seedling cross-section area of 2.00 cm^2. Also, the lowest value of requirement energy was 4.599 kW.h/fed achieved the highest actual field capacity of 0.285 fed/h was obtained at machine forward speed of 1.75 km/h, intra-row hill spacing of 22 cm, and seedling cross-section area of 1.00 cm^2.

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